Yours very truly
Fred B Jacobs

Abrasives & Abrasive Wheels

Their Nature, Manufacture and Use

A COMPLETE TREATISE ON
THE MANUFACTURE AND PRACTICAL USE OF
ABRASIVES, ABRASIVE WHEELS AND GRINDING OPERATIONS

INCLUDING

NATURAL AND ARTIFICIAL ABRASIVES, PRODUCTION AND PREPARATION OF ABRASIVES, GRITS, GRADES AND BONDS, SHARPENING AND GRINDING STONES AND WHEELS, TESTING WHEELS FOR EFFICIENCY, TRUING, REBUSHING AND INSTALLING WHEELS, SAFETY DEVICES, AND DUST-COLLECTING SYSTEMS, COMPLETE EXPOSITION ON SURFACE, EXTERNAL AND INTERNAL GRINDING AND COMPREHENSIVE DATA COVERING THE PHYSICAL AND CHEMICAL NATURE OF ABRASIVES IN GENERAL

BY

FRED B. JACOBS

A PRACTICAL HANDBOOK FOR ENGINEERS, FACTORY SUPERINTENDENTS, FOUNDRYMEN, SHOP FOREMEN AND MECHANICS IN GENERAL

FULLY ILLUSTRATED

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PREFACE

The art of finishing metals by abrasion is one of the oldest mechanical practices in existence, dating from the time prehistoric man discovered that he could fashion his wood and bone implements by rubbing them on rocks of a gritty nature.

The grindstone is, without doubt, the oldest form of grinding wheel known. With the early development of the mechanical arts, it was discovered that a sandstone cut in circular shape and mounted upon a revolving shaft, showed higher efficiency than the side of a rock for sharpening and shaping various implements. It is definitely known that grindstones, rotated by power, were used in the manufacture of armor as early as the year 1570. It is also known that the emery deposits of the Grecian Archipelago were known to the ancients and the value of this abrasive recognized, as many writers of early days referred to emery under various names. In considering some of the mechanical achievements of the handicraftsmen who worked with metals centuries before the Christian era, it is hard to conceive how they attained so high a degree of perfection without the use of an alumina abrasive for tool-sharpening purposes.

While the practice of fashioning tools and implements by abrasion is in all probability as old as civilization itself, modern grinding, as we accept this term, is a comparatively recent development. About half a century ago, the individual workman made his own grinding wheels of glue and emery.

The first attempt at precision grinding consisted of finishing the chilled iron calender rolls used in the paper-making industry. Owing to the hard nature of the material in question, it was a long and tedious process to turn these rolls accurately.

The development of the sewing-machine industry in the New England States gave impetus to the development of the grinding-wheel business. As a matter of fact, the first attempts at cylindrical grinding, aside from roll grinding, consisted of finishing parts of the Wilcox & Gibbs sewing machine. The work was done by the Brown & Sharpe Mfg. Co.

With the advent of the automobile industry, over twenty years ago, the grinding-wheel business received a fresh impetus as a rapid means was in demand for the accurate finishing of parts.

Today, the modern grinding wheel is among the most useful of modern shop accessories. Without it, it would be impossible to maintain the present-day standard of rapid production. In practically every line of metal working, the grinding wheel plays an important part, its usefulness ranging all the way from the rough grinding of castings and forgings to the finishing of accurate surfaces, both plane and cylindrical.

In presenting this work, the writer has taken great precaution to make sure that every statement is authentic. Aside from knowledge gained through many years as a journeyman machinist, later supplemented with several years' experience as a grinding-wheel salesman, many months were spent in collecting data, verifying statements and consulting reliable authorities, both in this country and abroad.

The writer is indebted to the following manufacturers and individuals who cheerfully answered numerous letters and supplied valuable data and photographs:

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FRED B. JACOBS.

June, 1919.

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CHAPTER ONE

NATURAL ABRASIVE SUBSTANCES

Nature of natural abrasives—Where found—History of natural abrasives—Commercial application—Sandstone—Emery—Corundum—Garnet—Diamond—Bort diamond—Flint—Quartz—Natural sharpening stones—Arkansas—Washita—Hindustan—Tripoli—Pumice.

NATURAL abrasives are being found in many parts of the world. In a broad sense, the list includes all minerals capable of abrasive action, but from a commercial point of view, the principal natural abrasives are sandstone, emery, corundum and garnet. The diamond is, of course, a natural abrasive; indeed it is the hardest of all, but it is needless to state that its rarity excludes it from the list of commercial abrasive materials.

SANDSTONE

The first abrasive to be used in the form of a wheel was in all probability sandstone. The use of a revolving stone for sharpening purposes is so old that the beginning is lost in antiquity. It seems reasonable to believe, however, that the artificers of early civilization borrowed the idea of a revolving sharpening stone from the crude mills used many centuries ago for the grinding of grain.

Sandstone is a very curious mineral, indeed, as it consists of uniform grains of sand (generally quartz with a small percentage of feldspar and mica) firmly cemented together with silica. Some varieties of sandstone, the Craigleith stones used in the cut-glass industry for instance, are practically pure silica, this material often running as high as 98 per cent. Sandstone is found in many parts of the world and in this country the most extensive deposits that are worked for the production of grindstones are in Ohio and Michigan. The Gray Canyon quarry at Amherst, Ohio, is classed as the largest quarry in the world. Sandstones are of various colors, these being derived from impurities that penetrated the mass during the formative stage. Pure siliceous stones are white, or pale yellow in cases where small quantities of iron oxide are present. A red tinge is generally due to hematite, yellow to limonite, green to glauconite, gray to clay and shale, and black, as observed in black Graileith stones for example, to manganese dioxide.

The average layman is of the opinion that all grindstones are alike, but this supposition is erroneous for, in forming the sandstone of which the grindstones of commerce are made, it would appear that Nature anticipated the wants of man by providing not only several grits to choose from, but several grades as well. To insure an ample supply of grits and grades, grindstone manufacturers generally control holdings in various localities.

Before the advent of the grinding wheel, sandstone was the only abrasive to be used in the form of a wheel. Its use was, of course, limited, as practically the only grinding done in the early manufacturing days consisted of tool sharpening. Grindstones are used at present in large quantities for sharpening edge tools, cutlery, etc., often in preference to modern abrasive wheels. Many reasons for this practice are explained later, under the heading, Grindstones Vs. Grinding Wheels.

EMERY

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Emery, which in reality is an impure form of corundum, has been known as an abrasive from very remote times. Its value as an abrasive was known to the ancient Greeks. ✓ Dioscorides referred to it as a stone used in gem engraving. Emery was also known to the Romans, Pliny and other writers referring to it as naxium. There is also some authority for the statement that in the "adamant" of the Old Testament, translated from the Hebrew, *shamir* referred to emery ore. The principal emery deposits that furnish the emery of commerce are located in Asia Minor, in the basins of the Sarabat and Mender rivers. In the Grecian Archipelago, the best known of these deposits are located on the Island of Naxos, and in this country near Chester, Mass., and Peekskill, N. Y.

Emery looks like iron ore, being of a dense, granular construction. Its luster is metallic, while its color runs from blue-black to black. It can truly be called a unique mineral, as it is a mixture of alumina oxide and iron as magnetite and hematite. At one time, all of the world's supply of emery came from the Grecian Isles, principally Naxos, but during the year 1847 Dr. J. Lawrence Smith located important emery deposits in Asia Minor. Dr. Smith's discoveries proved to be of great benefit to the emery-consuming trade owing to the fact that the price of emery was materially reduced. Asia Minor or Turkish emery, as the new material was called, at once became popular, as it proved to be an efficient abrasive for many purposes.

Turkish emery always occurs in limestone or marble, the deposits resting on gneiss, schist and mica slates, while Naxos emery is generally found in limestone beds, being associated with crystalline schists. One noticeable difference between the emery of the Grecian Archipelago and that of Asia Minor is that in the former are numerous small particles of mica which are seldom observed in the latter.

The mining of both Turkish and Naxos emery is generally carried on in a very primitive manner. Being near the surface, the ore is easily removed as it is often present in loose boulders. Masses that are too large for transportation to the sea coast, are generally broken into fragments through the process of heating them for a number of hours followed by a sudden cooling with water. This causes the ore to fracture in many places, and, by means of hammer blows, it is an easy matter to reduce the ore to pieces suitable for transportation. The low cost of mining, together with moderate transportation costs, accounts for the fact that Turkish emery finds a ready sale in this country in competition with American emery. For the purpose of grinding-wheel manufacture, however, Naxos emery is considered superior to all other kinds as it is the hardest, toughest and most uniform. The foregoing sounds like a broad statement, to be sure, but it is the consensus of opinion expressed by leading grinding-wheel manufacturers who make wheels of emery.

The discovery of emery in this country dates back to about the year 1830, at which time a railroad was being built from Boston to the Hudson River. In making a cut near Chester, Mass., a deposit of emery ore was uncovered, which, at the time, was taken for iron ore. As previously stated, emery and iron ore resemble each other closely. Blast furnaces were erected and provision made for working the ore on a moderately large scale. At the first attempt to smelt the ore, however, great difficulties were encountered in separating the iron from the alumina and the deposits were ultimately condemned as too refractory for practical purposes.

The mine remained idle and almost forgotten for a number of years. In 1864 or thereabout, Dr. H. S. Lucas, realizing the possibilities of working the deposits as a source of abrasive supply to compete with the foreign product, bought the property and began to successfully operate it as an emery mine. Operations have been continued in this district until the present day. The emery in question is associated with amphibolite and serpentine, and, as the veins of ore reach several hundred feet underground, it is necessary to work them by extensive tunneling.

Mention should also be made of the emery deposits in New York state in the vicinity of Peekskill. This emery, which is called a spinel emery, does not occur in a continuous vein, but in segregated masses, being associated with morite rocks. In this ore spinel, which is magnesium aluminate, $MgAl_2O_4$, furnishes the abrasive agent, since spinel has a relative hardness of 8, as against 9, the hardness of alumina, it is seen that spinel emery is somewhat softer than other varieties of true emery. The value of spinel emery should not be overlooked, however, as it furnishes an efficient polishing material in cases where a very hard and tough abrasive is not desired.

The specific gravity of emery varies in different specimens from 3.7 to 4.3 and the percentage of alumina oxide from 30 to 70. The abrasive power, sometimes called the effective hardness, is not proportional to the amount of alumina contained, being influenced to a great extent by the proportions of other component parts in the form of impurities such as silica, lime magnesia, etc., and the structure of the grain itself. For the purpose of grinding-wheel manufacture, the value of emery as an abrasive agent is determined by the amount of alumina oxide present and the toughness of the grain itself.

In common with other natural products, emery ore varies in a number of characteristics. This is true not only of specimens from different mines, but of the product of one mine as well. To market a high-grade emery, it is necessary to pay especial attention to the selection and grading of the crude ore, to which end the use of the microscope cannot be recommended too strongly, as by this means more can be learned of the quality of the emery than by resorting to any other method, aside from the actual working test of the finished product.

As emery may have a high percentage of alumina and at the same time the ore may be so constituted that, after crushing, the grains will seem to possess no cutting points. Such an emery does not make a very efficient grinding wheel.

Some specimens of emery crush up into the proper kind of grains, as far as cutting points are concerned, but at the same time nothing but fine grains are produced. Again it is sometimes noticed that small flakes of mica are scattered through the ore, which is sure to cause trouble in the vitrifying process if the emery is used in the manufacture of vitrified grinding wheels. It is readily seen that an efficient abrasive cannot be made of an emery ore selected at random. It is of the utmost importance to know the nature of the grain to adapt the same for a given abrasive purpose.

At one time, all grinding wheels were made of emery. Of late years, however, corundum and the different artificial abrasives are used. At the same time, notwithstanding the efficiency of modern abrasives, the more ancient emery wheel still has its field of usefulness, and, strange as it may seem, on some classes of grinding, steel castings and heavy malleables, for instance, emery wheels continue to show the highest efficiency. This statement is not made thoughtlessly, but is the result of several years of observation spent in representing grinding-wheel manufacturers.

From a theoretical point of view, it would seem that abrasives containing a higher percentage of alumina than is present in emery, would prove more efficient, regardless of the nature of the work. Actual tests, however, have proven beyond a doubt that for certain purposes the emery wheel is still in a position to successfully compete with artificial abrasives. This is explained in a subsequent chapter.

Again, emery wheels are comparatively low in price, and they find a ready market among consumers whose grinding-wheel wants are few. A manufacturer who uses grinding wheels intermittently, a few minutes at a time, is not concerned whether or not the wheel shows the highest efficiency. As long as it gives satisfaction, within certain limits, no good reason is seen why a higher price should be paid for a more improved abrasive.

Another factor, that should be mentioned while considering the emery wheel, is that owing to the high percentage of oxide of iron contained, this abrasive, grit for grit, leaves a finer finish than any other abrasive material used in grinding-wheel manufacture. Even on precision work, such as gauge grinding and other similar operations, the emery wheel still plays an important part and it is often the choice of many engineers who know abrasives for their actual worth.

Emery wheels, or emery stones, as they are termed in this case, are also largely used for hulling oats and rice, taking the place of the bed and runner natural stones as used in the ordinary buhr mill. To whom the credit belongs for introducing the above stones, is not known for a certainty, but experience has proven that the emery stone compares favorably with the natural stones heretofore used for this purpose.

Coarse emery is used in the form of bricks for rubbing stone and various metals while the finer grades of emery are made into sharpening stones, scythe stones, etc. Of late years, however, artificial sharpening stones made of electro-thermic abrasives (Carborundum, for example) have largely replaced those made of emery. For a few specific purposes, emery stones are still in use owing to the high finish they produce.

In the form of grains and powders, emery is used for a number of purposes such as finishing bevels on plate glass, lapping hardened steel, polishing precious stones, etc., or, in fact, for any purpose where a tough, durable abrasive in grain form is desired.

Emery grain is also used to a great extent on polishing, or set-up wheels, as they are termed, for finishing an endless variety of metal parts such as edge tools, cutlery, parts of firearms, etc. Various kinds of emery act differently on a polishing wheel and suitable grades for specific purposes are generally chosen after careful experiment. One reason why emery gives such good results on polishing wheels is that its comparatively rough fracture presents a good holding surface for the glue, which factor is not true of many of the manufactured abrasives. Carborundum, on account of its smooth, glassy surface, does not form a very efficient abrasive to use on a polishing wheel.

Emery paper and cloth are used to a large extent in the mechanical arts for smoothing and polishing small, intricate parts of small machinery and instruments.

In the study of the occurrence of emery, we are confronted with two very curious facts. First, emery is a mixture of iron oxides and alumina and, second, this composition occurs in but few places in the world—pin points on the earth's surface, as it were. In American emery, Prof. J. H. Pratt regards the alumina and iron oxides as basic segregations from an igneous magma. This, of course, is within reason since it is an accepted fact that the earth was at one time a molten mass of elements, and as this mass slowly cooled, the various elements combined and sometimes segregated. What force of nature caused the elements of iron and alumina to segregate together, in practically the same manner, is beyond the knowledge of the writer.

CORUNDUM

The name corundum was originally applied to the ruby and sapphire of India, the word being derived from the Sanskrit (*kuruvinda*) and literally means ruby. The variety of corundum we are dealing with is called, by the older mineralogists, impure corundum and comprises the numerous varieties that are not transparent or perfect enough to be used as gem stones.

Some thirty years ago, corundum was regarded as a comparatively rare mineral, but at the present time it is known to occur abundantly in several localities in this country and in Ontario, Canada. In this country, it occurs in igneous rocks, principally syenites, and in several gneisses and schists. It also occurs in alluvium deposits in sands and gravels. Canadian corundum occurs in nepheline syenite associated with Laurentian gneiss.

Of the origin of corundum but little is known for a certainty, as a study of his mineral calls for exhaustive research work on the part of the geologist, who is sometimes reticent when it comes to establishing hard and fast rules. Prof. J. H. Pratt, who has made a deep study of the occurrence of corundum, in this country and elsewhere, considers that the corundum of North Carolina segregated from a molten magma, the separation taking place at an early period of consolidation.

Canadian corundum has of recent years been regarded as an essential rock constituent. Regarding the corundum of Ontario, H. E. T. Haultain states that the corundum-bearing rocks are not dykes, that they are not eruptive, and that there is no sign of separation from magma.

The principal Canadian deposit of corundum occurs at Craig Mountain, which is situated in Raglan Township, Renfrew County, Ontario. In this country, corundum is found in the following states: Maine, Massachusetts, Connecticut, New York, Pennsylvania, Delaware, Virginia, North Carolina, South Carolina, Tennessee, Georgia, Colorado, Montana, California and Idaho.

Corundum is found in three different ways; block corundum, crystal corundum and sand corundum. Under the heading of block corundum, is included corundum found in masses whether large or small. This is the most difficult form of corundum to mine. Owing to its extreme hardness, it is impossible to drill it for the purpose of blasting. Thus it is not easily broken up. When block corundum is mixed with foreign substances, such as feldspar, hornblende, etc., it is often difficult to clean, whereas a block corundum free from superfluous foreign matter makes an ideal ore, provided the parting planes are not too well developed. The disadvantage of numerous parting planes is explained later.

Corundum crystallizes in the rhombohedral division of the hexagonal system and under the head of crystal corundum is included all the crystal varieties of corundum which occur in block corundum or in sand or gravel.

Some of these crystals take the form of a hexagon with a prism at each end, in which case the crystal is termed "barrel corundum." Many of these crystals are of no definite form, being enclosed in compact masses of surrounding material.

Very small crystals and small grains are termed sand corundum and often occur between a corundum-bearing peridotite rock and the surrounding gneiss or schist.

Corundum possesses no true cleavage, but parting planes are usually present along which the crystal fractures. However, if these planes are so numerous as to be present in the small grains of abrasive material that constitute a grinding wheel, a low abrasive efficiency will be the result because the grains will readily fracture, thus breaking away before becoming dull and useless.

An ideal corundum for an abrasive wheel is one wherein the grains are free from parting lines, thus they will, on becoming dull, break with the irregular to conchoidal fracture, which is a characteristic of corundum. As a matter of fact, all varieties of corundum have comparatively the same degree of hardness, that is, from 8.8 to 9., but some varieties are much higher in abrasive efficiency than others. This is due to the fact that the parting planes are sometimes too numerous as previously stated. This accounts for the fact that some makes of corundum wheels are superior to others. The only practical test for the abrasive efficiency of a doubtful corundum is to make some sample wheels of it and have them tested on actual work under every-day working conditions.

From a theoretical point of view, corundum contains but two elements, alumina and oxygen, its chemical formula being Al_2O_3. Commercial corundum, as well as the gem varieties, generally contains a trace of silica, ferric oxide and combined water. The following table, which is taken from Bulletin No. 269 of the United States Geological Survey, gives the chemical analyses of several well-known corundums.

ANALYSES OF CORUNDUM

Locality	Al_2O_3 Per Cent.	Fe_2O_3 Per Cent.	SiO_2 Per Cent.	(H_2O) Per Cent.	Insoluble residue Per Cent.	Total	Analyst
Hastings County, Ontario	96.92	.....	.....	2.43	1.36	100.71	Wells
Sapphire from India	97.51	1.89	0.80	.....	....	100.20	Smith
Ruby from India	97.32	1.09	1.21	.....	....	99.62	Smith
Corundum Hill Mine, N. Carolina	98.79	.75	.90	.78	....	100.22	Emerson
Laurel Creek Mine, Georgia	95.51	.88	1.45	.74	....	98.58	Emerson

Since corundum occurs more abundantly than emery, the consumer of grinding wheels often asks why corundum wheels command a higher price than wheels made of emery. It is true that corundum deposits are numerous, but not all of these corundums are of the correct structure for grinding-wheel use, as above explained, and, again, corundum goes through a comparatively expensive process before it is fit for the grinding-wheel manufacturers.

It must be borne in mind that corundum, as it comes from the mine, is not in a pure state, being mixed with other minerals, such as feldspar, hornblende, margartite, muscovite, etc. Corundum is sometimes found in huge masses weighing many tons and in cases of this kind, the elimination of the foreign matter is often a difficult problem. Again, a corundum that is to be used in the manufacture of vitrified wheels should be free from such substances as mica, garnet and feldspar. Otherwise difficulties are sure to be encountered in the vitrifying process.

In describing the methods used in mining and cleaning corundum for the market, it may be well to first consider the mines at Craigmont, Canada, as the methods and facilities used there are generally acknowledged to be the most up-to-date and practicable.

The above mine is worked by the Manufacturers Corundum Company, Limited, and the following account of the cleaning methods, etc., is taken from an article: "Corundum at Craigmont," which appeared in the *Canadian Mining Journal* under the date of August 1st, 1907. As this article was written by Mr. H. E. T. Haultain, who was general manager of the company at the time, it is interesting as well as authentic.

"The first discovery of corundum in Ontario was made nearly thirty years ago on this Craig Mountain, then known as Robillard's Hill, by Henry Robillard's daughter. As a small child, she picked up and carried home a crystal that 'looked like a cruet stopper.' For years it remained as an unnamed curiosity, but at the time of the phosphate excitement, it was declared to be phosphate, and Robillard and Fitzgerald located the ground as a phosphate mine.

"In 1896, Ferrier, of the Geological Survey, described the presence of corundum in the neighboring township. Mining operations were commenced in May, 1900, the ore being transported in wagons half a mile to a small mill driven by water power. In March, 1904, the present mill commenced crushing. This mill is by far the largest corundum mill ever built, and is the largest concentrating plant in Canada. It has three divisions, the main mill, the grader, and the finishing department. The latter is a comparatively recent development.

"In the main mill, the rock is crushed on till 90 per cent. of it will pass through a 2.5 millimeter hole, by means of four rock breakers and five sets of rolls. It is concentrated on 20 Overstrom tables; the concentrates, which contain from 50 to 60 per cent. corundum, passing into bins for drainage.

"In the grader, these concentrates are dried, passed over magnetic separators, separated into 20 sizes, from 8 mesh to 200 mesh, and still further subjected to concentration on Wilfley tables and Hooper pneumatic jigs. The resulting product is again dried and again sized and passed into bins, from which it is drawn off into 100-pound bags. The run of bags each day is sampled by hand, every size by itself, and these samples are carefully assayed, and according to the assay results, the bags are stocked in the finishing department.

"The finishing department performs three functions. It thoroughly mixes the product so as to give a uniform material complying closely with fixed standards. It re-screens each size so as to eliminate the results of carelessness in the grader. It automatically samples every lot of thirty bags.

"The finishing foreman, knowing the assays of the contents of his bags, mixes thirty hundredweight at a time in a hopper. From this hopper, the corundum passes in a thin, flat stream past a draft of air, which blows away the mica. It then passes over a set of shaking screens, which screen out both undersize and oversize particles and from this it passes to a bin whence it is drawn off past an automatic sampler direct into canvas bags, which are filled to contain 100 pounds of corundum.

"The bags are then sewn up by machinery and marked for size and lot number. The samples are tested by hand screens for accuracy of sizing, by the eye for pyrites and hornblende contents, by the magnet for magnetite contents, and in the assay office for both corundum and iron content.

"On receipt of the assay results, the bags are marked G or G1, G grade being for silicate wheels and the polishing trade, and G1 for the vitrified wheel trade. A sample weighing about half a pound, representing each lot of thirty bags, is stored for reference."

As before stated, corundum is found in many parts of this country; one of the well-known mines is called the Corundum Hill Mine. It is located in Macon County, North Carolina. Corundum was discovered here in 1870 and mining operations were commenced a year later. This corundum is found in a peridotite rock. The above mine yields block, crystal and sand corundum having a high abrasive efficiency in both silicate and vitrified wheels.

The corundum of this mine enjoys a wide reputation, indeed, one well-known manufacturer of grinding wheels advertises the fact that this brand of corundum is used.

Another famous mine, the Laurel Creek mine, is located in Rabun County, Georgia. This corundum is also found in peridotite and often in massive blocks, many of them weighing several hundred pounds. One mass of corundum taken from this mine is reported to have weighed over 5,000 pounds. It is said that this mine has furnished the largest masses of corundum ever mined in any locality.

An excellent grade of corundum is also found in Gallatin County, Montana, where it occurs in a syenite rock. The crystals are of all sizes up to eight inches long and some have been found that weighed two pounds. Montana corundum is being worked by modern methods. The mills are equipped with up-to-date machinery. Several grinding-wheel manufacturers have used this corundum, reporting it as making an excellent grinding-wheel grade.

The above corundum deposits are mentioned because they are well known to the corundum-consuming trade. It must not be inferred from this, however, that excellent grades of corundum are not found elsewhere in this country. As a matter of fact, there are over 160 corundum deposits that have been listed by geologists, many of them yielding an excellent grade of material.

Abrasive engineers admit that corundum of the right kind makes a very efficient grinding wheel for all purposes, with the exception of materials of low tensile strength such as cast iron, etc., and since corundum occurs so plentifully, the question is often asked: why is it not used more extensively? This is at best a difficult question to answer, but we may throw some light on the subject by considering some facts that exist concerning the corundum industry.

To begin with, the older methods of preparing the abrasive for the market were unsatisfactory; this resulting in an imperfectly cleaned grain not wholly free from impurities, for it is only within the last few years, comparatively speaking, that modern appliances, such as used at the Canadian mines, have been installed in this country.

In the old process of cleaning, the ore was crushed in rock crushers and then re-crushed by passing it between a series of rolls. The resulting grain was then washed in running water, the corundum, being the heaviest, settled while the lighter impurities were carried away. This, of course, applied only to such substances as were not attached to the grains of corundum themselves. The material was then "scoured" by passing it through a machine not unlike a screw conveyor and afterward re-washed. The grain then received a further cleaning in a wet pan muller, which consists of a revolving pan having a shaft over it carrying two wooden rollers. The action of the muller caused the grains to rub against each other, thus gradually wearing away the impurities which were carried away by a stream of running water. The material was then thoroughly dried and sieved to the various commercial sizes.

The old process was expensive and uncertain as to results. Again, severe competition with artificial abrasives began to creep in. The Carborundum Company was spending large sums of money introducing their product to the manufacturing world and the Norton Company was not far behind in extolling the merits of their artificial corundum called Alundum. That it pays to advertise is an old and true saying and artificial abrasives certainly have had the advantage of wide publicity. Again, the artificial abrasives were uniform, whereas corundum, when taken as a whole, was not, since it was the product of many deposits, which naturally varied to some extent.

It is the writer's opinion, given for what it is worth, that corundum as an abrasive has been handled wrong from the start. It has always been sold as a raw material, in competition with emery at first and later in competition with the artificial abrasives. The miners of corundum, even of the very best qualities, were more than willing to sell their product to all who wished to purchase, regardless of the fact that not all manufacturers, a few years ago, knew how to make the best quality of grinding wheels.

The writer fully realizes that it is a simple matter to say, "I told you so," but, nevertheless he ventures the opinion that if, upon the discovery of an exceedingly good quality of corundum, the mine owners had gone into the wheel-making business, absolutely controlling the sale of their product and keeping the same up to a high standard, the story of corundum could have been written differently at the present time.

As a means of verifying the above statement, let us consider The Carborundum Company for a moment. Suppose they had been willing to sell their product to all wheel manufacturers who cared to purchase. Would the carborundum grinding wheel hold the high position that it does at the present day? Decidedly not. Carborundum wheels of all kinds, good and bad, would have been on the market and the result would have been that carborundum would have lost favor in a great many cases.

Now it is a far easier matter to make a poor grinding wheel than it is to produce a good one and here we have the answer regarding corundum, an abrasive occurring abundantly and possessing the highest abrasive qualities, which now occupies an inferior position simply because "too many cooks spoiled the broth." Everybody had corundum wheels for sale—wheels made of pure corundum—certainly. At the same time, however, some of this "pure" corundum was unfit for wheel manufacture, while in other cases corundum of the highest grade was given a bad name because the actual value of the abrasive was hidden in a poorly made grinding wheel.

How, then, should corundum have been handled? some one is sure to ask. The answer is simple. As before stated, the owners of a good corundum deposit should have engaged in the wheel-making end of the business, given their brand of corundum a good name, spent a hundred thousand dollars in equipment, and several hundred thousand more in advertising their product, and the business would have developed itself. The sole ownership of a widely advertised product is a gold mine in itself provided, of course, the business is properly handled, and this is one factor that has made manufactured abrasives with distinctive names so universally used.

Corundum is used for a number of purposes, and, in comparing it with emery, it is a faster cutting abrasive owing to its pure state. Corundum wheels are used principally for steel grinding on both rough and precision work, while corundum in grain and powder form is used for various grinding and polishing operations. Sharpening stones made of corundum are very efficient, while corundum-coated paper and cloth are also put to a number of uses, principally in the form of discs used on the disc-type of grinder for finishing steel parts, both hard and soft. Taken as a whole, corundum covers a wide field and by many it is considered to be the best all-round abrasive known.

DIAMOND

Diamonds are divided into three groups, the transparent and practically flawless varieties used as gem stones and imperfect stones called bort diamonds. There is also a black diamond often called carbonado. The diamond has a specific gravity of 3.50 and is the hardest substance known, being placed at 10 on the mineralogist's scale. The diamond crystallizes in the cubic system, generally taking the form of an octahedron.

The fracture of the diamond is conchoidal and the crystals invariably cleave along planes parallel to the octahedral faces. Diamond cutters avail themselves of this characteristic when reducing the stone to the best shape for cutting. Of late years, however, a sawing process has been developed which is said to be superior to the older method of cleaving by means of a sharp blow.

The diamond is found in India, South America, South

Africa, New South Wales, Borneo, and British Guiana. At the present time, most of the diamond industry centers in South Africa, the mines in this locality having been worked since 1870. Previous to this time, diamonds were found in alluvial deposits and in conglomerates, but in the South African mines, the most famous of which are the Kimberley and the De Beers mines, the diamonds are found imbedded in a kind of blue clay in what are termed "pipes." These are supposed to be filled-up craters of long-extinct volcanoes.

Of the origin of the diamond but little is known, although many eminent geologists have advanced well-grounded theories concerning its formation, but, as the original condition of the carbon, of which the diamond is composed, remains a question, the genesis of the diamond is still unsolved.

The De Beers Company mine many hundred thousand dollars' worth of diamonds weekly and it is needless to state that operations are conducted on a large scale, under the supervision of the most able mining engineers available. To get at the diamond-bearing blue clay, a shaft is sunk several hundred feet into the earth just outside the pipe, tunnels from this shaft running into the diamond-bearing deposits. This material is hoisted to the ground above, where it is spread out in large fields to allow the sun and rain to crumble it to the extent of being easily washed. This weathering process is materially aided by going over the deposits occasionally with steam-plows.

The disintegrated soil is next washed in shallow cylindrical troughs wherein the diamonds are swept to the rim by means of revolving toothed arms, the lighter material escaping at the center. The findings are now concentrated to separate the diamonds from hard foreign substances and then a further separation is effected by passing the concentrates over a greased surface. For some unaccountable reason, the greased surface holds the diamonds while the other worthless materials escape.

It takes, on an average, four tons of blue ground to yield one carat weight of diamond, and as the De Beers mines often yield from three to four pounds of diamonds a day, it is seen that an immense amount of blue ground has to be worked.

The next step, and a very interesting one, is to sort out the diamonds both for color and purity. The color runs from clear white to black, a pale yellow being the most common color. The only difference between a gem stone and a bort diamond is that the former is practically flawless and of good color, while the latter contains black specks and other flaws, has no brilliancy and possesses an irregular fracture.

It is needless to state that the diamond sorters are expert at their work and they never let a gem stone pass for a bort. As a matter of fact, dealers in bort stones look in vain for a gem stone that might have missed the eye of the inspector, but there is no record of their efforts being rewarded.

Aside from truing grinding wheels, bort diamonds are used for many other purposes. In powdered form, they are used for diamond cutting, this process being introduced by L. von Berquen in the year 1476, for cutting and drilling very hard substances, for certain kinds of delicate lapping and grinding in watch factories and occasionally for very minute turning operations in the watch or jeweler's lathe.

The process of converting bort diamonds into diamond powder is simple, being carried out as follows: Several bort stones are first crushed in a little mortar made especially for this purpose and the material thus obtained is placed in a quantity of the very best olive oil. The mixture is thoroughly stirred and allowed to stand for five minutes. The oil is then poured off and the diamond powder that remains in the vessel is called No. 0. The oil is now allowed to stand for ten minutes and again poured off, the remaining powder being known as No. 1. To get the various grades, the time limits used are shown in the accompanying table.

Five minutes	No. 0
Ten minutes	No. 1
Thirty minutes	No. 2
One hour	No. 3
Two hours	No. 4
Ten hours	No. 5

The oil is now allowed to stand until it shows clear, the particles settling at the bottom being known as No. 6.

Carbonado, often called black diamond, is a form of diamond found in Brazil, South America. It is of irregular form and of a black, gray or brown color. It possesses no cleavage and breaks with a granular fracture. Its specific gravity is less than that of the true diamond. It is found almost exclusively in the state of Bahia in what is called *cascalho*, or diamond-bearing gravel. It is generally found in small pieces, although occasionally a large piece is discovered, the largest on record having a weight of 3,150 carats.

For truing grinding wheels, carbonado is superior to bort diamond owing to the fact that absence of cleavage makes the stone less liable to fracture. Thus carbonado is the ideal form of diamond to use in rock drills and diamond saws where the stone must withstand the impact of repeated shocks that would speedily ruin a bort stone.

GARNET

The name garnet is applied to a group of very closely related minerals, some of which, in the pure varieties, are used as gem stones. There are six kinds of garnet known as follows:

Lime alumina garnet	$Ca_3Al_2Si_3O_{12}$
Lime iron garnet	$Ca_3Fe_2Si_3O_{12}$
Lime chrome garnet	$Ca_3Cr_2Si_3O_{12}$
Magnesia alumina garnet	$Mg_3Al_2Si_3O_{12}$
Iron alumina garnet	$Fe_3Al_2Si_3O_{12}$
Manganese alumina garnet	$Mn_3Al_2Si_3O_{12}$

Garnet crystallizes in the cubic system, generally in rhombic dodecahedra. It possesses an imperfect cleavage, the parting lines running parallel to the dodecahedron. Its hardness varies from 6.5 to 7.5 while its specific gravity also varies to quite an extent, in different specimens running from 3.4 to 4.3.

Garnet has been found in crystalline schists, gneiss, granite, metamorphic limestone, serpentine and volcanic rocks. In this country, deposits are located in New York, New Hampshire, Connecticut, Pennsylvania and North Carolina. Large quantities of garnet are mined in New York state, the deposits being located in the vicinity of the Adirondack Mountains. This garnet, which occurs in limestone and gneiss, is of the iron-alumina variety. It is often called Almandine. The garnet of New Hampshire is also of the above variety while North Carolina garnet occurs in two forms, the iron-alumina and a subdivision called rhodolite, which consists of two parts magnesia alumina and one of iron-alumina garnet.

An excellent garnet, known to the trade as Spanish mineral, is mined in Spain. This material is extensively used in this country; in fact, one large manufacturer of garnet paper uses it exclusively. There are no analyses on record to establish the composition of this material, although The United States Geological Survey informed the writer that it is probably an iron-alumina garnet, or almandine.

Garnet is prepared for abrasive uses by crushing, concentrating and magnetic separation to remove the superfluous iron oxide, after which it is graded into various commercial sizes. As an abrasive for smoothing wood, garnet paper and cloth enjoys great popularity, showing high efficiency over ordinary sandpaper, especially on comparatively hard woods, such as oak, cherry, maple, etc. It is not a suitable abrasive for grinding-wheel manufacture, owing to its soft nature, although it is sometimes mixed with corundum in the manufacture of silicate wheels for such operations as knife grinding.

The pure varieties of garnet are often cut as gem stones of which there are many colors from deep red to light rose.

Some of the finest garnet gem stones are found in loose gravel in Macon County, N. C.

QUARTZ

Quartz is one of the most common of minerals and has a wide distribution throughout the world. It is composed of silicon dioxide, or silica SiO_2. Aside from being an essential constituent of some igneous rocks, as granite, it occurs as sand and in crystals. Its specific gravity is 2.65 while its hardness is placed at 7 on Moh's scale. It crystallizes in the trapezohedral-hemihedral class of the rhombohedral division of the hexagonal system. In its pure state, it forms many semi-precious stones such as the amethyst, bloodstone, sardonyx and others. It has no true cleavage and breaks with a conchoidal fracture.

As an abrasive, quartz has many uses. In grain form, large quantities of it are used for plate-glass grinding and in other forms of glass work. Glued on belts, it is used for sanding implement and tool handles. Owing to its hardness and sharpness, it is often used for sand blasting. For sawing stone of the softer varieties, such as marble and limestone, quartz forms a cheap and efficient medium. It is not adapted to grinding-wheel manufacture although it is sometimes mixed with other abrasives in making knife-grinding wheels.

FLINT

Flint is a very hard, brown-colored stone being composed principally of silica and having a specific gravity of 2.6. Its fracture is conchoidal. It is one of the oldest known minerals, being used by prehistoric man in the manufacture of implements and weapons. It was once widely used for striking fire and until the invention of the percussion cap the flint-lock musket was used the world over. Thus it is seen that this now little used material once played an important part in shaping the destinies of nations. A form of flint called flint-quartz is used in making the flint paper of commerce which is more commonly spoken of as sand-paper. In this country, the material in question is mined in several places, the more important deposits being in Maine, Maryland and Wisconsin.

NATURAL SHARPENING STONES

Under this heading are included all the natural stones used, as hand stones, hones, etc., for various sharpening operations. Sharpening stones are of very ancient origin, specimens having been unearthed in Egypt dating back to 1500 B. C. Pliny, writing early in the Christian era, tells of a stone from Crete used with oil and one from Naxos used with water. The latter, in all probability, was nothing more or less than a fragment of emery ore. The oldest natural stone of modern civilization is the Turkey stone mined in Asia Minor. This stone became popular over one hundred years ago and to some extent is used at the present day. Other famous sharpening stones of a century ago were the Belgian razor hone, which owes its abrasive qualities to minute particles of garnet, and the German water hone. Both of these stones are sold at the present time.

The well-known Arkansas and Ouachita (Washita) stones were discovered in Arkansas in the year 1815. These are found in the foot-hills of the Ozark Mountains. There are two varieties of Arkansas stones; hard Arkansas and soft Arkansas. The former consists of 99½ per cent. pure silica, being composed of very small particles of hexagonal-shaped crystals to which it owes its cutting qualities. This stone is widely used by watchmakers, engravers, toolmakers, etc., for putting a very fine edge on cutting tools. Soft Arkansas stones, although not as hard as the former variety, are freer cutting, therefore they are the choice of the carpenter, cabinet maker and pattern maker for putting the correct cutting edge on chisels, plane irons, etc.

Another famous natural stone is the Indian Pond scythe stone, discovered in New Hampshire in the year 1821. Upon this discovery was founded the well-known business of the Pike Manufacturing Company, whose goods are known to mechanics throughout the world. Several grades of fine sandstone are used in making sharpening stones for various purposes, scythe stones, axe stones, etc., large deposits being located in Ohio. As a matter of fact, this state furnishes many varieties of natural sharpening stones such as the Hindustan, Queer Creek and Chagrin Falls brands. These are all excellent stones and find a ready market for purposes to which they are adapted.

TRIPOLI

Tripoli is a trade name given to a yellowish abrasive material which results from the leaching of calcareous material from limestones and cherts. This material is also often called rotten stone. It is found principally in Illinois and Missouri. For abrasive purposes, it is used principally for "cutting down" before polishing soft metals. It is put on the market in the form of cakes, being mixed with tallow and compressed.

PUMICE

Pumice is of volcanic origin, being an igneous rock which was cooled so quickly that it did not have time to crystallize. It sometimes contains impurities, such as feldspar and hornblende, which diminish the general value of the material as an abrasive, as the impurities leave deep scratches owing to their hard nature. Natural pumice is found in California, Kansas, Nebraska, Idaho, South Dakota and Utah in this country while much of the imported article comes from various islands in the Mediterranean Sea. As an abrasive, pumice is used principally for very fine varnish rubbing and in the manufacture of metal polishes.

CHAPTER TWO

ARTIFICIAL ABRASIVES

Various artificial abrasives—Their physical and chemical properties—Their commercial application—Methods and processes employed in the production of artificial abrasives—Carborundum—Alundum—Aloxite—Boro-Carbone—Oxalumina—Adamite—Crystolon, etc.—Relative hardness and abrasive efficiency of various materials—Artificial production of precious stones—Their abrasive properties—Other artificial abrasives and their production—Experimental work—Electro-thermic processes—Production of rouge and crocus—Diamonds and crushed steel—Angular grit.

UNDER this heading can be included all grinding and polishing materials produced by the arts of man; the most commonly used being divided into two classes, carbide of silicon abrasives, the original of which is Carborundum, and artificial corundum, which material, in the form of precious stones, has been made for more than seventy years.

In reality, the artificial corundum of today, sold under various trade names, such as Aloxite, Alundum, Boro-Carbone, Oxalumina, etc., is an indirect outgrowth of the experiments of other days, wherein scientific investigators had to content themselves with making artificial rubies and sapphires, while vainly striving to produce the artificial diamond.

To class rouge and crocus as abrasives may seem rather far fetched on first thought, but it must be borne in mind that while these materials are used for polishing purposes only, their mission is accomplished through abrasion, since the finest mechanically finished surface possible to produce, when viewed under a powerful microscope, is seen to consist of a multitude of fine scratches.

Crushed steel and chilled iron are abrasives in the true sense of the word. The former is used for grinding and the latter for sand blasting, which is a process of removing superfluous material by abrasive action.

Carborundum is undeniably the best known and, for many purposes, the most useful of all the artificial abrasives; indeed, it is often called the father of them all, since its introduction into the mechanical world gave electrochemical engineers an impetus to produce competitive material.

For the sake of clearness, the various well-known artificial abrasives will be considered in chronological order, Carborundum being at the head of the list as it was the first artificial abrasive to be recognized commercially.

CARBORUNDUM

Carborundum is a trade name given to carbide of silicon, a substance discovered during the year 1891 by Edward G. Acheson. It can truly be called the most unique of all abrasives as it has never been found in nature, therefore it is not an imitation of nature's work, but a distinct creation in a class by itself. It is a chemical combination of the two elements carbon and silicon, its chemical formula being SiC.

The raw materials entering into the manufacture of Carborundum are coke, sand, salt and sawdust. Coke supplies the element carbon, while the element silicon is derived from the sand. The object of the sawdust is simply to make the mass porous, thereby permitting the gases generated during the burning operation a free passage to the open air. The object of the salt is to eliminate impurities such as iron, etc. As the salt volatilizes, it impregnates the whole mass, taking up impurities in the form of chlorides.

The Carborundum furnaces used at the present time are fifty feet long, ten feet wide, and five feet high. The original furnaces, however, were somewhat smaller. Both types are of open construction, the sides and ends being built of brick. The end walls are approximately two feet thick, through which run the terminals for the electric current. These terminals are made of carbon rods three feet long and three inches in diameter, arranged parallel in bundles of sixty, the spaces between the rods being packed tightly with graphite. At the outer ends of the rods, copper terminals are let in, which, in turn, are connected to a large copper cap. Current is supplied by means of cables from overhead bus bars.

In charging the Carborundum furnaces preparatory to burning, a mixture of thirty-four parts coke, fifty-four parts sand, ten parts sawdust and two parts salt is used. The materials are thoroughly mixed and brought to the furnaces by means of mechanical conveyors. Enough of this mixture is placed in the furnace to bring the upper layer level with the ends of the electrodes. A trench is now made between the terminals, wherein a core of granulated coke is laid. The object of the coke is to allow a free passage for the electric current. More of the material is now introduced and built up in the form of a mound as shown in Fig 1.

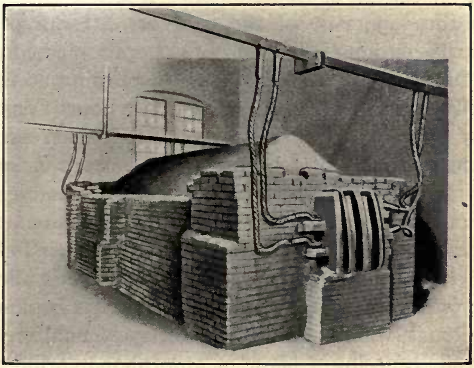


Fig. 1.—Carborundum furnace charged with raw material, ready for burning.

An alternating current of 190 volts and 6,000 amperes is now turned on. As the mass heats, the resistance to the current gradually diminishes, and after about four hours' operation, it remains constant at 125 volts and 6,000 amperes. The sawdust, of course, burns away first, after which carbon monoxide is given off. This burns freely at the sides and top of the furnace with a yellow flame. As the process of burning progresses, the mass shrinks somewhat, which necessitates adding more raw material. Occasionally the phenomenon of "blowing" occurs, which makes the furnace look not unlike a miniature volcano. This is caused by an over-charge of gas suddenly igniting and bursting through the top crust of the charge. After a period of about thirty-six hours, the burning operation is completed. Several furnaces are in the process of burning at the same time, being started at intervals of a few hours apart. The object of this is to insure constant production as well as the economical use of current. The current is carefully watched at all times by an electrical engineer especially trained on electric-furnace work. This is quite essential, otherwise a uniform product would be an impossibility.

After the burning is completed, the furnace is allowed to cool for twenty-four hours, after which it is broken open. The top crust, which is in a comparatively unaltered state, is removed, exposing a layer of amorphous carbide of silicon under which lies the pure crystallized Carborundum. Next comes a mixture of Carborundum and graphite and, last of all, the core. The intense heat, estimated at approximately 7,500° Fahrenheit, transforms the core into practically pure graphite. The amorphous carbide of silicon previously mentioned was at first considered of no value and consequently thrown away. Later scientific investigation, however, showed that it possessed a high refractory value. At the present time it finds a ready market as a refractory material for lining furnaces subjected to high heats of long duration.

The Carborundum crystals, while well developed, are not regular in appearance, some being hexagonal and others rhombohedral. The crystals have no lines of cleavage, breaking with a distinct crystalline fracture, invariably leaving sharp cutting edges.

Carborundum crystals are of various colors, being truly beautiful from an artistic point of view; coal black, deep brown, light green, pale blue, deep blue and purple are all intermingled in a gorgeous riot of colors seldom equaled in nature. In the early days of the industry, green Carborundum predominated and at present many are of the opinion that green Carborundum is superior in cutting qualities to specimens of other colors. Actual tests, however, conducted by abrasive engineers, have proven beyond all reasonable doubt that the above theory is absolutely groundless, the color being the result of oxidation.

On Moh's scale of hardness, Carborundum is placed between nine and ten. It is probably nearer ten than nine as Carborundum has been known to scratch rubies, sapphires, and diamonds. Compared with other abrasives, Carborundum is comparatively light, its specific gravity being approximately 3.18. This factor should not be underestimated since the centrifugal force of a revolving body is proportional to the square of the velocity. Thus, wheels running at the high speeds recommended in present-day grinding practice are under a severe centrifugal strain, and it is apparent that the lightest abrasive makes the safest wheel.

Fig. 2 gives a good idea of the appearance of Carborundum as it comes from the furnace, the photograph being taken after the outer layers and core had been removed. As this material looks like the products of the mine and quarry, the question is sometimes asked, "Why is carbide of silicon not found in nature?" The only reasonable answer the writer can give is that the degree of heat at which both carbide of silicon and graphite are formed is so near the same temperature that nature seemed content to produce graphite alone.

An interesting feature of the production of Carborundum, from the electrical engineer's point of view, at least, is the form of circuit breaker used in making and breaking the heavy current. As this amounts to 750 kilowatts it is seen that the ordinary form of contact switch would be destroyed in short order. To overcome this difficulty, a special circuit breaker of the water-regulator type is used. This consists of a number of iron plates working in a salt-water solution.

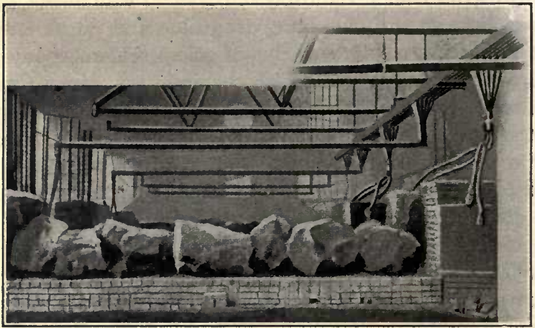


Fig. 2.—How Carborundum looks as it comes from the furnace.

The large masses of crystals produced in the Carborundum furnace are reduced in crushing machines of the dry-pan muller type, illustrated in Fig. 3. Under the weight of the rolls (two tons each) and the rotary motion of the pan (thirty revolutions per minute), the Carborundum masses are rapidly crushed to small crystals. These range all the way from very coarse to an impalpable powder. Although the crushing rolls are made of manganese steel, they do not last long, owing to the abrasive action of the Carborundum grains, a pair lasting but six months at the longest.

Carborundum as it comes from the furnace is impregnated with a small amount of iron oxide taken from the sand and other minor impurities derived from the coke. To eliminate these the crystals are transferred to wooden vats, lined with lead, where they are lixiviated with strong sulphuric acid. The crystals are next washed in long wooden troughs, the washing being passed through settling tanks which help to separate the grains from the fine powder. The crystals are now thoroughly dried by coke fires, after which they are ready for "grading," or "screening," as this operation is sometimes termed.

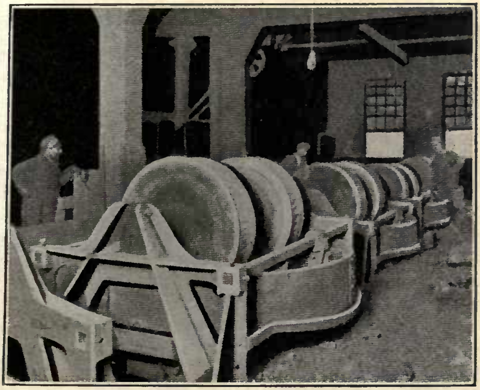


Fig. 3.—Muller type of crusher used in preparing Carborundum.

The screening machine, as shown in Fig. 4, consists of a series of screens set on a slight incline with their ends meeting. The fine screens are made of a superior quality of milling silk, while the coarser type are made of brass wire. The Carborundum grains are fed on the screen at the high end, and a vibratory motion, imparted to the screen frame, causes them to journey downward. In passing over the screens, they find an outlet suitable for their size. After passing through the screens, the grain flows into receptacles placed under the delivery openings as the illustration shows. The screens vary from six meshes to the inch to two hundred and twenty meshes to the inch.

Owing to the abrasive action of the grain the screens wear readily. Thus care has to be exercised to insure uniform grading. This is accomplished by frequently testing samples that have passed through the several screens in testing machines carrying master screens. When the grains are out of grade, it is a sign that the screen through which it passed has worn to the extent of warranting renewal.

Fig. 4.—Screening machines used in grading Carborundum.

This is promptly attended to and all over-size material regraded.

It is not practicable to grade Carborundum finer than two hundred and twenty by the screening method. Therefore another method is used for grading the powders as they are termed. In this system the fine powder is carried by a stream of water through a series of settling tanks. In passing through the tanks, one after another, the heavier grains sink. Thus, the last tank contains nothing but the very finest powder. At the works of The Carborundum Company, the following grains and powders are carried in stock: 6, 8, 10, 12, 14, 16, 20, 24, 30, 36, 40, 50, 60, 70, 80, 90, 100, 120, 150, 180, 220 and powders F, FF, FFF.

Carborundum is very hard, exceedingly sharp, and when made into grinding wheels, it furnishes a highly efficient abrasive for the grinding of materials of comparatively low tensile strength, such as gray iron, chilled iron, brass, bronze, marble, pearl, bone, horn, etc. In grain and powder form, Carborundum is extensively used for lapidary work, valve grinding, plate-glass beveling, stone finishing, etc. It is sometimes used on "set up" wheels for polishing cast iron, but owing to the fact that considerable skill is required, both in preparing the glue and in covering the wheels, the above practice has not become universal.

Carborundum coated paper and cloth enjoy an immense sale in the boot-and-shoe industry, where they are used for such operations as fore-part buffing, heel breasting, heel scouring, etc. In the wood-working industries, however, Carborundum paper does not show efficiency over flint and garnet paper as its sharp nature causes the coated paper to fill up very readily.

In the leather-manufacturing industries, Carborundum is used in a barrel-shaped wheel form, for the "wet wheeling" of leather, as this operation on skins is termed. In grain form, it is used on a special shaped cylinder for "bucktailing," while in the form of paper and cloth, it is used for various finishing operations.

It is often stated that Carborundum will not grind steel economically, but this statement is erroneous. At one time The Carborundum Company sold a large number of wheels to the lumber industry for saw gumming. As a matter of fact, this is an operation calling for a very cool and rapid-cutting wheel. The writer has used Carborundum wheels for the cylindrical grinding of cold rolled and machine steel with excellent results. Not only did the wheels produce an excellent finish, but they were very uniform in grade, a feature not at all common some ten years ago. The writer has seen Carborundum wheels used for automobile crank-shaft grinding by one of the largest manufacturers in the Middle West. The results were satisfactory, Carborundum being preferred to all other makes of wheels.

It must be considered that the above instances happened some years ago, before the high development and accurate grading of manufactured alumina abrasives, which at the present time show higher efficiency on steel grinding than is possible to attain with Carborundum. The above statements are made simply to show that at one time in the history of grinding, Carborundum held its own on steel.

Why, then, does not Carborundum, which is acknowledged to be the hardest and sharpest of all abrasives, both natural and artificial, show high efficiency on steel grinding? This is, at best, a hard question to answer and one upon which opinions are at great variance. The writer's opinion, based upon many years of observation, close study, and practical application, is that if Carborundum was not quite so hard, and broke with a conchoidal instead of a crystalline fracture, it would eventually drive the alumina abrasives out of the market.

The above opinion can be called pure speculation without a suitable hypothesis, therefore it is open to question. However this may be, it is set down for what it is worth, for opinions, no matter how theoretical they may appear, possess some merit, at least until they have been disproved by actual demonstration, and as it is an impossibility to produce the type of Carborundum described, the above theory may be as rational as any other.

The name Carborundum is registered as a trade mark, thus it is the sole property of The Carborundum Company. If, however, grinding wheels are made of Carborundum, no matter by whom, they can lawfully be sold as genuine Carborundum wheels.

OTHER CARBIDE OF SILICON ABRASIVES

A carbide of silicon abrasive called "Carbosolite" is made in Germany. It has been sold in this country to a limited extent, chiefly in the granite-finishing business. It is mostly of a dark-gray color and it is not considered as pure as Carborundum. Aside from the granite trade, a limited amount of this material is made into grinding wheels.

Crystolon is a trade name given to a carbide of silicon abrasive made by Norton Company at their electric-furnace plant in Chippawa, Canada. It is made by practically the same method used in producing Carborundum; the same raw material forming the ingredients. It was first put on the market about seven years ago, and at the present time it enjoys a large sale, both in the form of wheels and grain.

The Abrasive Company of Philadelphia market grinding wheels made of carbide of silicon, calling the same "Electrolon." This material is an electric-furnace product, being made of selected materials, the grain being specially treated before being incorporated into grinding wheels. This material was first put on the market during the year 1914 and it is considered by many large consumers of grinding wheels to be a very efficient abrasive.

ARTIFICIAL CORUNDUM

As stated at the beginning of this chapter, artificial corundum has been produced for more than seventy years and in considering the subject in the abstract, a little light thrown on the experimentalists of other days may not be out of place at the present time.

It is a well-known fact among those conversant with the values of precious stones that a true Oriental ruby, of fine color and flawless, is worth more, carat for carat, than the finest diamonds of Brazil or South Africa. The term ruby is often misconstrued to embrace the spinel or balas ruby. Indeed, the famous "ruby" set in the Maltese cross in front of the imperial state crown of England is in reality a spinel. It is, of course, possible for experts to readily distinguish the difference between true and spinel rubies, but since the ruby is nothing more or less than pure crystallized alumina, colored with a small quantity of chromium, it is evident that a laboratory product of the above materials is a true synthesis of the ruby. It is as much entitled to the name as the choicest specimens of nature from the Mandalay district of Upper Burma, where the finest rubies have been found.

In the year 1837, M. A. A. Gaudin successfully made true rubies by fusing alum in a carbon crucible at a very high temperature, a little chromium being added to impart the desired color. The rubies, while of a very small size, hardly visible to the naked eye, proved that it was within the means of science to produce corundum artificially.

J. J. Ebelmen's experiments during the year 1847 resulted in the artificial production of the white sapphire and rose-colored spinel. The process consisted of fusing the desired constituents at high temperature in boracic acid. He also produced the ruby by using borax as a solvent.

Not until the year 1877, however, was it proved possible to produce crystallized artificial alumina of a size suitable for cutting into small stones, the process being the result of experiments on the part of E. Frémy and C. Feil. The process used was as follows: By the fusion of lead oxide and alumina in a fire-clay crucible, lead aluminate was formed. Silica enters into the composition of fire clay, and under the influence of high temperature, the silica of the crucible gradually decomposes the lead aluminate, forming lead silicate, which remains in a liquid state while the alumina crystallizes as white sapphire. By mixing in a small amount of chromium, rubies were formed. The experiments of Sainte-Claire Deville, Caron, Elsner, Debray, and De Senarmont, too lengthy to be described fully here, did much toward reducing the art of producing artificial corundum to an exact science.

So much for the experimentalists of other days. They did not attempt to produce artificial corundum for abrasive purposes, to be sure, such a possibility being undreamed of in their day. The fact remains, however, that their investigations were of value as by their means it was shown conclusively that it was possible to produce artificial corundum.

One of the first inventors to achieve success in the manufacture of an artificial abrasive of the alumina type was Franz Hasslacher of Frankfurt-on-Main, Germany. As stated elsewhere, emery contains a high percentage of iron oxide, which possesses no abrasive value, and aside from this fact most specimens of emery are hydrous, often containing as high as 5 per cent. of combined water, which causes trouble in the kilns where wheels, in which this emery is incorporated, are made by the vitrified process. The above-named inventor was granted a patent for changing natural emery into iron-and-water-free corundum (German patent No. 85,021, issued Nov. 20, 1894), the method of procedure being as follows:

Crushed emery ore and charcoal or coke are first mixed together, the percentage of the latter being equal to the proportion of iron oxide contained in the emery ore. This mixture is then placed in an electric furnace, an illustration of which is shown in Fig. 5. The furnace consists of firebrick walls (A), supported by the uprights (H), the electric current being transmitted by the carbons (C).

In charging the furnace the opening at the bottom (D) is closed by means of a glass plate (P) and the furnace filled with the emery-and-coke mixture until the top of the mass is level with the center of the carbons. The carbons are placed about 1–½ inches apart, the space between them being packed with a few lumps of coke. The furnace is now completely filled and heaped up as shown at (S).

An alternating current of 300 amperes at a pressure of 110 volts is now turned on, under the influence of which the pieces of coke between the carbons are brought up to incandescence, which causes the surrounding emery to assume a molten state. The pieces of coke are soon absorbed and an electric arc established between the terminals, the presence of which is proven by a loud buzzing sound.

Carbon monoxide gas escapes through the mass, burning with a blue flame. The presence of this gas indicates that the iron oxides are in the process of reduction. A large mass of molten emery soon forms about the electrodes, the furnace walls being protected by the surrounding, unmelted material as the illustration shows. When a sufficient amount of emery has been melted, the glass plate fuses, causing the emery to run through to the floor in a dazzling, white-hot stream.

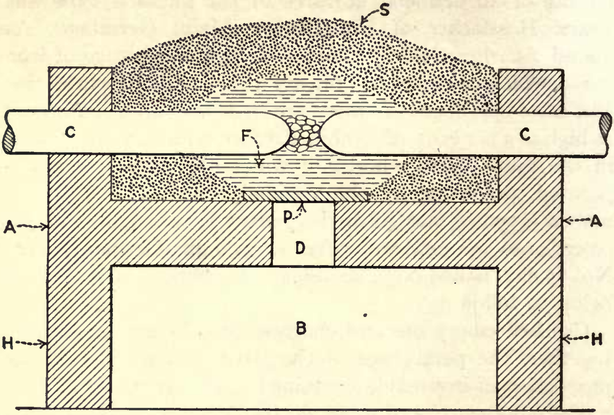


Fig. 5.—Hasslecher's furnace for making artificial corundum.

At this point, the top crust is broken in, whereat the descending crust of emery cools the molten emery around the opening, causing the same to close. The furnace is then charged again and the process continued. In about fifteen minutes, the molten emery again breaks through. Thus the process can be continued as long as convenient.

The resulting product is fairly well crystallized alumina, running from white to blue in color, possessing a luster not unlike that of quartz. This material, being free from iron, possesses a higher abrasive efficiency than emery and for some purposes it gives excellent results. It has been used in this country to quite an extent, but at the present time, and in fact for the last fifteen years, it has not been able to successfully compete with American-made products.

Another process for making artificial alumina was patented by Dr. G. Döllner of Rixdorf, Germany (German patent No. 97,408, issued Feb. 28th, 1897). The method is quite simple and easily carried out, consisting of mixing crushed aluminum with oxides, peroxides and other metallic compounds with oxygen. This mixture, when ignited, owing to the high combustion temperature of aluminum, reacts in an endothermic manner causing the formation of oxide of alumina. This phenomenon is accompanied by the separation of the metals, the oxides and peroxides of which were used.

In the reaction, the oxide of alumina is brought to a state of fusion, and, on cooling, it is characterized by extreme hardness. In his patent specifications, the inventor claims that this material is of a degree of sufficient hardness to replace diamonds for technical purposes, and further states that it is superior to other artificial abrasives as by this process grinding wheels can be prepared in solid blocks—that is a grinding wheel produced without a bonding material. Whether or not this has been carried out successfully the writer cannot state. Even if it were possible, however, such a wheel would be of one grade only, thus its field of usefulness would be limited.

It may be well at this time to consider an abrasive called Corubin, which is a by-product resulting from the manufacture of chromium by the Goldschmidt Thermit aluminothermic process. The above process is one for making metallic chromium through endothermic action, the slag or by-product of which forms an excellent abrasive material as the following analysis shows.

Chromium	13.2	per cent.
SiO_2	3.08	"
Al_2O_3	71.65	"
Fe	2.00	"
CaO	Trace	
MgO	1.35	"

From the above, it is seen that this material is composed chiefly of alumina and chromium, the percentage of alumina being high enough to form an efficient abrasive, while the amount of chromium contained renders the abrasive very hard and tough.

In the manufacture of other metals by the Goldschmidt Thermit process, other slags are obtained being only slightly inferior in abrasive efficiency to Corubin. The writer is informed on good authority that these abrasives are giving satisfaction, owing to the fact that several thousand tons of them are sold annually to responsible abrasive-wheel manufacturers in this country. Large quantities of Corubin are used abroad in the manufacture of lenses, wherein the abrasive is used to grind the glass, and in other abrasive work.

That the experimentalists made great strides in perfecting methods for the manufacture of artificial abrasives (after Acheson and The Carborundum Company proved to the world that there was a ready market for an artificial abrasive) no one will deny. The artificial corundum made previous to the year 1900, however, was incomplete in that it lacked what we term at the present day *abrasive temper*. We all know that high-carbon steel, or tool steel as it is called, possesses a valuable characteristic inasmuch as it can be made exceedingly hard by heating it red hot and suddenly cooling it by immersion in water, or a brine solution. Further, by tempering it, or drawing the color as the smith says, we get various degrees of temper for innumerable purposes; a very hard steel for razors, a somewhat softer material for machine reamers, softer still for lathe tools, and yet softer for cold chisels and axes.

A piece of tool steel that has been hardened but not drawn, is very brittle, thus its field is limited. For an illustration, a lathe tool, a pair of scissors, or an axe thus treated would be useless—the lathe tool would crumble away as soon as it was brought in contact with the piece of work to be turned, the scissors would break the first time they were dropped on the floor, while the axe would fly to pieces at the first stroke of the woodsman. Thus, it is seen, that the characteristic of temper is what gives tool steel its immense value in the arts and sciences.

To complete the parallel we will now consider artificial corundum, which, as originally made, was very hard and useful in a limited field only. It is evident that if means could be found whereby the temper of the material in question could be controlled, its usefulness would be increased a thousandfold.

This has been successfully accomplished and the credit is due to an American, Charles B. Jacobs (no relation to the writer), who in the year 1900 obtained a process patent for manufacturing an abrasive from bauxite and tempering the same to a degree of hardness suitable for abrasive purposes. Briefly stated, Mr. Jacobs' process consists of fusing bauxite in an electric furnace of the arc type and cooling the resultant alumina oxide in a manner to impart the desired degree of temper.

Before considering Mr. Jacobs' process, it will be of advantage at this point to touch briefly on the material bauxite as we will have occasion to refer to it several times later.

BAUXITE

Bauxite is a clay-like mineral, or rather a combination of minerals, containing among other constituents alumina oxide, iron oxide, silica and titanic acid. It is taken to be a decomposition product of igneous rock. It was first discovered in France as long ago as the year 1821 by P. Berthier, who called it alumina hydratée de Beaux. The present name of bauxite was given to the material in question by E. H. Sainte-Claire Deville in 1861. The name was derived from the village of Les Beaux in Southern France where the material was first observed.

Bauxite is never found in a crystallized state, but always as a clay-like earth. Its color varies from light yellow to deep red. The material, while always impure, contains a high percentage of alumina oxide. Hence its value as a raw material for the manufacture of an alumina abrasive claimed the attention of abrasive manufacturers some years ago, when a substitute for natural alumina abrasives, that is to say emery and corundum, was seriously given consideration.

In this country, bauxite is found in Georgia, Alabama and Arkansas. In these localities, the material in question is generally associated with limestone and its origin is attributed to the action of solutions of aluminum sulphate on limestone.

CHARLES B. JACOBS' PROCESS

Mr. Jacobs' electric furnace for carrying out his process of converting bauxite into artificial corundum is shown in Fig. 6. It consists of a rectangular casing (1) with a sloping top, at the apex of which is an opening (2) which serves the double purpose of charging the furnace and carrying off the volatile matter of the charge. The furnace casing is constructed with a sheet-iron shell (3) which is lined with fire brick (4), which serves as a non-conducting material in regard to electricity as well as heat. Next to this, are laid carbon bricks (5).

The hearth of the furnace consists of a cast-iron plate (6) lined first with ground lime (7) and then carbon bricks (8) laid in the lime. The hearth is mounted on a screw (9) by means of which it can be lowered or raised at will. By lowering the hearth during the furnace run, in a gradual manner, a thick body of the fused material is obtained.

Over the earth are mounted four pairs of carbon electrodes (10) between which the electric arc is produced. The furnace is supported by cast-iron legs (11). These are of sufficient height to allow the hearth to be lowered clear of the bottom of the furnace. It is seen that the two outside pairs of electrodes are away from the furnace walls; the object being to keep the walls clear of fused material. The hearth

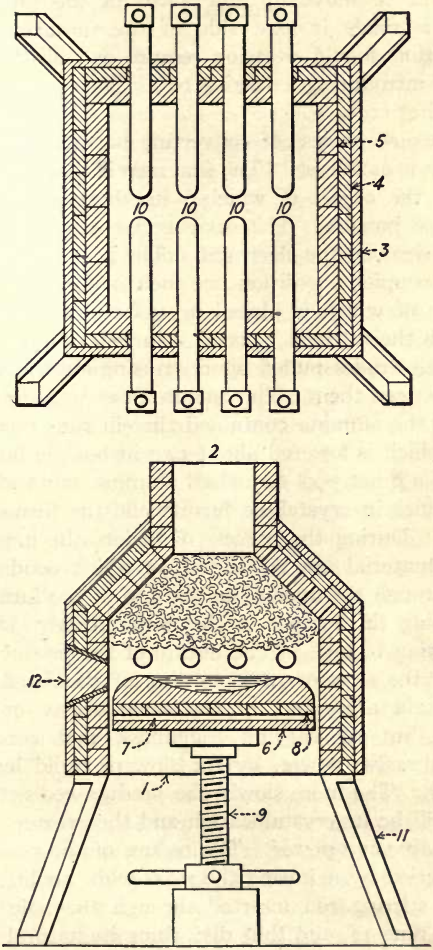


Fig. 6.—Jacobs' artificial corundum furnace.

is left free to move up and down in the furnace. An opening is made in one side of the furnace to permit of inspection should occasion require and also to provide means of introducing a stirring rod. The opening is closed by the plug (12).

Mr. Jacobs' process of converting bauxite into artificial corundum is as follows: The first step is to calcine the raw material, the object of which is to drive away as much moisture as possible. This saves undue expenditure of current and wear on the electrodes. The hearth is now raised until it occupies a position one inch below the electrodes, each pair of which is placed in contact, and the furnace filled with the calcined bauxite. Current is now turned on and the electrodes pulled apart, causing electric arcs to be set up between them. The bauxite fuses under the intense heat and the alumina contained therein runs down on the hearth, which is lowered about two inches per hour. This results in a quiet pool of melted alumina oxide which cools and solidifies in crystalline form while the furnace hearth descends. During the process of fusion, the impurities in the raw material are volatilized, in which condition they escape through the opening at the top of the furnace.

Regarding the temper of the material, Mr. Jacobs has the following to say: "The nature of the product may be varied by the slow or rapid cooling of the fused mass, so as to obtain a product of the same degree of absolute hardness, but of varying toughness, and consequently varying abrasive power, by the slow or rapid lowering of the hearth. The more slowly the product cools, the better defined will be its crystallization and the greater its toughness and abrasive power. The nature of the product may also be varied by agitating the mass while cooling, as by a poker or stirring rod inserted through the hole normally closed by plug 12, and thus disturbing its natural tendency of crystallization, producing thereby a finer grain of crystalline structure than when the material cools without disturbance."

ALUNDUM

Alundum is a trade name originated by Norton Company and is applied to an alumina abrasive manufactured under the above-described patent. However, the process has been modified somewhat as shown by the following account of the same by Richard G. Williams, Mechanical Engineer and Special Investigator of Norton Company, in a paper presented at the thirty-first general meeting of the American Electrochemical Society held in Detroit, Mich., May 2—5, 1917.

"The raw material must necessarily be a substance high in aluminum oxide. The most satisfactory material is a high-grade bauxite, although satisfactory abrasives are being made from other materials, such as low-grade bauxite and emery. Aluminous abrasives are made in the arc type of furnace. These furnaces often consist of a wrought-iron shell, or some form of pot, lined with carbon. The electrodes are suspended in the pot and then lowered to the bottom of the furnace, a train of graphite or fine coke placed between the electrodes, the current turned on and an arc suitable for fusing is available as soon as the train of graphite or coke has volatilized.

"Before fusion in the electric furnace, the bauxite receives a calcining treatment to drive off 30 per cent. of combined water. Suitable chemicals are mixed with the calcined ore in order to facilitate the removal of such materials as iron and silicon. Furnaces of three-ton capacity consume between 650 and 700 horse power and it takes approximately 24 hours for a furnace run. After the run is completed, the shell is stripped off or the furnace sides removed and the pigs allowed to cool. When the pigs have cooled to a sufficient temperature, they are broken up by sledge hammers into pieces convenient for putting through a large jaw crusher. This operation reduces the material to pieces about the size of a man's fist, and in this condition the abrasive is sent to the grinding-wheel factory for further treatment."

Alundum, as put on the market, consists of two kinds; ordinary Alundum and white Alundum. White Alundum makes an almost white wheel when bonded by the silicate process and a deep red-colored wheel when the vitrified process is employed. White Alundum is designated by the prefix 38. A 60 grit wheel made of white Alundum is marked 3860. Ordinary Alundum is used for general steel grinding on both rough and precision work, while white Alundum is used principally for grinding such materials as high-alloy steels and general precision tool-room grinding.

ALOXITE

Aloxite is the trade name of an alumina abrasive manufactured by The Carborundum Company. It is made from bauxite in an electric furnace of the arc type. The Carborundum Company's Aloxite plant is located at Sarrancolin, a small town in the province of Hautes Pyrenees in Southern France, so as to be near an adequate supply of the raw material. As a precautionary measure, however, several furnaces are operated at the Niagara Falls plant.

An Aloxite furnace is quite a simple affair, consisting of an outer shell resting on a base, and two electrodes for supplying the current. The outer shell is water-cooled, but does not have a refractory lining as the charge forms this itself. It is placed on wheels to facilitate moving it from under the electrodes when the burning operation is completed.

In charging the furnace, the bottom is first lined with a mixture of carbon and tar. Next a layer of bauxite is introduced and the electrodes lowered until they rest on the bauxite. A path of graphite is now laid between the electrodes, the object being to form a free passage for the current. As soon as the charge is in a molten state, however, it forms a good conductor in itself. The current is now turned on and the bauxite brought to a molten state. An alternating current of 6,000 amperes at a pressure of 100 volts is used.

As soon as the first layer of bauxite is in a molten state, another layer is introduced, the electrodes raised, and this layer melted. This process is continued until the furnace is full, which requires about thirty-six hours. During the melting process, the oxide of iron and silicon in the raw material unite in the form of ferro silicon, thus practically freeing the alumina from all impurities. As a matter of fact, Aloxite runs about 97 per cent. pure alumina. The ferro silicon, being heavier than the alumina, sinks to the bottom of the furnace where it is easily disposed of. Several furnaces are operated at the same time, the object being twofold; that is, to produce a large supply of material and to keep the current consumption as uniform as possible.

After the furnace has cooled sufficiently, the outer shell is removed, exposing the Aloxite ingot. Two of these are shown in Fig. 7. The ingots are first broken into pieces of about fifty pounds weight by means of a heavy breaker of the skull-cracker type. The pieces thus obtained are next crushed in an ore crusher of the type illustrated in Fig. 8. Two crushers are employed, the first one being set to produce lumps about as large as a man's fist while the second crusher breaks them still smaller. The Aloxite lumps are now passed through a magnetic separator which re-

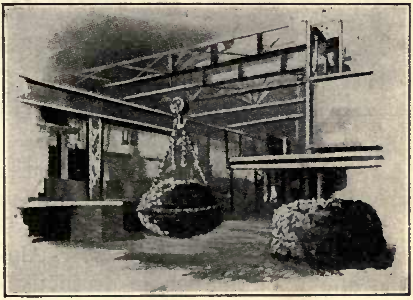


Fig. 7.—Aloxite ingots as they come from the furnace.

moves any lumps of silicon which may have clung to the ingot. A roller-type crusher is next used which completes the crushing operation. Aloxite is screened in the same manner as Carborundum and the numbers of the grades and powers are identical.

Aloxite is very tough and possesses what might be termed a well-regulated temper. The grains are hard enough to cut rapidly, yet not so tough that they will not fracture when dull. The temper of the grain is under control, thus a uniform abrasive is the result. In color, Aloxite is of a purplish blue and its formation is distinctly crystalline, as Fig. 9 shows.

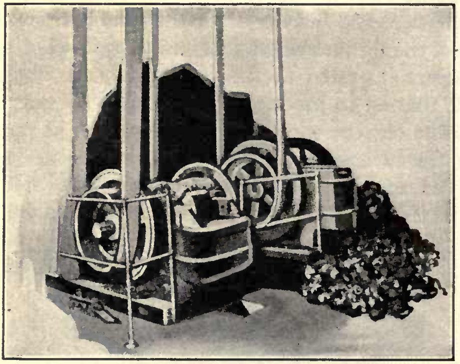


Fig. 8.—Ore crushers used in preparing Aloxite.

Aloxite is adapted for all kinds of steel grinding, especially on precision work such as surface grinding, cylindrical grinding, cutter and reamer sharpening, special grinding operations such as crank-shaft grinding, wherein it is absolutely essential that the corner of the wheel hold a well-defined radius for some time, and for the general grinding of high-speed and alloy steels. As a substitute for emery cloth, Aloxite-coated cloth has found favor with many manufacturers of motor-cars and other products. Aloxite grain is also being used for many grinding and polishing operations heretofore done with emery grain. In the cut-glass industry, Aloxite wheels are used for finishing the beautiful and intricate cuts seen on the best ware, having to a great extent taken the place of the black Craigleith natural stones which were used for this purpose for many years. Aloxite has been on the market since 1909.

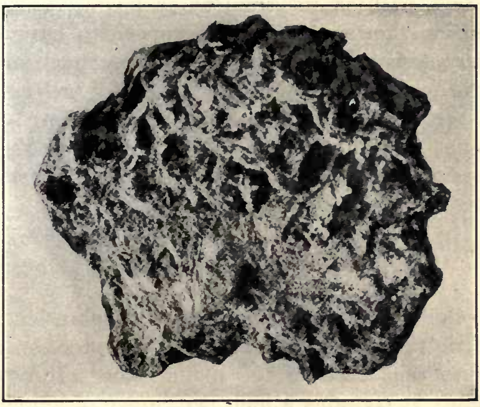


Fig. 9.—Aloxite as it is formed in the furnace.

WERLEIN'S ARTIFICIAL ABRASIVE

A comparatively recent patent (French patent No. 430,932, issued Aug. 28th, 1911) for the manufacture of an artificial abrasive has been granted to Ivan Werlein of Seine, France. It is an electric-furnace product composed of alumina and silicon. In his patent specifications, the inventor states: "This alumina and silicon compound produced at high temperature may be obtained in various ways. For instance, a mixture of 80 to 95 parts of alumina and 5 to 20 parts of silicon is melted in an electric furnace.

When the mass has reached about 2,888 to 3,000° C. it is kept at that temperature for about 20 minutes and then cooled."

The writer has never seen this abrasive, therefore he is not in a position to comment on its merits. From its composition, however, it would appear to have some of the characteristics of Carborundum combined with those of the various alumina abrasives. Just what such an abrasive would accomplish, judging from an American efficiency standpoint, is a question of conjecture and to the best of the writer's knowledge, this abrasive has not as yet claimed the attention of American abrasive engineers.

BORO-CARBONE

Boro-Carbone is an artificial alumina abrasive made in an electric furnace of the arc type by a process somewhat similar to that used in the manufacture of Aloxite and Alundum. It contains a high percentage of alumina oxide with a small amount of impurities. In color, this abrasive varies from a milky white to a light blue and its crystallization is very pronounced.

Boro-Carbone is made in France, the raw material being bauxite, and in one respect it enjoys a unique reputation in that it is the only foreign abrasive that has been successfully able to compete with American-made products. To be sure, Aloxite might be called a foreign abrasive, but in the strictest sense of the word, this is a fallacy, as it is a product of American engineering talent, originating at The Carborundum Company's Niagara Falls plant.

The sale of Boro-Carbone is controlled in this country by the Abrasive Company of Philadelphia, Pa., to whom is really due the credit of perfecting this abrasive to a point where it could compete with American-made products. It was put on the market in 1912 and at the present time enjoys a large sale, being adapted for all kinds of steel grinding. The Abrasive Company state that the temper of Boro-

Carbone can be varied according to the kind of grinding it is to do.

OXALUMINA

Oxalumina is a name given to a manufactured abrasive of the artificial alumina type by the Cortland Grinding Wheel Corporation. Physically, it is composed of microscopic crystals of alumina; chemically, it contains about 98 per cent. of aluminum oxide. It is prepared by fusing and refining various alumina-bearing clays and ores in carefully regulated furnaces. The resulting mass is properly cooled, then crushed and graded for use as an abrasive. This abrasive is widely advertised and sold in competition with other American artificial abrasives principally for precision grinding operations.

ADAMITE

This material is an electric-furnace product made in Austria. It contains approximately 80 per cent. alumina oxide. It is dark blue to black in color, being of a compact, well crystallized nature. It is a very tough abrasive and by some American grinding-wheel manufacturers it is used to a limited extent in the manufacture of very durable wheels.

ROUGE AND CROCUS

Both of these materials are made by the same process, which consists of calcining sulphate of iron in crystal form. The sulphate of iron crystals are subjected to high temperature in crucibles and the powder that forms at the bottom is crocus, while that at the top is rouge. These materials differ in color, rouge being red while crocus is purple. These materials are used in buffing and polishing operations.

DIAMOND CRUSHED STEEL

This material is manufactured by the Pittsburgh Crushed Steel Company of Pittsburgh, Pa. It is made of crucible steel, subjected to a special treatment, after which it is crushed and graded into the following sizes: 4, 6, 8, 10, 12, 14, 16, 18, 20, 30, 36, 40, 50, 60, 70, 90, 120, 150, 170, 190, 200. The sizes from 60 to 200 inclusive are known to the trade as Diamond Steel Emery.

The material in question is a new departure in abrasives; a scientifically prepared material designed to replace emery for grinding operations on granite, onyx, marble, brick, glass, etc., or in fact for any purpose wherein an abrasive is used in grain form. As this material has three important characteristics; hardness, sharpness and toughness, it should prove a very durable grinding agent in cases where a rolling and crushing action is present.

Crushed steel is not an ideal abrasive to employ in grinding-wheel manufacture inasmuch as its tough nature tends to prevent the grains from fracturing upon becoming dull.

ANGULAR GRIT

This is another abrasive material made by the above concern, being used in the place of sand for sand-blasting operations. It is a crushed chilled-iron product marketed in the following sizes: 10, 12, 20, 30, 40, 60, 90. This material is, without doubt, an excellent medium to use for sand blasting as the individual grains have a number of cutting points and the material does not break away, or pulverize, as quickly as sand, thus reducing the objectionable factor of dust to a minimum.

CHAPTER THREE

THE MANUFACTURE OF GRINDING WHEELS

Composition of grinding wheels—Desirable and undesirable properties—Bonds—Shellac—Rubber—Fusible clays—Silicate of soda—Vitrified wheels—Method of producing vitrified wheels—Puddled process—Pressed process—Silicate wheels—Shellac wheels—Rubber wheels—Clay bond used in vitrified wheels—Choice of bonding material—Wheel-turning—Kiln used—Heating of kiln and work—Cooling of kiln—Dressing wheels—Bushing wheels—Speed tests for wheels—Elastic process—Rubber process.

A GRINDING wheel consists of two parts—the abrasive material that does the cutting and a suitable bonding material to hold the countless grains of which the wheel is composed in a solid mass. Grinding wheels for some purposes, such as the rough grinding of heavy gray-iron castings, should be hard and compact, to resist undue wear. A cylinder wheel designed for a vertical spindle surface grinding machine, such as the Pratt & Whitney Company manufacture, must be open and porous to insure free cutting. Thus it is seen that the *dressing action* which a particular work has on the wheel in any given operation must be given consideration in the manufacturing process.

The two kinds of wheels above mentioned are at extremes, but in the making of wheels for various other purposes, equally important factors must not be overlooked. As an illustration, wheels for various tool and cutter sharpening operations must be very cool cutting, while wheels for such special grinding operations as crankshaft finishing are required to hold their peripheral shape for a reasonable length of time; otherwise more time would be consumed in keeping them in proper condition than would be spent in actual production.

Some years ago, when grinding wheels were used only for a few simple operations such as tool sharpening and general grinding, simple "rule of thumb" manufacturing methods answered very well. At the present day, however, owing to keen competition and the high standard required by modern efficiency engineers, grinding-wheel manufacture is fast becoming an exact science, as it were, wherein the manufacturer studies the requirements of his customers and perfects his production methods to a point where only the highest quality of goods receive the final inspector's approval.

When we speak of the bond of a grinding wheel, we refer to the material used to hold the grains in the wheel together. In the vitrified bond, the binding medium is a high grade of kaolin, or other refractory or fusible clays, the process of vitrification taking place in a kiln patterned after a pottery kiln. In the elastic bond, a good grade of shellac is employed, while in the rubber bond, the particles of abrasive material are held together by vulcanized rubber. In another process, silicate of soda, sometimes called waterglass, is used. All these bonds possess merit for specific purposes, but as a matter of fact the majority of grinding wheels in use at the present time are made by the vitrified process. This bond is used so much more extensively than the others that it is possible to obtain with it a greater range of grade than is possible with other wheels. Again, years of experience, to say nothing of costly laboratory experimentation, have proven that the bond of a grinding wheel is always a detriment to fast cutting, but as a bond of some kind is, of course, a necessity the one that will produce the least friction and at the same time produce the desired grade is always preferable. Thus, the vitrified bond has been found by practice to be the best adapted for the majority of purposes.

For the sake of clearness, all the above methods of wheel manufacture will be considered separately. The selection of correct bonding materials and the perfection of the various processes involved is the result of many years of research work and close study on the part of ceramic engineers and experts on abrasives.

THE VITRIFIED PROCESS

As before stated, in the vitrified process, the binding material is a good grade of kaolin, or other refractory or fusible clay, which comes to the grinding-wheel manufacturer in carload lots, just as it is taken from the earth. By means of standardized formulas, the chemist tests this material to make sure that it comes up to a predetermined standard. Otherwise several thousand finished wheels might prove to be absolutely worthless. Further to test the value of the bonding material, several small wheels and briquets are made up and run through the kilns to make sure that the material in question stands a satisfactory heat and resistance test.

The foregoing may seem to the layman like an elaborate procedure for the testing of a carload of clay, but eternal vigilance is the watchword of the grinding-wheel manufacturer who desires to get new trade and successfully hold it against competition. After it has been assured that the bonding material is up to the correct standard, it is carefully ground and thoroughly dried and sifted.

The hardness, or resistance to wear, in a grinding wheel is determined by the percentage of bond used with a certain amount of abrasive material. A hard wheel has a heavy bond, while in a soft wheel, the percentage of bonding material is less. To adapt an abrasive to many different kinds of work calls for a variety of bonds, the most common being the close tough and close brittle, open tough and open brittle. It must also be borne in mind that bonds are employed to produce texture between these extremes. The standardization of grinding-wheel bonds is the result of many years of research work and actual experimentation. It is needless to state that bond mixtures are kept as close secrets.

In the manufacture of vitrified grinding wheels, there are three methods used in mixing the abrasive material with the bond; dry mixing, wet mixing and a combination of both these methods. A dry mixed wheel is made by what is known as the pressed process while a wet mixed wheel is made by the puddled method. In a puddled and pressed wheel, a combination of both mixing methods is employed.

In making wheels by the pressed process, the first step is to determine the correct proportions of grain and bonding material by weight, after which the mixture is dampened a little and tumbled about in a tumbling barrel for a few hours. The object of this procedure is twofold; to mix the materials thoroughly and to surround each individual grain of abrasive material with a matrix of bonding mixture, to hold it in place in the finished wheel.

The mixed material now goes to the press room to be formed into wheels. In this department are a number of hydraulic presses, some of them capable of exerting a pressure of 5,000 pounds per square inch. The process of pressing a wheel is quite simple and easily carried out. An operator carefully weighs out the correct amount of mixture and places it in a steel mold of the desired size. After leveling the mixture carefully, a cover that fits the bore of the mold is placed on the wheel mixture and the mold placed in position over the ram of the press. With his eye on the pressure gauge, the operator opens the water inlet and as the ram rises under the water pressure, and as the hand of the pressure gauge mounts upward a crunching sound is heard as the enormous pressure exerted by the water is transmitted to the wheel in process of formation. When just the exact pressure required is recorded by the gauge, the operator opens the release, the ram descends and the mold is removed. The pressed wheel is now taken from the mold, ready for the vitrifing kiln.

Wheels made by the pressed process are very compact but not necessarily hard. As an illustration, a Carborundum wheel in O grade, G2 bond is a pressed wheel, although it is six grades softer than an I grade wheel in B6 bond, which is a puddled wheel. On the other hand, a Carborundum wheel in BI6 bond, which is made by the puddled process, is very hard but not as compact as an I grade wheel in G6 bond which is a pressed wheel, and although six grades softer, it is more compact: It is seen that the object of making wheels by the pressed process is to make them compact, which characteristic is to be desired in wheels for a variety of grinding purposes.

In making wheels by the puddled process, the correct proportions of grain and bonding material are agitated for several hours in mechanical mixers as shown in Fig. 10.

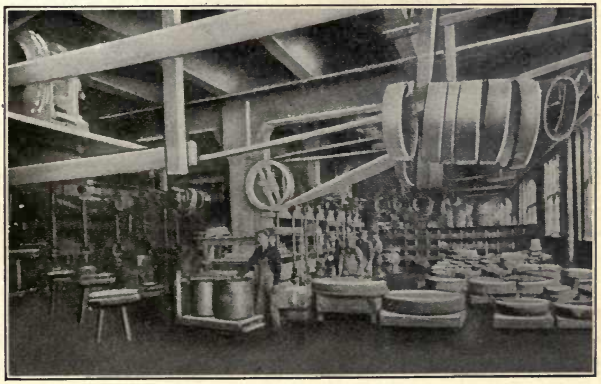


Fig. 10.—Mixing the materials to form puddled wheels.

The mixture is then poured into a sheet-iron mold and thoroughly dried by steam heat. After drying sufficiently, which consumes several weeks for very large wheels, the embryo wheel is placed on what is termed a shaving machine, an illustration of which is shown in Fig. 11. This machine is constructed on the principle of a potter's wheel, consisting of a revolving circular table upon which the wheel is placed, and a cross-slide over which travels the head carrying the tools used in shaping the wheel.

The process of turning the wheel to the correct size and shape, and boring the hole for the lead bushing, is comparatively simple although considerable skill is required in turning wheels of irregular shape, such as certain wheels for special tool grinders, cup wheels, large cylinder wheels, recessed wheels for cylindrical grinding, etc. The wheel-shaving operator is a skilled artisan in his particular line of work, prosecuting his work by means of a blue print, or other drawing, and obtaining the necessary dimensions by means of scales and calipers such as are used by the machinist.

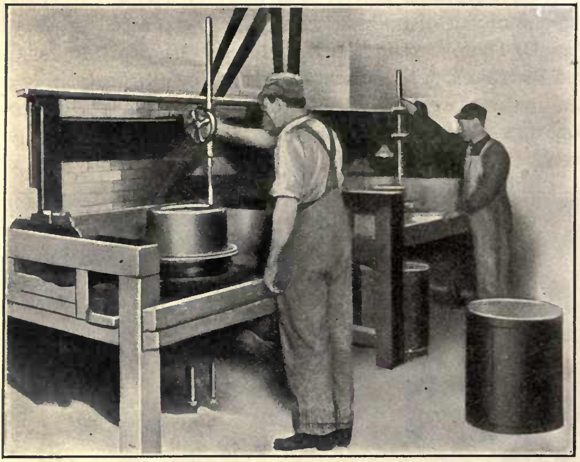


Fig. 11.—Shaving grinding wheels preparatory to vitrifying.

The next step consists of vitrifying the wheels. The vitrifying kilns used by grinding-wheel manufacturers are patterned after those used in the pottery industry for vitrifying china and earthenware. They are approximately sixty feet high and sixteen feet in diameter, being constructed on what is called the down-draft principle. A secondary interior wall is built inside the kiln, coming to a crown about twenty feet from the kiln floor. The heat is so distributed that it circulates freely in all parts of the kiln interior, finding an outlet at the bottom.

The wheels, as they come from the press and puddling rooms, are placed in earthenware receptacles technically termed sagers, a few of which are shown at the left-side foreground of Fig. 12. As the wheels are in what is termed a "green" state, care is necessary in handling them. To insure even bedding in the sagers, the wheels are placed on a layer of sand. Several small wheels are loaded in one sager but with medium-sized wheels, say 12 x 2, one to a sager is considered sufficient. Wheels 14 inches in diameter and over are piled one over the other in sectional sagers, each wheel being bedded in sand.

Fig. 12.—Loading a grinding-wheel kiln.

An interior view of a grinding-wheel kiln is shown in Fig. 13, wherein several piles of sagers are shown in the background. After the kiln is completely filled, the door is sealed tight and the kiln is ready for firing. To correctly burn a kiln of grinding wheels is an operation calling for long practice. It consists of bringing the kiln up to the correct heat, keeping it there for the necessary period and then letting it cool gradually. Too much heat would result in over-burning, the effect being the destruction of the bond, leaving it in a burnt-up or honeycombed condition, while too little heat would produce an under-vitrified wheel. Again, if the kiln is brought up to full heat too rapidly, wheels having hard and soft spots are liable to result. Further, if the kiln is allowed to cool too rapidly 75 per cent. of its contents will come out in a cracked state, being absolutely of no value, for, unlike the good housewife's pie-crust, grinding wheels cannot be worked over again.

Fig. 13.—Interior of a grinding-wheel kiln.

Arranged around the base of the kiln, are approximately ten fire boxes, the fuel used being a good grade of either anthracite or bituminous coal. Two fires are started at a time and allowed to burn for some time, after which two more are started at regular intervals until all are burning. The kiln is now brought up to the first, or red heat, which takes fifteen hours. The heat is gradually increased until the kiln is at what is termed the "low melting point." Tests are frequently made by means of sets of pyrometric cones which are inserted in the kiln through test holes. There are several of these test holes in every kiln arranged at regular intervals and it is important that the readings of each test hole tally, otherwise it is a sign that the heating is uneven. The test cones are made of clays having different melting points. Three cones having different melting temperatures are placed on one base. When the first one melts and topples over, it is a sign that the kiln is at "red heat."

The next one succumbs at low melting point and when the third one wilts under the heat, it signifies that the kiln is up to full heat or a trifle higher than 2,500° Fahr. A set of the cones used is illustrated in Fig. 14. For many years, the pyrometrical cone was the only means used for determining the heat of the kiln. Of late years, however, owing to the high degree of perfection reached in the manufacture of various types of pyrometers for accurately determining high temperatures, the latter are now used in connection with the former in grinding-wheel kiln burning.

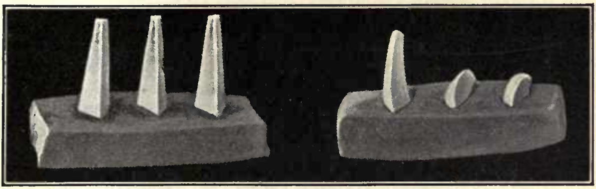


Fig. 14.—Pyrometric cones used for measuring degree of temperature in grinding-wheel kilns.

After the kiln has reached full heat, it is sealed up and allowed to cool for several days. As much care has to be exercised in cooling the kiln as in heating it, for sudden or uneven cooling would bring about disastrous results to the contents. It takes three days to load a kiln, five days to burn it, a week is allowed for cooling and three days for unloading. Small wonder, then, that the grinding-wheel manufacturer cannot ship special wheels a few days after the order for the same has been entered. Burning a kiln of grinding wheels is an operation that cannot be carried on too carefully, as a slight error in judgment is sufficient to turn success into failure. The men who have charge of this important work become skilled through long experience, and it is needless to state that they are numbered among the grinding-wheel manufacturer's trusted employees.

From the kilns, the grinding wheels go to the sorting room where they are sorted according to size, grit and grade. The grits and grades are determined by markings scratched on the wheels while in the "green" state, before vitrifying. The wheels are next inspected for soundness by tapping them with a light hammer. A sound wheel will emit a faint, bell-like tone when tapped, this tone having a distinct reverberation, whereas a cracked wheel gives out a dead sound in which no reverberation is detected.

The wheels that pass this inspection go to the lathe room, where they are faced and edged. The type of lathe used for facing is not unlike an ordinary engine lathe with the possible exception that the former is slightly heavier than the latter. The wheel is firmly gripped in a universal chuck and a cut taken over one side, bringing the surface as near to a true plane as possible within practical limits. The wheel is now reversed in the chuck and the other side faced, care being exercised to make sure that the sides are parallel; otherwise the wheel might be out of balance, which feature is to be avoided.

For facing large wheels, star-toothed dressers of the type familiar to every mechanic are used. These are mounted in suitable holders which are gripped in the tool post. For fine, comparatively small wheels, diamonds mounted in copper bars are used. Being in constant use, these stones soon wear out; thus the diamond bill of the grinding-wheel manufacturer amounts to a large sum annually.

After being faced, the wheels are ready for the first inspection for grade. This operation is done by hand as shown in Fig. 15. The instrument used looks not unlike a short, wide screw-driver mounted in a heavy handle. To determine the grade, the operator depends wholly on his senses of hearing and touch, which, through constant practice, are very reliable. The testing is done simply by gouging into the wheel in several places, noting the sound given out and feeling the amount of resistance met in separating the particles of abrasive from the bond.

Constant practice makes these operators very expert, especially in grading medium hard, medium and medium soft wheels. With the very hard wheels, however, it is almost impossible to make an impression with the grading tool. In this case, the operator relies almost wholly upon the sound emitted. Several mechanical means have been devised for grading grinding wheels, but as yet not one has been perfected that is as reliable as the simple hand-grading tool in the hands of an expert.

Fig. 15.—Grading grinding wheels by the hand-test method.

The next step is to provide the wheels with lead bushings. In this operation, the wheel is held in a special fixture which locates it centrally. A mandrel of the desired size is now inserted and the space between the mandrel and the grinding-wheel hole filled with molten lead. As soon as the lead cools sufficiently, the bushing is stamped with the grit and grade, and, in the case of Carborundum wheels, the bond also, as a means of permanent identification. This practice originated with The Carborundum Company, and it is needless to state that it fills a long-felt want as the consumer has at hand a reliable guide in duplicating a successful wheel.

The next operation is to true the periphery of the wheel. This is done by men called wheel edgers. The wheels are mounted on heavy grinding stands and the edging done by means of star-shaped dressers fed by hand. Diamonds are used on the smaller and more delicate wheels. The grinding-wheel stands are equipped with guards to eliminate danger from flying fragments in case a wheel should happen to burst, and the workman's health is also taken into consideration as an efficient exhaust system is provided to carry away the dust.

The wheels are now ready for another important operation, that of balancing. Owing to the high speed at which they are operated, it is very necessary for grinding wheels to be in almost perfect running balance. Carefully worked-out tables, prepared by the engineering department, show the exact amount any size of wheel can be out of balance, and all wheels failing to come up to this predetermined standard are rejected.

The balancing is done by mounting the wheel on an arbor which is placed on balancing ways. If a heavy side is in evidence, a weight of the required number of ounces allowed on this particular size of wheel is clamped on the periphery opposite the heavy side. If this weight fails to counterbalance the wheel, it shows that the wheel is out of balance to the extent of warranting rejection for the particular size in question, although it can be turned smaller when, in all probability, it will pass a satisfactory test. It is very necessary that the balance of wheels intended for precision grinding be almost perfect; otherwise accurate work on the part of the grinding-machine operator is sometimes impossible.

Owing to the fact that grinding wheels are used under various conditions, some of which are far from ideal, chances for serious accidents owing to the bursting of the wheel must be guarded against by the manufacturer who aims to market reliable goods. To this end, grinding wheels are given a speed test before going to the shipping-room.

As the centrifugal force of a body moving with different velocities in the same circle is proportional to the square of the velocity, it is evident that if the velocity is doubled the centrifugal force will be four times as great. Thus it is seen that if a wheel is speeded fifty per cent. faster than the recommended operating speed, the centrifugal force would be twice as great. The Carborundum Company make a practice of speeding all wheels above eight inches in diameter seventy per cent. higher than the recommended operating speed. After this test, it is safe to assume that the wheel is sound and when used under the proper operating conditions the danger of breakage is practically *nil.*

The speed-testing machines consist of substantial grinding-wheel stands equipped with variable-speed counter-shafts for increasing and decreasing the speed as desired, accurate tachometers for registering the number of revolutions, and stout, iron-bound oak boxes surrounding the wheels to retain the fragments in case a wheel fails to withstand the speed test. Two testing machines are shown in Fig. 16. The tests are conducted in a very deliberate manner by men whose integrity can be depended upon and at the completion of each day's work these men subscribe and swear before a notary public to the tests they have made. The number and conditions of each test are kept in a book provided for this purpose and a certificate is attached to the tested wheel, showing both the test speed and the recommended operating speed.

Accidents caused by grinding-wheel imperfections are indeed very rare. The writer has personally investigated many cases of broken grinding wheels and has yet to find a case where the accident was caused directly by imperfections in the manufacture of the wheel. That all grinding-wheel manufacturers intend to market dependable wheels is borne out by the following paragraph taken verbatim from The Carborundum Company's Number Five catalogue.

"In May, 1902, the Association of German Engineers began an exhaustive series of speed tests of abrasive wheels.

These tests were conducted by Professor Grüber of the Technical High School, Dresden. All manufacturers were invited to submit a 20-inch wheel to be speeded until it burst. About sixty wheels, including almost all standard makes, were tested in this manner. The result, as a whole, demonstrated the entire safety of all makes of wheels when properly used; for, while the proper operating speed for a 20-inch wheel is 955 revolutions per minute, the poorest record made by any wheel tested was 2,615 revolutions per minute before bursting. The regular grade of Carborundum wheel tested made 4,340 revolutions per minute before bursting, which was the best record made by any wheel tested."

Fig. 16.—Speed-testing grinding wheels for safety.

The above statements bear out the writer's opinion, *i. e.*, that the specific gravity of Carborundum, being less than that of other abrasives, makes it a very efficient and safe wheel.

THE SILICATE PROCESS

In making wheels by the silicate process, silicate of soda and the abrasive material are first mixed together in the proper proportions in mechanical mixers. This mixture is then tamped by hand in iron molds. The operation of tamping the mixture calls for a high degree of skill, thus the work can only be intrusted to experienced men. Machines have been devised for tamping silicate wheels, but the mechanical process does not produce as satisfactory results as are obtained with the hand-tamping process. Why this is so is a matter of conjecture. Nevertheless, the fact remains that hand-tamped wheels are turned out in large lots daily by grinding-wheel manufacturers.

On first thought, it would appear that silicate wheels could be readily pressed in molds by the same process used in making pressed vitrified wheels as heretofore explained. This method has been the basis of lengthy experiments without tangible results, the product always showing inferior in actual tests.

The process of hand tamping is comparatively slow and laborious as it has to be done in a thorough manner, but when properly carried out excellent wheels are the result. After tamping, the wheels are baked slightly under low heat, which sets the bond. For many years it was considered an impossibility to make Carborundum wheels by the silicate process, inasmuch as the glassy nature of this abrasive and the same characteristic in the bonding material, after baking, did not form a good contact. Of late years, however, this difficulty has been overcome.

Silicate wheels are very close in texture and they are successfully used on grinding operations where a compact, but at the same time a comparatively free cutting wheel is desired. For tool grinding in the machine shop, saw gumming and knife grinding in wood-working establishments and on other operations of like nature, silicate wheels are successfully used. Again, the silicate process is extensively used by small grinding-wheel manufacturers who have not the facilities for turning out vitrified wheels in large lots. Further, an inferior abrasive, one containing an excess of mica or garnet, for instance, can be used in the manufacture of silicate wheels, whereas these impurities would ruin a vitrified wheel. Inasmuch as the silicate process is of short duration, hurry orders for grinding wheels can be filled in far less time than is required to make them by the vitrified process. This factor is, of course, worth consideration in a few specific cases.

In the early days of the grinding-wheel industry, the silicate process was quite popular owing to the fact that wire-web wheels, wherein a screen of brass wire was inserted, were considered as an ample safeguard against accidents. At the present day, however, owing to the high development of the vitrified process and the subsequent safety of the finished product, there is no logical excuse for using silicate wheels purely as a matter of safety.

THE ELASTIC PROCESS

In making wheels by the elastic process, wherein the binding medium is shellac, the first step is to melt the shellac, which is afterward cooled and broken into lumps. The lumps are next finely ground and the proper proportions of shellac and abrasive mixed together. This mixture is then transferred to a hot mold and thoroughly melted under pressure. A slight baking in specially constructed ovens completes the process.

Shellac-bonded wheels are very cool cutting, imparting a high degree of finish to the work, and, owing to the firm nature of the bonding material, they are the safest form of wheel to use for any purpose. This bond is especially desirable for comparatively thin wheels as used for grinding out slots, fine saw gumming, marble coping, etc. Small, delicate cup and dish wheels, as used for certain kinds of cutter sharpening in the machine shop, are generally made by the shellac process. For the finish grinding of the large calender rolls used in paper making, the shellac bond is the accepted favorite, owing to the high degree of finish imparted. Hones of various shapes used in polishing marble are also made by this process.

The layman is inclined to associate shellac with the sticky variety used in liquid form by the pattern maker and other wood workers and therefore is sometimes inclined to think that a grinding wheel bonded with this material would soon fill up, and consequently refuse to cut. Actual tests, however, have proven beyond all doubt that the shellac-bonded grinding wheel is very free cutting; probably owing to the fact that the heat used in baking brings about a chemical change in the bond which eliminates the tendency of the material to retain the minute particles removed from the work by the action of abrasion.

THE RUBBER PROCESS

In cases where grinding wheels are subjected to very severe strains, especially when very thin wheels are used, the rubber process makes a very satisfactory wheel. Many years ago, before the present-day state of perfection in grinding-wheel manufacture, large wheels were made by the rubber process, and in a very few cases, there is a demand for these wheels at the present time. The majority of rubber wheels used today, however, are comparatively thin ones used for such purposes as grinding slots in cast-iron stove doors, sawing stone, etc., or in fact for any operation where an exceedingly durable wheel is desired.

The process of making rubber bonded wheels is quite simple, consisting of passing carefully selected crude rubber and abrasive material between steam-heated chilled iron rolls. The material is passed and re-passed until all the abrasive material is thoroughly imbedded in the rubber. When the required amount of material is worked up, the operator scribes a circle of the desired diameter on the sheet of material with a pair of dividers, cuts the outline thus made with a sharp knife, punches a hole in the center of the disc and the wheel is ready for the final process, that is vulcanizing the rubber. This is done in a small furnace, electrically heated, and takes but a short time.

CHAPTER FOUR

ARTIFICIAL SHARPENING STONES

Properties of artificial stones—Carborundum stones—Method of manufacture—Bond—Grit—Grade—Finishing—Combination stones—Carborundum rubs.

ARTIFICIAL sharpening stones have been on the market for many years, dating from the time when the early grinding-wheel manufacturers put them on the market in small lots. It is a fact that when any abrasive material is crushed, much of the same is reduced to a fine powder, which is of no value in the manufacture of grinding wheels. Thus, one reason for the introduction of artificial sharpening stones in competition with the natural product was that the grinding wheel and abrasive manufacturer sought a market for the fine grains that otherwise have but little market value.

Artificial sharpening stones possess one merit that should not be undervalued, in that they are generally very uniform in grit and grade. Absence of hard and soft spots is another good characteristic which is not always present in natural stones. Any good abrasive material can be made into sharpening stones, but the artificial abrasives seem to hold the preference, owing to their purity and uniformity as compared to natural abrasives.

The first artificial abrasive to be put on the market in the form of sharpening stones was Carborundum. During the last few years, the demand for these stones has advanced by leaps and bounds, so to speak, two reasons being assigned for this. First, they are carefully made by skilled workmen, which procedure always results in a superior product, and, again, they are universally advertised, being on sale in every town and city throughout the civilized world. Over a million and a quarter of Carborundum sharpening stones are sold annually in more than one hundred and fifty different sizes, styles, etc.

Carborundum sharpening stones are made in vitrified bond by the pressed process, the principle being the same as employed in making pressed wheels, with the exception that the work is carried on on a smaller scale. Great care is exercised in molding the stones. Careful workmen determine the amount of grain and bond mixture by weight; thus, exactly the same amount of material is incorporated into all stones of a given size. This material is evenly distributed in the mold, otherwise the finished stone would have what is technically termed "heavy spots." Again, the amount of pressure exerted on the mixture after the mold is placed in position in the hydraulic press must be

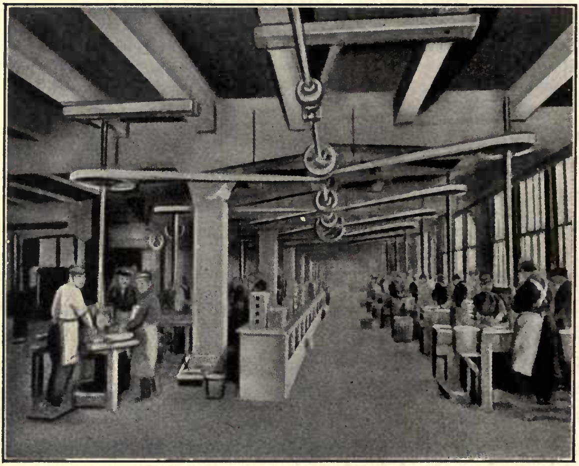


Fig. 17.—Finishing Carborundum sharpening stones on rotary laps.

watched carefully, otherwise the finished product would vary in grade. As the stones are very delicate in the "green" state, and thus easily damaged, it is necessary to handle them carefully. They are loaded in sagers and vitrified by the same process and in the same kilns used in the manufacture of vitrified Carborundum wheels.

Carborundum sharpening stones are made in three grits, namely, coarse, medium and fine. The coarsest grain is used in number 120, while number 180 is used in medium stones. Fine stones are made in F, FF, and FFF powders. A superfine powder called 60-minute powder (so called because it takes 60 minutes to settle in water) is used in making several very fine stones.

Fig. 18.—Part of the specialty department at The Carborundum Company's plant.

Large flat stones are made in G–7 bond for fine grits and in G–5 bond for coarse grits. For other stones, points, sticks, etc., G–12 bond is used. For making razor hones and other fine instrument stones a special bond is used to give the desired hardness, the nature of this bond being a trade secret.

In making combination stones, that is, stones composed of two grits, fine on one side and coarse on the other, two methods are used. One method is to level the fine mixture in the mold and over this place the coarse mixture, both being pressed together. The other method consists of cementing two finished stones, a coarse one and a fine one, together.

After the stones come from the vitrifying kilns, they are carefully inspected for imperfections such as cracks, burned spots, etc., and all imperfect specimens thrown aside. The stones which pass this inspection go to the finishing department, where skilled artisans rub them smooth on horizontal rubbing beds, or rotary laps. The abrasive used in this operation is Carborundum grain mixed with water. This operation is shown in Fig. 17.

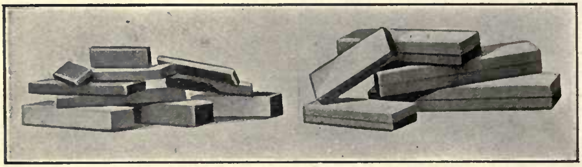


Fig. 19.—A few varieties of Carborundum sharpening stones.

The stones are now transferred to the specialty department, where they are carefully buffed, cleaned, inspected and packed in boxes and display cases. A view of this department is shown in Fig. 18. As before stated, Carborundum sharpening stones are made in upwards of one hundred and fifty different styles, being used for a diversity of purposes too numerous to mention here. Some of the well-known varieties are shown in Fig. 19.

A form of stone technically called a "rub" is much used for smoothing castings, marble, granite, cement, etc. These are made in the same manner as sharpening stones, with the exception that the grits are coarser and no extra finish is imparted after they come from the vitrifying kilns.

ARTIFICIAL SHARPENING STONES

Considerable skill has been developed in the manufacture of Carborundum sharpening stones and rubs, through the study of proper bonding materials, methods of manufacture, etc., thus the finished products are very uniform and do not vary to any noticeable extent.

CHAPTER FIVE

GRITS AND GRADES

Designation of grits and grades—Mixed grits—Grits of abrasive papers—Standard grades—Wheels—Relation of speed to grade and grit—Wheel speeds for various operations.

THE grit, or grain as it is sometimes called, of a grinding wheel alludes to the size of the particles of abrasive material of which it is composed. Thus, a wheel in 24 grit is made up of particles of abrasive material that were separated from the mass that passed over the grading machine by a screen having 24 meshes to the linear inch. It is sometimes erroneously stated that the particles of grit composing a 24-grain grinding wheel are 1/24 inch in diameter. This is not true, because the size of the wire of which the screen is made must be taken into consideration. Therefore, if the screen was made of very coarse wire, the particles of grit passing through it would be somewhat finer than those passing through a screen having the same number of meshes per inch but made of finer wire.

Grinding-wheel grits are referred to as straight, mixed, combination and combination mixed. A straight grit is one wherein the abrasive is of one size only; thus if 40 grit was used the wheel would be a 40 straight grit. For convenience, the word "straight" is generally omitted in speaking of a straight grit wheel. When a 40 grit wheel is ordered, it is understood that a straight grit is required.

A mixed grit is one composed of two or three different kinds of abrasive materials. Thus, a wheel designed for grinding steel castings, for an illustration, made of a mixture of emery, corundum and adamite, would be a mixed-grit wheel.

By a combination grit, which term is sometimes erroneously used to designate a mixed grit, is meant a combination of various-sized grits, scientifically selected, and incorporated into one wheel. A combination mixed grit is one wherein two or more abrasives are used, the grains being of different sizes.

A wheel composed of a combination of 24, 36 and 80 grit is known as a 24-combination grit. Successful grit combinations are standardized only through long experiment and actual tests, and the grinding-wheel manufacturer generally keeps them secret. The Norton Company make many combination grits, referring to them simply as 24 combination, 36 combination, etc. The Carborundum Company, who have investigated the theory and practical results derived from combination grits in a very thorough manner, have originated a simple means for designating their grit combinations, which is of great benefit to the customer in re-ordering. They use a number of grit combinations designated 1, 2, 3, 4, etc. This number is annexed to the grit number, thus a 365 combination grit has 36 grain for its base while 5 stands for the combination number.

For certain operations, combination grits offer decided advantages. On cylindrical grinding, for instance, a wheel in a combination grit with a comparatively coarse base, 24 to 36, cuts very fast and at the same time leaves a smooth finish, leading to the deduction that the coarse grains remove material rapidly, while the finer grains impart the desired finish. On certain operations where a very durable wheel is required, on car-wheel grinding, for example, a combination grit gives entire satisfaction, showing high efficiency over a straight grit used for the same purpose.

Manufacturers of abrasive paper and cloth designate the different grits by numbers: 1, 1–1/2, 2, 2–1/2, etc. At one time, the various grits used by different manufacturers varied to quite an extent even though they were designated by the same number. This often led to confusion and sometimes enabled one manufacturer to gain an unfair advantage over another. For instance, a certain manufacturer of garnet paper uses a specified size of grain which he calls No. 1–1/2. A competitor uses a slightly coarser grain which he, too, designates as No. 1–1/2, and while the sizes of the two grains are so near alike that detection with the naked eye is impossible, it often happened that the manufacturer using the coarser grain was enabled to show a slight efficiency over his competitor, the consumer in the meanwhile being ignorant of the fact that the grains were not the same. To eliminate misunderstandings among the consumers, and to bring competition to a fair basis, the majority of abrasive paper and cloth manufacturers of the present day use the same sizes of grains for each grade. Thus 2–1/2, for an illustration, designates a grain that has passed through a standard sieve, the mesh of which has been agreed upon.

In thinking of the various grit numbers used to designate the sizes of abrasive papers and cloths, it is sometimes advantageous to know how they compare with the grain numbers commonly used in sizing abrasive materials. The following table is authentic and up to date, being recently furnished by The Carborundum Company.

Carborundum.	*Flint.*	*Garnet.*	*Emery.*	*Aloxite.*
FF				
F				
220				
180	3/0	4/0	3/0	3/0
150		3/0	2/0	2/0
120	2/0		0	0
100	0	2/0	100	100
90	1/2	0	1/2	1/2
80			1	1
70			1–1/2	1–1/2
60	1	1/2	2	2
50	1–1/2	1		
40	2	1–1/2	2–1/2	2–1/2
36	2–1/2	2		
30		2–1/2	3	3
24	3	3	3–1/2	3–1/2
20	3–1/2	3–1/2		

By the expression "grade" we refer to the relative hardness of a grinding wheel. In the early days of the grinding-wheel industry, a few grades sufficed. These were known generally as medium, medium hard, hard, medium soft and soft. As the industry grew, however, and the grinding wheel became adapted to a diversity of operations, closer and more accurate grades were required which led to the adoption of somewhat elaborate grade scales. A grade is a certain value, within very close limits at least. An L grade wheel offers the same resistance to disintegration by means of the hand-grading tool as the grinding-wheel manufacturer's master block in the same grade. By way of explanation, it may be well to state that all reliable grinding-wheel manufacturers have a set of master grade blocks as standards. These are carefully made from the correct proportions of grain and bond to form the various grades, and are referred to as a check in determining the actual grade of doubtful wheels. Thus an M grade wheel made by a reliable manufacturer is not somewhere between L and M or M and N in which case it might be a de-grade. De-graded wheels are used in some cases, to be sure, but they are made as such. The Carborundum Company make three de-grades: G plus, H plus, and I plus.

The various grinding-wheel manufacturers use different markings to designate their various wheel grades. Some use the letters of the alphabet (not always arranged the same) while others use numbers, including whole numbers, mixed numbers and fractions. All grinding-wheel manufacturers have comparative grade lists, the object of which is to show the difference between their grades and those of their competitors. The writer has, from time to time, examined and compared many of these grade lists and, unfortunately, they vary to such an extent that it is an impossibility to state for a fact which one is absolutely correct.

To compile a comparative grade list that would satisfy all grinding-wheel manufacturers, and, at the same time, impart reliable information to the layman, the writer used the following method in arranging the list here given. Taking Norton Company's grade list as a basis, a chart was drawn up on tracing paper including the letters used, with spaces between each for de-grades. A number of blue prints were made from this chart, one being sent to every prominent grinding-wheel manufacturer in this country with the request that they fill in on the same, their wheel grades, showing the comparison with Norton Company's grading. Many complied with the request, while some declined, and the chart in question was compiled from the date thus obtained. Inasmuch as every individual grinding-wheel manufacturer knows more about his own grades than does his competitors, and supplied his wheel grades in comparison to a given standard, in this case Norton Company's grading, it is safe to assume that a comparative grade scale compiled in this manner is as reliable as it is possible to arrange the same.

The grinding-wheel manufacturers who use the letters of the alphabet in regular order as a grade scale designate the letter M as showing their medium grade. This has led many technical writers who are not conversant with the grinding-wheel industry to show the comparison between Carborundum and Alundum wheels with the two M's together. This is a fallacy, as The Carborundum Company's M grade is equal to Norton Company's K, which brings the L's of both grade scales together. While both The Carborundum Company and Norton Company consider their respective M grades as medium, they do not agree as to what constitutes a medium grade.

It is to be regretted that the various grinding-wheel manufacturers do not standardize on a universal grade scale, which procedure, it is needless to state, would eliminate much confusion. In all probability they will never agree on a universal grade scale, the nature of which would cause them to abandon their gradings for a standard already

COMPARATIVE GRADING VITRIFIED AND SILICATE WHEELS

Abrasive Company Philadelphia, Pa.			G	H	I	J	K		L	M	N	O		P		Q		R	S	T	U	V	W	X		Z
American Emery Wheel Works Providence, R.I.		G	H	I	J	K		L		M	N	O		P		Q		R	S	T						
American Emery Wheel Works (Silicate Process)		½	¾	1	1½	2		2½		3	3½	4		4½		5		6	7							
The Carborundum Company Niagara Falls, N.Y.	U	S	R	P	O	N	M		L	K	J	I	I+	H	H+	G	G+	F	E	E+	D					
Chicago Wheel & Mfg. Co. Chicago, Ill.	A_3	B	B_1	B_2	B_3	C	C_1		C_2	C_3	D_1	D_2		D_3		E		E_2	E_3	F	F_2	F_3	G			
Cortland Grinding Wheel Corp. Cortland, N.Y.	E	F	G	H	I	J	K		L	M	N	O		P		Q		R	S	T	U	V	W	X	Y	Z
Cortland Grinding Wheel Corp. (Carborundum Wheels)						W	W+		W_1	W_1+	W_2	W_2+		W_3		W_3+		W_4	W_5	W_6						
Detroit Grinding Wheel Co. Detroit, Mich.	F	G	H	I	J	K	L		M	N	O	P		Q		R		S	T	U	V	W	X	Y	Z	Z+1
Hampden Corundum Wheel Co. Springfield, Mass.	E	F	G	H	I	J	K		L	M	N	O		P		Q		R	S	T	U	V	W	X	Y	Z
Norton Company Worcester, Mass.	E	F	G	H	I	J	K		L	M	N	O		P		Q		R	S	T	U	V	W	X	Y	Z
Safety Emery Wheel Co. Springfield, Ohio	A	A¼	A½	A¾	M	M¼	M½		M¾	P	P¼	P½		P¾		I		I¼	I½	I¾	O	O¼	O½	O¾	N	N½
Springfield Grinding Co. Chester, Mass.			G	H	I	J	K		L	M	N	O		P		Q		R	S	T	U	V	W	X	Y	Z
Springfield Mfg. Co. Bridgeport, Conn.	8¼	8	7¾	7½	7	6¾	6½		6	5	4½	4		3½		3		2¾	2½	2¼	2	1¾	1½	1	¾	
Sterling Grinding Wheel Co. Tiffin, Ohio.			1	1¼	1½	1¾	2		2¼	2½	3	3¼		3½		3¾		4	4¼	4½	5	5¼	5½	6		
Superior Carborundum Wheel Co. Walthom, Mass.		F	G	H	I	J	K		L	M	N	O		P		Q		R	S	T	U	V	W	X	Y	Z
Vitrified Wheel Co. Westfield Mass.	C	C_1	C_2	C_3	D	D_1	D_2		D_3	E	E_1	E_2		E_3		F		F_1	F_2	F_3	G					
Waltham Grinding Wheel Co. Waltham, Mass.	1½K	1¾K	2K	2¼K	2½K	2¾K	3K		3¼K	3½K	3¾K	4K		4¼K		4½K		4¾K	5K		5¼K		5½K			
Waltham Grinding Wheel Co. (Silicate Process)	1½N	1¾N	2N	2¼N	2½N	2¾N	3N		3¼N	3½N	3¾N	4N		4¼N		4½N		4¾N	5N		5¼N		5½N			
Fred. B. Jacobs' proposed Universal grade scale	1	2	3	4	5	6	7		8	9	10	11		12		13		14	15	16	17	18	19	20	21	22

Note:- Letters and figures in same vertical column indicate approximately the same degree of hardness.

in use, but perhaps if they all agreed to adopt a universal grade scale, the nature of which would cause every manufacturer to discard his present grade scale and adopt a new one, the change might be brought about.

By referring to the bottom of the comparative grade scale here shown, it is seen that the writer has had the presumption to take a step toward standardizing wheel grades. Figures 1 to 22 are used, a space being left between each for de-grades. Thus The Carborundum Company's G-plus grade would be designated 13 plus. A leading grinding-wheel manufacturer, with whom the writer had some correspondence regarding wheel grades, has the following to say concerning a standard grade list: "Nevertheless, go ahead. We will never get anywhere unless some one makes the attempt." If a universal grade scale is to be adopted eventually, the one shown has merit in one respect that should not be undervalued; that is to say, it would require each manufacturer to discard his present grade scale, putting all on the same level. In this case, no one manufacturer would be in a position to state that other manufacturers adopted his grade scale because it was the most comprehensive, or because he was regarded as the leading grinding-wheel manufacturer.

It is often stated on good authority, that it is impossible to arrange a grade scale which is absolutely reliable in all respects and cases. In a measure, the above statement is correct, owing to the fact that the abrasive efficiency of wheels of the same grade, but made of different abrasives, or combinations of different grits, is not always the same. For an illustration, a Carborundum wheel in 20 grit, G-plus grade, is universally acknowledged to be highly efficient for grinding gray iron castings. Now if we should test an Alundum wheel in Q plus, which corresponds in grade to Carborundum G plus, the latter would prove low in abrasive efficiency because Alumdum is an alumina abrasive not adapted for grinding materials of low tensile strength. Again, suppose we had a wheel made of pure corundum in

46 grit, M grade, vitrified bond and tested it in competition with a wheel made of the same material, in the same grit and grade, bonded by the silicate process. In this case, we would find that the wheel made by the vitrified process would show the highest efficiency, inasmuch as the silicate bond is closer, thus making the wheel more compact and less free in cutting. Further, if we should test a wheel in a combination grit against one in a straight grit, both being of the same material in a like grade, one will show high efficiency over the other. However, let it be assumed that several manufacturers agreed to make a 24 x 3 wheel in 20 grit, 13 universal grade for the purpose of grinding drop forgings, and let it be further assumed that they used the same material, which could be corundum from one mine, Aloxite, Alundum, Boro-Carbone, or in fact any standard abrasive. In this case, it is very probable that the abrasive efficiency of the several wheels would be so close that it would require the services of an expert abrasive engineer to accurately determine which wheel really was the most efficient.

It may seem out of place to many to consider wheel speeds in connection with grades, but, as a matter of fact, one bears on the other to a remarkable degree, as shown in the data supplied by the Abrasive Company in another chapter. Let it be assumed that we are using a wheel made of artificial corundum for grinding the flash marks from drop forgings, running the same at a peripheral speed of 5,000 feet per minute, and that the wheel seems to wear readily. We state at once that the wheel is too soft. However, if we speed up the wheel slightly, say to a peripheral speed of 5,300 feet per minute, it seems to appear harder, for while it cuts just as good as it did previously, it does not wear away so readily. Again, if at a surface speed of 5,000 feet per minute the wheel glazed and refused to cut, the objection could be overcome by reducing the speed slightly. In other words, it is a good rule to speed up a wheel that appears soft and to decrease the speed of one that seems to be unduly hard.

From the foregoing, it is seen that speed has everything to do with, what the writer will call for want of a better expression, the running or working grade. As wheels wear away, their speed should, of course, be increased slightly to keep them working at their maximum efficiency. It is not always possible to do this, however, and hundreds of thousands of grinding wheels are worn out prematurely.

To overcome this difficulty by providing a constant working grade, regardless of the peripheral speed, an American inventor recently obtained a patent on a grinding wheel having a gradually increasing grade from the periphery to the hub. Thus as the wheel wears, its hardness at the periphery keeps increasing, which offsets the tendency to wear away rapidly, owing to the reduced surface speed. Wheels made by this process should be productive of economical results.

For different grinding operations, wheel speeds vary to quite a remarkable degree. The following table shows the speeds generally recommended for various grinding operations.

Cylindrical grinding	5,000 to 7,000	feet	per minute
Surface grinding	4,000 to 5,000	"	"
Automatic knife grinding	2,500 (disc wheels)	"	"
Automatic knife grinding	2,000 (cup wheels)	"	"
Drill grinding	4,000 to 4,500	"	"
Tool grinding (dry)	4,000	"	"
Tool grinding (wet)	3,500	"	"
Cup wheels in general	3,500	"	"
General grinding	5,000	"	"
Set-up polishing wheels	7,500	"	"
Vulcanite wheels	10,000	"	"

CHAPTER SIX

TESTING WHEELS FOR EFFICIENCY

Selection of wheels—Improper methods of testing—Practical testing methods —Items to be noted in a wheel test—How to figure result—Formula for finding volume of abrasive material in a wheel—General considerations —Wheel tests.

MANUFACTURERS who use grinding wheels in large quantities are desirous of getting the most efficient wheel for a specific purpose. To determine which is the most efficient abrasive or make of wheel, and, further, what grit and grade of any particular make of wheel is the most desirable to use for a predetermined purpose, is not an offhand procedure. Results that can be relied upon are arrived at only by carefully conducted tests arranged along practical lines. Grinding-wheel manufacturers are frank to admit that there is no absolute rule for the selection of grits and grades as the following, which appears on page 96, 1916 edition of Norton Company's catalogue, plainly states: "Conditions under which grinding wheels are used vary to such an extent that no absolute rule can be given for selecting the right grades for the work."

Because a certain kind of wheel gives entire satisfaction in one plant, is no indication that it will do equally well in another shop, even though the work is identical in both cases. The reason for this is that local conditions generally have to be taken into consideration and as they often cannot be altered, it is best, when practicable, to test trial wheels on actual routine work under the supervision of careful and painstaking efficiency engineers who have some knowledge of abrasives and grinding practice.

To give a trial wheel to the grinder with the injunction:

"Here, Bill, try this wheel and see what you think of it," is one way of testing a trial wheel and a practice that is too prevalent with many grinding-wheel consumers. Bill may have the best intentions in the world, but it requires more than good intentions to test a grinding wheel to determine its actual worth. He uses the wheel for a day or so, maybe a week, and then forms a decision which may or may not be correct. He is not to blame in nine cases out of ten if his verdict is incorrect because the actual user of grinding wheels, on rough operations at least, has but little use for mathematics, therefore he is at a loss to form an accurate decision regarding actual cost of production. In his opinion, the wheel may be a good one or a poor one. Unless the wheel shows a remarkable saving in grinding time, his decision is liable to be a guess pure and simple and it may be influenced by a deep-rooted prejudice in favor of a certain make of wheel. He may use a trial wheel for a few weeks and report that he sees no apparent saving, and if the wheel in question happens to be a comparatively high-priced one, the test is ended then and there.

On the other hand, if the wheel was tested according to common-sense methods the production department would have actual figures to show the purchasing department regarding the actual earning power of the wheel. There are over twenty grinding-wheel manufacturers in this country and they all make reliable products. They have brought the grinding-wheel industry to its present high state of development through tireless and painstaking effort, being ready at any time to make special wheels for trial purposes for any operation that appears practicable. Since they are ever ready to help the manufacturer in reducing his production costs, why should not the manufacturer meet them half-way by giving trial wheels a fair and impartial test?

The average manufacturer is broad-minded; he is generally willing to grant the grinding-wheel salesman a courteous interview and often orders trial wheels for test purposes. After the wheels have been tested, however, it is seldom that the salesman who supplied them is able to get an accurate report of their performance. Unless the saving is readily apparent, as in testing Carborundum against emery for cast-iron grinding for instance, the trial wheel is in many cases reported as showing no saving as compared with the wheels regularly used.

A report of this kind, lacking in figures to verify it, is unsatisfactory to all parties concerned. The consumer does not know for a certainty whether the wheel tested actually did or did not show efficiency; the salesman is at a loss to make an intelligent report to his employer; while the grinding-wheel manufacturer, although compelled to acknowledge defeat in the specific case in question, is justified in forming the conclusion that his wheel was not given a fair test since no figures were submitted to verify the unsatisfactory report.

In analyzing the above case, we must admit that the salesman exercised the talents of his profession in getting permission to submit a sample of his product for test purposes, while the grinding-wheel manufacturer did his part in supplying a test wheel made to meet the grinding conditions as specified on the salesman's trial order. The consumer, however, to state the case in plain English, condemned the wheel without furnishing any figures to substantiate his claim.

A few cases have been called to the writer's attention wherein a trial order was given solely for the purpose of getting rid of a persistent salesman and an unsatisfactory report submitted to discourage further effort on the salesman's part. A procedure of this kind is unjust and not in accordance with good business ethics. To give the majority of successful manufacturers credit, however, we are safe in stating that cases like the above are happily not common.

We certainly are not justified in condemning all manufacturers at large for their apparent lack of interest in grinding-wheel tests, and the only reason the writer can assign for this state of affairs is that the average manufacturer is not an abrasive engineer, therefore he lacks technical knowledge of grinding wheels and often does not use the practical methods employed by the abrasive efficiency engineer in determining the actual earning power of a grinding wheel. In conducting a grinding-wheel test embracing wheels of several makes, or a few wheels of the same make in different grits and grades, it is a waste of time to attempt to state from observation alone which is the most efficient wheel. A careful record of each wheel should be kept and reliable figures submitted to use in comparing the different wheels.

To illustrate the principle of practical wheel testing as graphically as possible, it may be well to consider a few practical tests. Where a large number of comparatively small pieces are ground, we have ample opportunity to determine the actual earning power of the grinding wheel by considering the following factors: Time consumed, number of pieces ground, value of abrasive material used and the cost of labor. By comparing the amount of work produced with the actual cost involved, we readily determine the actual grinding cost per thousand pieces. This is what

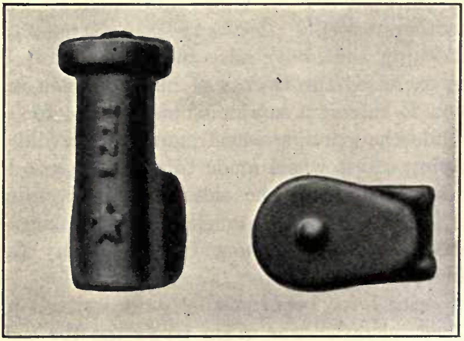


Fig. 20.—Ideal shape of castings for testing economy of wheels.

interests the successful manufacturer—actual production costs. What the grinding wheel is made of does not matter as far as he is concerned; if wheels made of river sand bonded with molasses showed the greatest earning power he would accept them just as readily as he does the comparatively high-priced products of the electric furnace.

In Fig. 20 is shown an ideal casting for making an efficiency test. It is of malleable iron weighing 10-1/2 oz., and the only grinding necessary is at the base to remove the sprue left when the casting was knocked off the gate. Let it be assumed that we are to test a 16 x 2 wheel for grinding these pieces. The workman is given the wheel together with an unlimited supply of castings and the test conducted for a period of fifty hours. At the end of this time, we might have a report like the following: Number of pieces ground 2,000, time consumed 50 hours, weight of wheel after test 30 lbs. In the meantime, we have drawn up a form like the following to aid us in determining the grinding cost.

Part tested	Rocker arm short bracket
Make of wheel	Duplex
Size	16 x 2
Grit	20
Grade	Q
Bond	Vitrified
Cost	$6.63
Weight	34 lbs.
Cost per pound	$00.195
Operating speed	1,200 R.P.M.
Material ground	Malleable iron
Length of test	50 hours
Workman's name	G. Harris
Workman's rate	$0.25 per hour
Number of pieces ground	2,000
Cost of labor	$12.50
Weight of wheel after test	30 lbs.
Pounds of abrasive used	4
Value of abrasive used	$0.78
Total cost of grinding	$13.28
Cost per thousand pieces	$6.64
Cost per piece	$0.00664

Here we have sufficient data to satisfy the most critical efficiency engineer. Nothing is contained in the above that is superfluous; in fact every item is for a distinct purpose. The total grinding cost means something because it represents actual dollars and cents that have been expended on a certain operation. How much better it is to have a statement like the above than to rely upon the foreman's statement that a certain wheel cuts good and that one of them lasts the operator three months. This statement conveys no real information as regards actual production costs. Suppose, for the sake of an argument, that he tried another make of wheel which lasted only two months. He would, in all probability, condemn it as too short-lived, never taking into consideration that a practical test as outlined above might prove that it actually reduced grinding costs while it lasted. The first cost of a grinding wheel is of no consideration; it is its earning power that should be known to be appreciated. To illustrate the point clearly, let us consider a cheap wheel.

As in the previous test, we will use a 16 x 2 wheel, but of such a quality that it can be purchased at a rock-bottom price of $4.54. Owing to the low price of the wheel, it naturally follows that it cannot be made of a very expensive abrasive, the ultimate result being that it is slow cutting when compared with wheels that bring better prices. As before, the workman is given an unlimited number of castings, the wheel weighed, and the test run for fifty hours. At the expiration of the test, we might have the following report: Number of pieces ground 1,500. Time consumed 50 hours. Weight of wheel after test 28 pounds. From this report we proceed as before and draw up a summary.

Part tested	Rocker arm short bracket
Make of wheel	Complex
Size	16 x 2
Grit	20
Grade	Q
Bond	Vitrified
Cost	$4.54

Weight	34 lbs.
Cost per pound	$0.13325
Operating speed	1,200 R.P.M.
Material ground	Malleable iron
Length of test	50 hours
Workman's name	G. Harris
Workman's rate	$0.25 per hour
Number of pieces ground	1,500
Cost of labor	$12.50
Weight of wheel after test	28 lbs.
Pounds of abrasive used	6
Value of abrasive used	$0.7995
Total cost of grinding	$13.2995
Cost per thousand pieces	$8.866

From this test, it is seen that it cost more to use the cheap wheel than it did to use the moderate-priced one. As a general thing the purchasing agent sees the first cost only, and as long as he can keep his purchases at a low figure he is not concerned with actual operating expenses in the production department. In due justice to the purchasing agent, however, he should not be blamed for buying at as low a cost as possible when the shop management is not armed with figures to show actual grinding costs for different operations. It is the purchasing agent's duty to buy standard goods at the best prices obtainable and it is up to the shop to test the material purchased to see that it is efficient.

In carrying the test farther, let it be assumed that we have bought a high-priced wheel for test purposes, the same costing us $9.27 or over twice the price paid for the wheel previously tested. It is tested in the same manner as the previous wheels and the following report submitted: Number of pieces ground 3,000, time consumed 50 hours, weight of wheel after test 25 lbs. As before we draw up a summary from the report.

Part tested	Rocker arm short bracket
Make of wheel	Simplex
Size	16 x 2
Grit	20

Grade	H pl.
Bond	Vitrified
Cost	$9.27
Weight	34 lbs.
Cost per pound	$0.2726
Operating speed	1,200 R.P.M.
Material ground	Malleable iron
Length of test	50 hours
Workman's name	G. Harris
Workman's rate	$0.25 per hour
Number of pieces ground	3,000
Cost of labor	$12.50
Weight of wheel after test	25 lbs.
Pounds of abrasive used	9
Value of abrasive used	$2.4534
Total cost of grinding	$14.9534
Cost per thousand pieces	$4.9844

It is seen that by using a first-class abrasive we have actually reduced our grinding cost, although the first cost of the wheel was over twice that of the wheel previously tested and the wear per week is 50 per cent. greater.

If a wheel seems to wear rapidly there is no cause for alarm, for it must be borne in mind that the ideal grade of grinding wheel for a specific operation is of just the correct degree of hardness to allow the particles of abrasive material to be pulled from the bonding material as soon as they have lost their cutting power. A hard wheel will last longer than a soft one, to be sure, but at the same time its earning power is greatly reduced, as it is slow cutting. It is a very good plan to determine the earning power of a wheel before condemning it for wearing out too rapidly. There is, of course, a limit beyond which we cannot go in installing comparatively soft wheels for rough work. If the wheel is too soft, the grains of the abrasive will be pulled from the bonding material before accomplishing a fair amount of work. Instead of removing metal from the work, we are truing off the grinding wheel.

That a softer grade will oftentimes accomplish more work on a given operation is a fact known to every grinding-wheel salesman, and the following incident which came to the writer's notice, may be of interest while considering this factor. The work in question consisted of cast-iron cream-separator frames which were ground all over with the object of preparing an even surface for the painter. Here it was necessary to go over the surface of the casting carefully, and as this was somewhat of a tedious operation at best, a free cutting wheel, which would enable the operator to finish a frame in the quickest possible time, was very much desired.

With the work in question, the operator had been using Carborundum wheels 8 in. dia., 1 in. face, 30 grit, G pl. grade in V A bond. The output with this wheel was thirty castings per day. One day, one of The Carborundum Company's efficiency engineers investigated the operation and induced the management to try wheels of a softer grade, stating that, while the softer wheel would not last as long, it would materially increase production while it lasted. The result was that wheels in 30 grit H pl. grade were tried out and, much to the operator's surprise, he was enabled to finish fifty castings per day.

Assuming that we were conducting a test of this kind today we would use a day's wage of $3.00 as a basis on which to conduct our cost test. In finishing thirty castings per day, our grinding cost for labor would be ten cents per casting as against six cents per casting when fifty are ground per day. Thus, it is seen that an actual saving of 40 per cent. in production cost is accomplished through a little experiment in changing the grade of the wheel.

A slight change in grade often makes a great difference, as the above-mentioned test illustrates, and another simple experiment along the same lines, that came to the writer's attention a few years ago, may be of interest. In any farming country may be found blacksmiths and others who net quite a sum annually grinding plow points during the plowing season. The operation is simple, consisting of grinding the plow point until it is sharp. To the city-bred man it may seem laughable that the point of a plow has to be sharp, but such, nevertheless, is well known by those who have had occasion to guide a plow.

The man in question used a Carborundum wheel in 20 grit, G pl. grade and V A bond with which he could grind forty plow points per day, netting him $8.00. He was dubious about trying a softer wheel, claiming that $8.00 per day was a nice little sum in itself and that it was sometimes a good plan to let well enough alone. However, he was induced to try a wheel one grade softer, that is H pl., with the result of grinding sixty points per day, netting him $12.00. It is seen that by using a wheel more adapted for his work he put $4.00 extra in his pocket daily during the plow-point grinding season.

Now the business of grinding plow points in a country cross-roads shop may not amount to much in itself, but that is not the point. The lesson is here: If one man, who knows but little of efficiency from the average manufacturer's point of view, can put an extra $4.00 in his pocket every day, using one wheel only, the same being graded properly, what are the possibilities for saving with the manufacturer whose grinding-wheel bill, and subsequent grinding costs, runs into big figures? The possibilities for saving are enormous.

The tests so far considered have dealt only with comparatively light work, but from this it must not be inferred that accurate tests for production costs cannot be conducted on heavy work. Car-wheel grinding furnishes an ideal means of determining the efficiency of a grinding wheel on heavy work, and the following test, which came to the writer's notice a few years ago, embodies all the data necessary for computing the actual grinding cost per wheel.

The work consisted of grinding the small fins left by the molds on Barr contracted chilled-iron car wheels, often used on freight cars. The work was done on a car-wheel grinder, of regular pattern, and the wheel used was Carborundum 18 in. dia., 4-1/4 in. face, 166 grit, G pl. grade and V A bond. The average grinding time was 50 seconds per wheel and in 72 working days of ten hours each, the wheel was reduced to a diameter of 11-3/4 inches. If the wheel had been used constantly, ten hours per day, it would have ground 8,640 car wheels. This is, of course, a theoretical calculation as a certain amount of time was consumed in taking the car wheels to and from the grinder and in mounting them for the grinding operation. As it was, 6,343 car wheels were actually ground during the test of 72 days.

Let us assume that the operator of the car-wheel grinder receives \$2.50 per day, and proceed to ascertain our grinding cost per wheel. As $72 \times 2.50 = 180$, we have a cost of \$180.00 for labor. A Carborundum wheel 18 x 4-1/4 inches costs \$13.07, but in the case in question it was not completely worn out, therefore we will compute the actual cost of the abrasive used. Instead of considering the number of pounds of abrasive used we will, for the sake of variety, use another method of figuring the cost of a partial wheel by ascertaining its volume in cubic inches and subtracting the number of cubic inches in the worn portion of the wheel, which will give us the number of cubic inches actually used in grinding the 6,343 car wheels. Knowing the volume of the new wheel and its value it is an easy matter to find the value per cubic inch and also the value of the amount of abrasive used.

To find the volume of an 18 x 4-1/4 grinding wheel, we can use the following formula, in which V stands for volume, D for diameter, W for width, while the decimal .7854 is a constant.

$$V = .7854 \times D \times W$$

Thus, $.7854 \times 18 \times 18 \times 4\text{-}1/4 = 1{,}044.3168$ cubic inches, which is the volume of an 18 x 4-1/4 wheel.

Again, $.7854 \times 11\text{-}3/4 \times 11\text{-}3/4 \times 4\text{-}1/4 = 445.0026$ cubic inches, which is the volume of a 11-3/4 x 4-1/4 wheel.

Further, if 1,044.3168 cubic inches of material cost \$13.07, one cubic inch will cost \$0.01251.

By subtracting 445.0026 cubic inches from 1,044.3168 cubic inches, we have 599.2905 cubic inches as the amount of material used. Multiplying this amount by the cost per cubic inch, we have $7.4971 or the actual cost of abrasive used. Adding this to $180.00, our labor cost, we have a total cost of $187.4871.

We will call our cost $187.50 for convenience in figuring, and dividing this amount by 6,343, the number of car wheels ground, we find an actual grinding cost of $0.02956 per wheel or $29.56 per thousand wheels. It is seen that by using a simple practical method it is possible to accurately determine the grinding cost under everyday working conditions. It is reliable figures of this kind that the manufacturers desire.

In grinding comparatively large work, it is possible to determine the grinding cost while working on an individual piece, as the following report on the grinding of a large chilled-iron roll, by Mr. J. H. Hollinger, of The Landis Tool Company, published in the Oct. 26, 1911, number of the *American Machinist*, graphically illustrates.

"I have ground a chilled cast-iron roll 20–3/16 inches diameter by 28 inches long on a Landis 20 x 96 inch roll grinder, removing 1/4 inch from the diameter of the body only. Surface speed of roll, roughing 52–1/2 feet, finishing 52–1/2 feet; traverse of wheel for each revolution of the work, 7/8 inch; wheel feed at each reversal, 0.006 inch for roughing; 0.001 inch for finishing. The roll was ground with a 22–9/16 x 2 inch Carborundum wheel having an 8-inch hole, 403 grit, P grade, O F bond, running at 925 revolutions per minute, 5,472 surface feet and it was reduced in diameter 19/32 inch, which represents a cost of 90 cents. This wheel wore just fast enough to keep itself sharp and, for roughing, was only dressed once with a diamond. Time for grinding the roll to a smooth finish, good enough for hot rolling, 4 hours; total cubic inches removed, 221; cubic inches removed per minute to finished surface, 0.92 inch. The motor used on this work was a variable speed 25 horsepower. Average horsepower consumed, 21."

In the above report it is seen that Mr. Hollinger has embodied all the data necessary for computing an accurate grinding cost, which is quite essential when testing wheels on large work. It is needless to state that comparatively long grinding operations on large pieces are expensive and without accurate data, compiled by one who understands the art of grinding thoroughly, it is an impossibility to determine the actual cost.

The operation shown in Fig. 21, furnishes another instance wherein the grinding cost can be computed through working on one piece. The work in question consists of actually grinding long shafting used in textile machinery. The shafting comes slightly oversize and after being centered is kept in racks and ground as needed. With shafts of the same length and with a like amount of material to remove, it is obvious that a record of the grinding cost for each size can be kept. When another make of wheel is to be tested, it is a simple matter to determine its earning power by

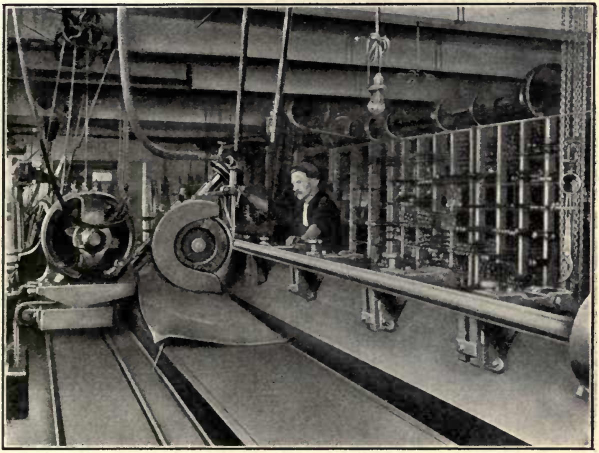


Fig. 21.—Grinding long shafting used in textile machinery.

noting the length of time taken to remove a certain amount of material and the wheel wear meanwhile.

Still another instance where the grinding cost can be computed while working on one comparatively large piece is shown in Fig. 22. In this case, the work consists of grinding locomotive guide bars to produce a smooth and true surface for the cross-head gibs to slide upon. Different types of locomotives have various kinds of guide bars, but with the kind shown four constitute a set. Thus, to determine the grinding cost, all that is necessary is to measure the thickness of the wheel with a pair of calipers before and after grinding the four bars and taking note of the time consumed in the grinding operation. The actual grinding cost is arrived at by adding the labor cost and value of abrasive material used. In tests of this kind, it is truly surprising how some makes of wheels show remarkable

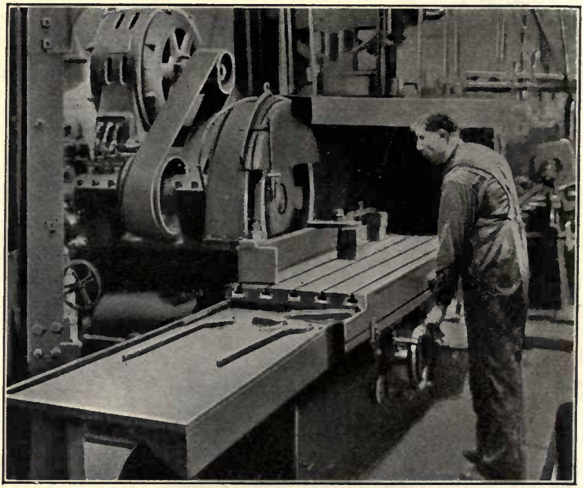


Fig. 22.—Grinding a locomotive guide bar.

saving in grinding costs over others. Thus the man who thinks that it is not worth while to test grinding wheels for efficiency is often needlessly grinding away dollars, so to speak, instead of removing metal in the most efficient manner possible. It must be borne in mind that grinding operations on large work are expensive at best and too much cannot be said in favor of making accurate tests to determine actual grinding costs.

On certain classes of grinding of an automatic or semiautomatic nature, wherein the actual time of contact between the wheel and the work does not vary, the efficiency of the wheel can be determined by considering one factor only, that is the actual number of hours it lasts. The operation of grinding chain links of the kind illustrated in Fig. 23 furnishes an excellent means of determining the earning power of a grinding wheel by considering its life only. Chain links of this kind are used for transmitting power,

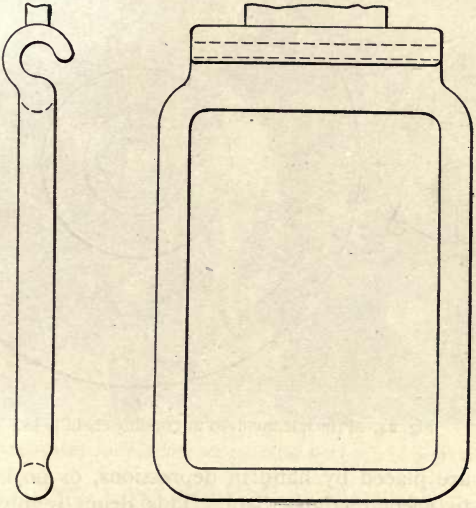


Fig. 23.—Type of chain links finished by semi-automatic grinding.

conveying material, etc., and are made in various sizes from small ones approximately an inch long to large sizes a foot or more in length. The smaller sizes are cast from a gated pattern and the object of the grinding is to remove the gate. This gate is shown on the top of the link illustrated in Fig. 23.

The means generally provided for this work are shown in Fig. 24, wherein A is the grinding wheel revolving as shown by the arrow and B the drum for carrying the links which are placed by hand in depressions, or pockets, provided to accommodate them. This drum revolves quite slowly in the direction shown by the arrow. The object of the slow motion is to give the wheel ample time to grind away the gate. The operator places the links in the pockets by hand and as the drum revolves they are brought in contact with the wheel. Means are provided for moving the shaft carrying the drum toward the wheel as it wears away, which is, of course, necessary in producing uniform work. As the speed of the drum is always constant, it is

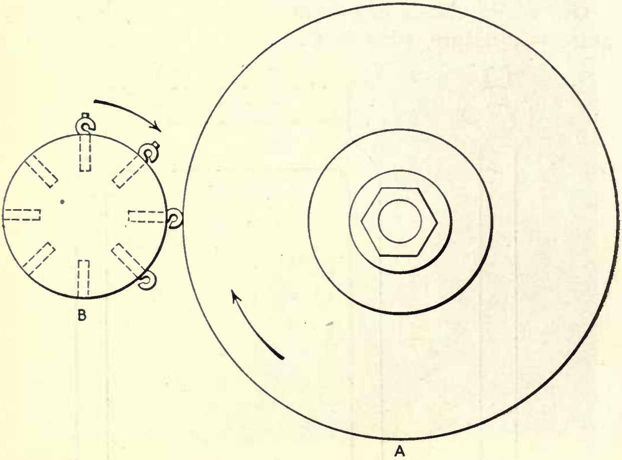


Fig. 24.—Principle involved in grinding chain links.

evident that the life of the wheel is the chief factor to consider, as a comparatively soft wheel would wear away very rapidly without performing its full quota of work and during its life would require almost constant attention in keeping the drum in proper relation to the periphery of the wheel.

Fig. 25.—Semi-automatic machine for rounding the backs of pearl buttons.

On the other hand, the wheel should not be too hard or it would glaze very readily, refuse to cut, and in some cases a fractured wheel would result. In testing wheels on work of this kind, it is a good plan to begin the test with comparatively soft wheels, taking note of the amount of links of a given size ground during the life of the wheel. Harder wheels are then tried and the hardest wheel that will cut satisfactorily without constant glazing is the one that should be selected.

Another case wherein the efficiency of the wheel is determined by its life is illustrated in Fig. 25. The machine shown is of semi-automatic construction and is designed for rounding the backs of pearl-button blanks. As the illustration shows, the operator has a box of button blanks and places them one at a time in the chucks which automatically grip them and carry them under the wheel shown at the right. The face of the wheel is slightly concaved and as the chucks revolve on their axes, as well as traveling in a circle, the blanks are given the desired rounded shape as they pass under the wheel. Provided the blanks are ground in a satisfactory manner, that is, without burning them, the wheel that will last the greatest number of working days is considered the most efficient. Tests of the above kind are, of course, easily conducted as they consist simply of selecting a wheel that will do the work in a satisfactory manner and noting how long it will last.

From the foregoing, it is seen that there are three practical methods used for testing the efficiency of a grinding wheel.

1. A definite time test wherein the wheel is used for a specified number of hours; the grinding cost being computed by adding the value of the abrasive used to the labor cost; from which the grinding cost per piece or per hundred or thousand pieces is computed.

2. The individual piece test, wherein the grinding time and cost of abrasive is noted while working on one piece of comparatively large work.

3. The life of wheel test in which the amount of grinding is noted during the whole time the wheel is in service.

All the above tests are practical, and can be relied upon to give accurate production costs on a variety of work; both of a rough and precision nature.

Grinding-wheel tests should, of course, be conducted by responsible men and the data regarding the performance of each wheel should be kept accurately, otherwise the tests will be of no practical value.

CHAPTER SEVEN

LABORATORY TESTS

Apparatus and appliances used—Limitations of laboratory tests—Factors to be considered—Laboratory testing machine—Data for test—Work used in testing.

THE simple methods used in testing grinding wheels on actual work, as described in the previous chapter, can be used only in cases where there are comparatively long runs of routine work. In many instances, however, the work is of such a nature that it is an impossibility to secure enough like pieces on which to test the efficiency of a particular wheel. This is often true in gray iron, brass, steel and malleable iron foundries, to say nothing of the innumerable manufacturing plants where a diversity of cylindrical grinding is done.

By means of simple appliances, as described in this chapter, however, it is possible to obtain absolute knowledge of the abrasive efficiency of any grinding wheel on practically any kind of material. The value of these laboratory tests should not be under-estimated as they give the efficiency engineer knowledge of the actual worth of different abrasives and different makes of wheels without resorting to the production department for data.

On cylindrical grinding especially, owing to the many factors to be considered while testing wheels on actual work, such as depth of cut, work speed, feed, etc., it is a difficult matter sometimes to determine which is the better wheel to use. Again, operators of cylindrical grinding machines are sometimes unduly prejudiced in favor of one particular make of wheel, often flatly refusing to be convinced that other grinding-wheel manufacturers, also, make dependable wheels. Other factors also, the nature of which it is not necessary to state here, sometimes unduly influence grinding-machine operators, or even department heads to whom is sometimes left the selection of grinding wheels. It is seen that laboratory tests can be relied upon as a sure means to the desired end; that is, to ascertain beyond reasonable doubt the actual abrasive efficiency of all wheels offered for test purposes.

A given number of cubic inches of abrasive material incorporated into a grinding wheel will, at a given surface speed, remove a definite amount of metal. This is the hypostasis upon which laboratory tests, to determine the abrasive efficiency of grinding wheels, are based.

In Fig. 26 is illustrated a simple testing machine for determining the efficiency of grinding wheels used for such purposes as grinding castings and forgings, general grinding in the machine shop, tool grinding, or, in fact, for any purpose where the work is held in contact with the wheel by hand.

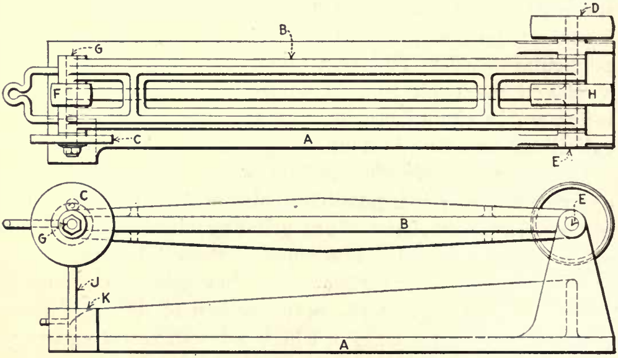


Fig. 26.—Laboratory grinding-wheel testing machine for testing grinding wheels used in hand-grinding operations.

This machine consists of a substantial base (A) upon which is mounted a swing frame (B) carrying the grinding wheel (C). The pulley (D) on the jack shaft (E) is driven from an overhead countershaft of the variable-speed type, while the pulley (F) on the wheel spindle (G) is driven by the pulley (H).

The work to be tested is shown at (J), consisting of a bar one inch square held in the anvil (K) by means of a set screw. The grinding wheel is always 12 inches in diameter with a one-inch face. The machine should be very rigid to absorb vibration, for, with a lightly constructed machine, vibration is sure to be present, which would cause chattering, thus preventing the end sought—to determine the efficiency of the grinding wheel under normal conditions. The wheel spindle is 2 inches in diameter while its pulley is 6 inches in diameter with a 4-inch face. Both pulleys on the jack shaft are 12 inches in diameter.

Power is transmitted by means of three-inch double-ply leather belt. The object of the ribs on the swing frame and the rib on the base is to make the construction as rigid as possible for the reason previously stated.

The swing frame should be counter-weighted by means of a weight attached to a cord passing over over-head pulleys. This cord is fastened to the rod at the front end of the swing frame. The counter-weight should be just heavy enough to cause the grinding wheel to exert a pressure of 10 pounds on the work, this being the average pressure exerted in hand-grinding operations. The pressure is determined by fastening a spring balance suspended from the ceiling to the eye on the swing frame directly over the spindle.

A little experimentation with a machine of this kind is sure to disclose startling results regarding the efficiency of different grinding wheels. Some wheels will be found to cut readily, holding their shape well, while others prove to be comparatively slow cutting. The wheels should all be run at the same speed, 1,592 R. P. M. being the correct speed for a 12-inch wheel, the above number of revolutions per minute giving a peripheral speed of 5,000 feet per minute, which surface speed is considered correct for hand-grinding operations. If the speed is retained constant at 1,592 R. P. M. and the same pressure exerted in all tests (10 pounds) it follows that all wheels tried are given a fair and impartial test since they are tried under the same conditions.

The test bar should, of course, be made of the same material on which the grinding wheel is used on actual production work. The wheel, after being carefully weighed, is placed in position on the spindle and carefully trued by means of the dresser shown in Fig. 27, which consists of a few star-wheel cutters mounted in a holder which fits the hole in the anvil. The test bar is now placed in position and the test conducted for one half-hour. At the expiration of this period, the number of cubic inches of material ground away are noted and the wheel taken off and weighed to determine the weight of abrasive material used. This should be done on a sensitive scale which accurately registers ounces.

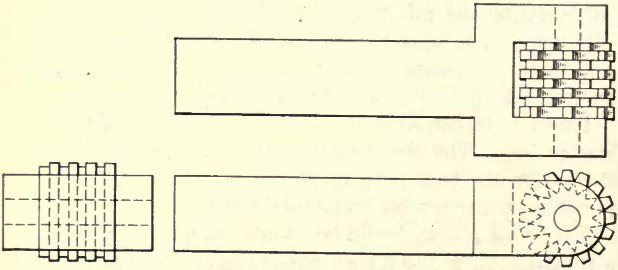


Fig. 27.—Star-wheel dresser for use with testing machine.

It is evident that the wheel which will grind away the greatest amount of material in a given time, with the least amount of loss to the wheel itself, is the most efficient wheel to use for the purpose in question. In ordering wheels for test purposes on a machine of this kind, it is best to get at least two from each maker. The performance of each wheel should be carefully noted and in comparing wheels of different makes, the most efficient of each is considered. The records of all tests conducted should be kept in a book provided for the purpose and, after a few weeks of experimenting the manufacturer should have at his disposal authentic data relating to the performance of many wheels. The records should be kept on a form like the following:

Make of wheel,
Cost,
Grit,
Grade,
Bond,
Diameter,
Face,
Weight,
Cost per lb.,
Material tested,
Grinding pressure,
Wheel speed,
Length of test,
Weight of wheel after test,
Wheel loss,
Cubic inches of material removed,
Grinding cost per cubic inch.
Remarks.

It is readily seen that it is a more simple matter to determine the abrasive efficiency of a grinding wheel on a machine of the above kind than it is to conduct a long test in the shop. Again, the results derived from these tests can be relied upon as the testing can be done under the direct supervision of the efficiency engineer, who cannot always spare the time personally to superintend a long test on actual work in the production department.

The machine shown in Fig. 28 is designed to test wheels as used for cylindrical grinding. It consists of a solid base (A) carrying a wheel spindle (B) on which is mounted a wheel 12 inches in diameter with a 1-inch face and 5-inch

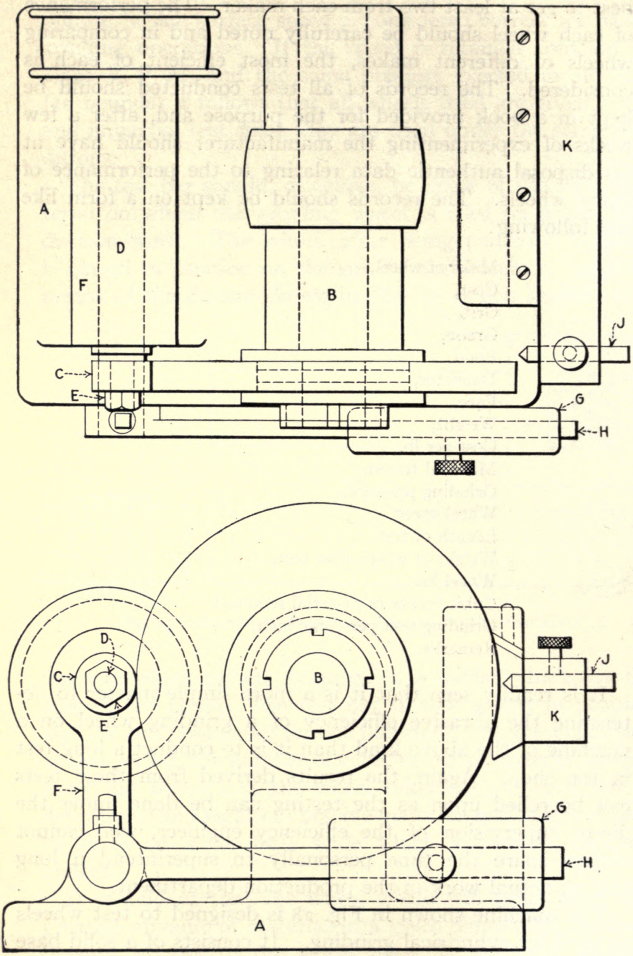


Fig. 28.—Laboratory grinding-wheel testing machine for testing grinding wheels used in cylindrical grinding operations.

hole. This wheel is a regular stock size as it fits several cylindrical grinding machines.

The piece to be tested consists of a disc (C) 2 inches in diameter, 1 inch wide with a 3/4-inch hole. It is made of the material upon which it is desired to test the wheel and is fastened in place on the work spindle (D) by means of the nut (E) which holds the piece against a shoulder on the work spindle. The work spindle is mounted on the swing frame (F).

The work is kept in contact with the wheel by means of the weight (G) on the lever (H). The weight is adjusted to make the wheel spark heavily as it does on regular production work when working at its maximum limit. The same amount of pressure should be used in testing all wheels otherwise a fair decision is not possible.

A diamond mounted in the holder (J) which fits the slide (K) at the back of the machine is for the purpose of truing the wheel. The testing can be done either wet or dry. The machine shown is designed for dry testing, but with the addition of a hood to cover the wheel and a pipe to supply water at the point of grinding contact, tests in wet grinding can be conducted.

The tests are carried on in the same manner as those just described with a view to determining which is the fastest cutting wheel with the least amount of wear. As previously stated, it is often a difficult matter to determine the actual efficiency of a wheel used for cylindrical grinding owing to the many factors to be considered. With a machine of this kind for conducting comparative tests, however, wherein the factors are simplified as much as possible, tangible results are possible in a very short time without the necessity of interrupting the regular work in the grinding department.

The manufacturer who wishes to reduce his grinding costs will do well to conduct a few simple tests as outlined in this and the previous chapter. The results of the tests should be carefully noted for future reference. and by testing different makes of wheels and different grits and grades of the same make, economical results in the production department are sure to follow. It costs comparatively little to test grinding wheels when the work is undertaken in the right way and the actual saving in dollars and cents that results from reliable tests makes it worth while to conduct them.

CHAPTER EIGHT

GRINDING WHEEL VS. GRINDSTONES

Advantages of natural and artificial abrasive used in wheels—Early use of grindstones—Special work where grindstones are still employed—Action of grinding wheel.

As previously stated in another chapter, the grindstone is the oldest form of grinding wheel known, being at one time exclusively used for all grinding operations. When the grinding wheel made of emery was first put on the market, some forty years ago, it did not readily meet with favor in the manufacturing world owing to many disadvantages. In the first place it was often dangerous; being liable to burst from centrifugal strain without a moment's notice and, again, the high speed at which it was run, together with the low abrasive efficiency of the grinding material used, caused it to draw the temper of edge tools unless great care was exercised in the grinding operation. The grinding-wheel industry of today being in its infancy, grinding-wheel manufacturers faced a serious problem in finding a market for their goods.

While the old-fashioned emery wheel of previous days did not successfully compete with the grindstone, in the edge tool, saw, file and other industries it began to be used for many operations heretofore accomplished by the slow hand method of filing. As a matter of fact, it was common practice to file all kinds of castings as late as twenty-five years ago, but as experience proved that the emery wheel furnished a more rapid means, together with the fact that emery-wheel manufacturers began to seriously consider the factor of safety, the grinding wheel slowly advanced in favor. In the year 1878, Mr. Hart of Detroit obtained a novel patent on a grinding wheel containing a wire web, the object of which was to prevent the fragments of the wheel from flying in case it burst. This was readily accepted as a great improvement, which indeed it was, and the grinding-wheel business thereby received a remarkable impetus.

With the general introduction of corundum in the early eighties, grinding wheels began to be used for other purposes aside from rough grinding owing to the fact that a cooler cutting wheel could be made by substituting corundum for emery. Thus corundum wheels found a limited market for certain tool-grinding operations hitherto done on the grindstone.

With the adoption of cylindrical grinding machines for finishing hardened parts of machinery, the grinding-wheel business was established on a firm basis owing to the fact that the cylindrical grinder furnished a sole means for a desired end; that is, doing work that could not be done either with the file or grindstone. With the improvement of cylindrical and other precision-grinding machinery, the grinding-wheel industry has kept pace; abrasive wheels being used at the present day for thousands of manufacturing operations.

Strange as it may seem, however, the modern grinding wheel has not wholly replaced the grindstone for certain operations owing chiefly to the cheapness of grindstones and to the manner in which they act on the work with which they are brought in contact.

A grindstone is run at a comparatively slow peripheral speed, so slow that it will not throw water from its surface. In the grinding operation, particles of quartz are torn from the stone and these floating in the surface water present a planing action on the work, often with a shearing cut as the particles of quartz are dragged under the piece being ground. Any mechanic realizes that a shearing cut is very effective and this peculiarity of "grindstone action," as it is termed, together with the fact that quartz in itself is a very efficient abrasive for some classes of work, accounts for the fact that the old grindstone is still in favor in certain phases of work.

At the present day, grindstones are used for a number of surfacing operations such as grinding the sides of saws, grinding file blanks, surfacing plows, axe grinding, etc. Large numbers of grindstones called pulp stones are used in preparing wood pulp for paper manufacturers. In this particular field, the grinding wheel cannot, or, at least, has not been able to compete successfully owing to the low initial cost of grindstones and to the fact that grinding wheels do not prepare the material in the desired manner to suit American paper manufacturers. In the Scandinavian countries, however, a special form of manufactured grinding wheel is used for pulp grinding, but these same wheels do not find favor in this country.

In the manufacture of files, the grindstone is still used in large quantities owing to the fact that it leaves just the proper kind of surface for the tools that cut the file teeth. Numerous experiments have been tried to develop a grinding wheel to do this class of work successfully, but to the best of the writer's knowledge no success has been attained.

That the grindstone still shows efficiency on certain classes of work cannot be doubted and as an illustration of this we can consider the subject of axe grinding. As they come to the grinding room, axes, like other products of the forge, are in a rough state and the operation of grinding them smooth before they are tempered is termed by the axe manufacturer "press grinding" or "pressing." A press in this case is nothing more or less than a stout iron bar to hold the axe firmly against the stone, pressure being applied by means of a foot-operated treadle.

The stones used for this work are six feet in diameter and twelve inches thick, costing at a fair market price, $25.00 each. One of these stones lasts approximately three weeks, during which time it grinds 3,500 axes. Considering ten hours as a day's work, it is seen that the operation of rough grinding one axe consumes three minutes. Now there are a good many square inches on the surface of an axe and any abrasive whatsoever that will do this work in the short time of three minutes is efficient to say the least. The cost of abrasive material used per axe is less than one cent, being approximately 7/10 of a cent.

If we invest our $25.00 in a grinding wheel we can, at a fair market price, purchase a wheel 30 inches in diameter with a 2–1/2-inch face, one 24 inches in diameter with a 3–1/2-inch face, or one 20 inches in diameter with a 5–1/4-inch face. A grindstone 6 feet in diameter with a 12-inch face, contains 48,858 cubic inches, whereas a typical grinding wheel that can be purchased for the same price, a 30 x 2–1/2 for an illustration, contains but 1,767 cubic inches. Thus it is seen that a decided factor is in favor of the grindstone; that is, its low cost per cubic inch. It naturally follows that a grinding wheel to compete with a grindstone on the work in question must be highly efficient owing to the fact that its cost per cubic inch is much greater. Again we must not lose sight of the fact that it takes a very fast-cutting grinding wheel to surface an axe in three minutes.

However, notwithstanding that grindstones are cheap and efficient, the grinding wheel is gradually creeping into the axe industry, owing to the fact that its adoption offers advantages that cannot be had while using grindstones. A prominent axe manufacturer with whom the writer has had some recent correspondence regarding the grinding wheel in the axe factory, has the following to say in favor of the grinding wheel.

"Our general opinion is that grinding-wheel grinding is as economical in labor cost and abrasive cost as wet-stone grinding, but the collateral advantages of the grinding-wheel grinding throw the advantages strongly in favor of this method. Grinding-wheel grinding takes up much less space, requires less power and permits better working conditions because the grinding wheels can be used with exhaust hoods to carry off the dust, and even if they are used wet the water can be confined; whereas with wet grinding with large grindstones, the men are constantly wet and the department cannot be kept either clean or sanitary."

Abrasive engineers and grinding-wheel salesmen are prone to discuss the possibilities of the grinding wheel wholly replacing the grindstone in various manufacturing pursuits. As a matter of fact, the above theme has been discussed more or less ever since the grinding wheel first made its appearance nearly fifty years ago. Notwithstanding that the grindstone is entirely different in grinding action from the grinding wheel, the latter is slowly gaining in favor owing to the rapid strides made in abrasive engineering, and in considering future possibilities in fields now occupied by the grindstone. we are confronted with two vital factors.

First, the grindstone is a natural product; thus it cannot be altered—it must be accepted just as nature formed it, millions of years ago when the earth was young. Different degrees of hardness and variations of the size of the quartz grain of which the stone is composed can be had, to be sure, but neither the abrasive itself, nor the natural bonding material that holds the innumerable grains of which the grindstone is composed can be changed by the arts of man.

Second, the grinding wheel can be made to differ in quite a number of ways to suit varied grinding conditions. It can be composed of various kinds of abrasives bonded together by many different means. Again, it can be coarse or fine, hard or soft, compact or open, brittle or tough. In fact the abrasive engineer of the present time first studies the work to be performed and then makes a wheel to suit the requirements, and in cases, where the experimental wheel fails to come up to his expectations, he profits by the failure and tries again.

By this method, and this method only, the grinding wheel has been adapted to purposes undreamed of a few years ago, comparatively speaking, thus it is reasonable to assume that the knowledge of future years will produce a grinding wheel that will eventually replace the grindstone just as artificial abrasives have practically replaced the emery wheel of yesterday.

CHAPTER NINE

THE ECONOMIC ADVANTAGE OF USING LARGE WHEELS

Factors to be considered in choosing a wheel—Comparative price of wheels of various sizes—Advantage of large wheels in certain work—Why large wheels are more efficient.

THOSE who purchase grinding wheels have probably noticed that the grinding-wheel salesman seems anxious to sell large wheels, that is 16 x 2 inches or over. This is not always because the salesman wishes to write up a "nice order," as it were. Contrary to this, he generally has his customer's interests in mind and realizes that there is true economy in using comparatively large wheels, as the following figures show. The wheel sizes and list prices are taken from the standard grinding-wheel list and a perusal of the same shows that the cost of grinding wheels, per cubic inch, in most instances, decreases as the size increases.

There are some exceptions to this rule, however, for, as the data shows, a 24 x 4-inch wheel costs more per cubic inch than a 20 x 3-inch wheel. It is well for the purchasing agent who wishes to buy as economically as possible to figure carefully the cost per cubic inch of the various-sized wheels that he buys to ascertain whether or not he is buying to advantage.

The greatest difference in cost per cubic inch is found in wheels below 20 inches in diameter. With wheels larger than this the cost difference per cubic inch is not so great, and in some instances there is no decrease in cost per cubic inch with an increase of size. As an illustration, a 30 x 4-inch wheel costs just as much per cubic inch as a 20 x 3-inch wheel, while the cost per cubic inch of a 60 x 8-inch wheel is only slightly less than that of a 30 x 4-inch wheel.

Size	10 x 1–1/2
List price	$10.20
Area in cubic inches	117.81
Cost per cubic inch	$00.0871
Cost per hundred cubic inches	$8.71
Size	12 x 2
List price	$16.70
Area in cubic inches	226.20
Cost per cubic inch	$00.0738
Cost per hundred cubic inches	$7.38
Size	16 x 2–1/2
List price	$32.40
Area in cubic inches	502.65
Cost per cubic inch	$00.0645
Cost per hundred cubic inches	$6.45
Size	20 x 3
List price	$58.00
Area in cubic inches	942.48
Cost per cubic inch	$00.0615
Cost per hundred cubic inches	$6.15
Size	24 x 4
List price	$113.00
Area in cubic inches	1,809.56
Cost per cubic inch	$00.0624
Cost per hundred cubic inches	$6.24
Size	30 x 4
List price	$174.00
Area in cubic inches	2,827.44
Cost per cubic inch	$00.0615
Cost per hundred cubic inches	$6.15
Size	60 x 8
List price	$1,358
Area in cubic inches	22,619.20
Cost per cubic inch	$00.060
Cost per hundred cubic inches	$6.00

The advantage of using comparatively large wheels is shown in the following comparison: Let it be assumed that a concern uses two hundred 12 x 2-inch grinding wheels annually. At a fair market price these wheels would cost $835.00. The two hundred wheels contain 45,240 cubic inches, and in using them until they are four inches in diameter, 40,214 cubic inches of material are actually used while 5,026 cubic inches are discarded in the stubs, which represent an actual cost of $92.47.

If 24 x 4-inch wheels were used in place of the 12 x 2-inch wheels, twenty-five will contain 45,239 cubic inches which is practically the cubical contents in inches of the two hundred 12 x 2-inch wheels. Twenty-five 24 x 4-inch wheels, bought at the same discount that applied to the 12 x 2-inch wheels, would cost $706.25. In using the wheels to a diameter of 8 inches, practically the same amount of abrasive material is used as heretofore, that is 40,213 cubic inches, and in comparing the two prices it is seen that there is an actual saving of $128.75. The twenty-five 8 x 4-inch stubs contain 5,026 cubic inches and represent an investment of $70.40 against $92.47, the cost of the stubs of the 12 x 2-inch wheels. Thus another saving, amounting to $14.07 is effected.

Another point that should not be overlooked in considering large wheels is that a pair of comparatively large wheels mounted on a heavy grinding stand are more free from vibration than small wheels mounted on light stands.

If we take an ordinary machinist's hammer and beat a piece of steel with it for a few seconds, the face of the anvil, for instance, both the hammer and the anvil become slightly heated, owing to the fact that the energy of the blows has been transformed into heat. Consider for a moment the wasted energy expended by a vibrating grinding wheel traveling at a peripheral speed of 5,000 feet per minute. Here the same principle above explained holds true even if the grinding wheel vibrated but very little.

A grinding wheel should generate as little heat as possible; the wheel that vibrates while in use is very inefficient because some of the energy that should be expended in removing metal is used in generating useless heat.

As the surface of a grinding wheel presents thousands of cutting points to the work, it is evident that the surface having the most points to present to a given piece of work will last the longest without becoming dulled, or glazed. In considering a 14 x 2-inch wheel in 20 grit, we have a cutting surface of 87.9648 square inches and allowing 400 cutting points to the square inch the sum of these equals 35,185. On the other hand, a 24 x 3-inch wheel has a cutting surface of 226.1952 square inches containing 90,478 cutting points. It is plainly seen that the latter is bound to remain in cutting condition longer than the former.

Why is it then, that many manufacturers persist in using comparatively small grinding wheels mounted on light stands? In the first place, small grinding-wheel stands are cheap to install and the wheels for the same are not an expensive item when bought a few at a time. There is, of course, a place for the small grinding wheel, but for the average run of general work, snagging castings and forgings, tool grinding, etc., it is false economy to use wheels smaller than 20 inches in diameter. An ideal size to use for any of the above purposes is 30 x 4 inches, but outside of the plow industry, this size is little used. The cheapest course in the long run is to consign the small grinding-wheel stands to the scrap heap and install larger ones; and in the meanwhile the consumer of grinding wheels should be educated to the fact that small wheels are expensive at any price.

CHAPTER TEN

TRUING DEVICES FOR GRINDING WHEELS

(Reprinted from *The Iron Age.*)

Abrasive action—Tools used in truing wheels—Use of bort and carbonado diamonds in tools—Getting stones in tool—Procedure in truing wheels.

GRINDING wheels are in reality cutting tools revolving at high speed whereby countless sharp points remove minute chips by what we call, for want of a better term, the action of abrasion. In the strictest sense of the word, this is not correct because the word abrasion means to wear or rub, whereas a modern grinding wheel actually removes material, be it hard or soft, by a cutting instead of a wearing action. To obtain the best results, the innumerable cutting points on the surface of the wheel should be kept sharp and the periphery concentric with the spindle; otherwise the efficiency of the wheel is materially lowered. In this chapter, a few simple methods for truing grinding wheels will be briefly considered.

The tools used for this purpose are of two kinds, diamonds and ordinary emery-wheel dressers. There are two varieties of diamonds used, that is to say bort stones, many of which are nearly white in color, and a black variety called carbonado or black diamond. Bort stones are comparatively inexpensive when compared with black diamonds, but they are not so hard and consequently are shorter lived. It is, therefore, more economical to use black diamonds. Both varieties are sold by the carat and can be bought loose or already mounted in steel or copper holders. The majority of manufacturers prefer to buy loose stones, as by this method flaws are more readily detected, and since the stones are never guaranteed it is important to see that only good specimens are selected.

The operation of setting the stones is comparatively simple and can be intrusted to any tool maker who has the reputation of being a careful workman. In setting a stone, all workmen do not proceed along the same lines, but the following method, which is used by many tool makers, is simple and satisfactory. First, select a drill of the same size as the stone. This is readily accomplished by passing the stone through the holes in an ordinary drill gauge. As stated before, both steel and copper holders are used, but in actual practice the latter makes the better holder for two reasons. First, it is very malleable and thus is easily worked, and also copper is an excellent conductor of heat and readily absorbs superfluous heat, thereby tending to prevent overheating the stone, which sometimes causes it to fracture. The rod should be about six inches long and of the correct diameter to fit the holder of the machine where it is to be used. A hole is drilled in the end of the rod deep enough to bury the stone, as shown in Fig. 29. The next step is to force over the metal over the edges of the stone firmly in place. This is done with a light hammer and a small staking chisel. The result is shown in Fig. 30.

Fig. 29.—First step in mounting the diamond.
Fig. 30.—The metal in position over the stone.
Fig. 31.—The finished setting with the superfluous metal removed.
Fig. 32.—Special type of diamond holder.

Care should be exercised as a diamond is quite brittle and easily broken by a chance blow. The completed setting is shown in Fig. 31, the superfluous metal having been turned away. Some tool makers prefer to braze the stone in position, and while this method no doubt holds the stone firmly in place, the heat necessary to melt the spelter is liable to crack the stone. However, as the method of brazing stones in place is often used by reliable manufacturers there certainly is some authority for employing it. The process consists of filling the hole about half full of spelter and flux, and when this has reached a molten state, the stone is pressed in place, which causes the spelter to rise in the hole, thus forming a matrix that grips the stone firmly. It may be well to add that the work should under no circumstances be cooled in water, as the sudden contraction of the diamond will in many cases cause it to fracture.

Even the hardest stones will wear flat in time. It is necessary to reset them occasionally, which brings a new cutting edge in position. This is done by turning the stone upside down or canting it sideways. The holder shown in Fig. 32 accomplishes this in a very simple manner. It consists of an auxiliary plug in which the stone is mounted, fitting a hole, the axis of which is at a slight angle with that of the main holder. The plug is held in place by means of a set screw. When the stone becomes flattened, the plug is turned slightly, which brings a new cutting edge in position. This device is covered by patent and it is not public property.

Care should be exercised while using a diamond as an undue strain caused by gouging it into the wheel often results in tearing the stone from its setting, in which event it is generally lost. In truing wheels on cylindrical grinding machines, water should always be used to keep down frictional heat and several light cuts are to be preferred to a few heavy ones. It is hardly necessary to state that the tool should never be guided by hand as it is impossible to do a satisfactory job in this manner. Nearly all grinding machines are equipped with suitable holders to accommodate truing devices and they should always be used.

The device illustrated in Fig. 33 is excellent for truing wheels used on surface-grinding machines. It is very simple, consisting of a diamond set in a holder 1-1/2 inches long, which is fastened in a block of cast iron by means of a set screw. It can be used on a magnetic chuck or clamped in a vise. For truing wheels on various types of cutter-grinding machines, an angle iron, as shown in Fig. 34,

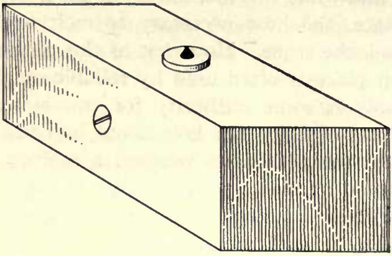


Fig. 33.—Simple device for truing wheels on surface grinders.

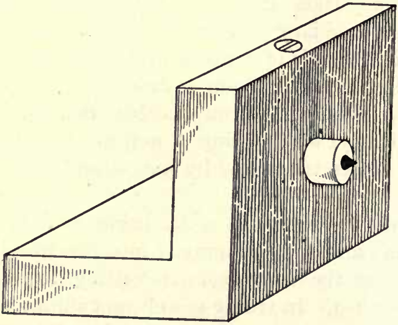


Fig. 34.—Device for truing wheels on cutter grinding machines.

gives good results. The diamond holder is fastened by means of a set screw and the angle iron is clamped to the platen of the machine by a strap, bolt, or other convenient means.

We are sometimes inclined to look askance at ordinary emery-wheel dressers in connection with wheels for precision grinding, but under certain limited conditions they are productive of excellent results. In ordinary cylindrical grinding, it is customary to rough out several hundred pieces before taking any finishing cuts, and as we are removing stock only, paying absolutely no attention to finish, all that we desire is a fast-cutting wheel. In cases of this kind, a few emery-wheel dresser cutters mounted in a holder, as shown in Fig. 35, will prove a revelation to the

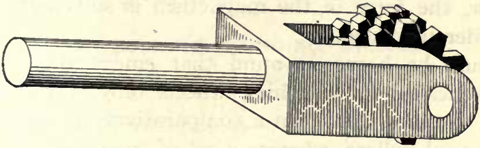


Fig. 35.—Grinding-wheel dressers mounted in a special holder for truing wheels used on cylindrical grinding machines.

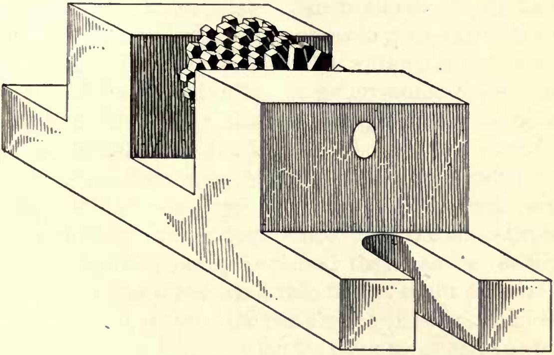


Fig. 36.—Truing device for use on large vertical spindle grinding machines.

man who has never used them. They keep the wheel rough and free cutting, which is just the condition required.

For truing the wheels used on large vertical spindle surface-grinding machines, a holder, as shown in Fig. 36, will be found a valuable accessory. It should be provided with slots for clamping it in place. On the magnetic chuck, however, the force of the magnetism is sufficient to keep the holder in place.

It must be borne in mind that emery-wheel dressers are practicable for roughing wheels only, but when we stop to consider that even a comparatively small diamond costs several dollars, whereas a set of emery-wheel dressers can be purchased for a few cents, their merits are well worth consideration.

CHAPTER ELEVEN

RE-BUSHING GRINDING WHEELS

(Reprinted from *Canadian Machinery*.)

Methods used in bushing wheels—Tools employed—Metals used.

MANY large manufacturing concerns use a number of grinding wheels in various departments for rough grinding of castings and general purpose work. As the stands upon which these wheels are used are generally of different makes and sizes, it is not uncommon for the diameters of the wheel ends of the spindles to vary from 1/16 to 1/4 inch or more. Thus, while 16-inch wheels might be used in several departments, it is necessary to carry a superfluous stock to accommodate the various sized spindles. To overcome this difficulty, many manufacturers make a practice of re-bushing their grinding wheels as occasion requires, thereby eliminating the necessity of carrying in stock individual grinding wheels for each department where the sizes of the wheel spindles vary. The wheels are ordered with the proper size arbor hole to fit the largest spindle, and with facilities easily procured they can be readily re-bushed to fit the other sized spindles at slight expense.

The following method for performing the work in question necessitates but a slight outlay for equipment and the results will be found to be satisfactory. The necessary tools are a cast-iron disc or plate as shown in Fig. 37 and several plugs of the same diameter as the various arbors on which the wheels are mounted. The plate should be as large in diameter as the largest wheel used, and, for the sake of illustration, the plate shown is 20 inches in diameter. It has three feet cast on it, which allows level setting on an uneven surface, should occasion require.

The rough casting is mounted in a large lathe chuck and the face turned off, after which a 3/4-inch hole is bored and reamed in the center. The next step is to turn several grooves 1/4 inch apart. These can be cut with an ordinary threading tool, and are used to set the grinding wheel central while re-bushing its hole. Two heavy lines are next scribed on the disc 90° apart, and near these lines the circles are stamped 1, 2, 3, 4, 5, 6, etc. Several plugs are now made with one end to fit the hole in the disc, while the diameters of the large ends should be 0.002-inch larger than the arbors on the grinding-wheel stands. This slight clearance is sufficient to allow the wheels to slip on freely. The large portion of the plugs should be one inch longer than the thickness of the grinding wheels. Thus, if wheels

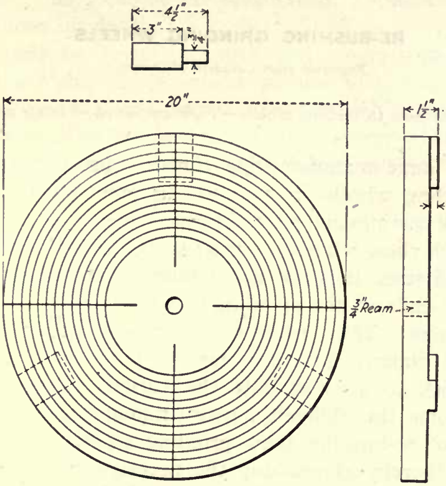


Fig. 37.—Appliance for re-bushing grinding wheels.

with a 2-inch face are used, the plugs should be 3 inches, as shown in the cut.

In re-bushing a grinding wheel, the first operation is to cut out the original lead bushing with a compass saw. By making two cuts diametrically opposite one another, the bushing is easily removed by means of a few light taps with a hammer. The wheel is now laid on the disc and carefully arranged in the center by means of the nearest circle to its periphery. A plug of the correct size is next inserted and the new bushing cast in place. Lead is the best material for this purpose, although any scrap stock of low melting point such as solder, die-casting metal, etc., will answer the purpose equally well.

The operation of re-bushing wheels is so simple that any boy or handy man can do the work in a satisfactory manner, while the cost of the necessary outfit should not exceed twenty dollars.

CHAPTER TWELVE

SUGGESTIONS TO FOLLOW IN ORDERING GRINDING WHEELS

Information to be given with grinding-wheel order—Factor governing selection of wheels—How to determine what kind of a wheel should be used —Ordering special wheels.

THE majority of grinding-wheel manufacturers include in their catalogues a list of various grinding operations, together with the grits and grades generally recommended for the different work. The object of these lists is to guide the purchasing agent in the selection of grinding wheels for various purposes.

An order for grinding wheels should, of course, give the diameter, thickness, size of arbor hole and quantity desired and, in case of a repeat order, the grit and grade. Otherwise it is a good plan to refer to the tables previously mentioned or give with the order full and complete information describing how, and for what purpose, the wheel is to be used. This information is of great value to the grinding-wheel manufacturer in filling the order intelligently, and also it is the means of saving much valuable time as unnecessary correspondence for the purpose of gaining full information is thereby eliminated.

There are indeed many factors governing the proper selection of grinding wheels as the following data, furnished the writer by the Abrasive Company of Philadelphia, plainly illustrate. It is with pleasure that the writer incorporates this material in his work as it states fully just how the grinding-wheel manufacturer views an order for grinding wheels that he may fill the same correctly, thereby being assured of future business.

"In order to obtain the best results, it is necessary to furnish full information to the wheel manufacturer.

"It is true that the size is generally given, but it is also necessary to know the kind of material to be ground, how the work is applied to the wheel and whether the same is edge or surface contact. In describing the class of materials to be ground, it is necessary to cover the point fully, or best results will not be obtained, no matter whose make of wheel is used.

"It is necessary to know the type of machine on which the wheels are to be used, whether the same is of the bench, floor, swing frame, flexible shaft or cylindrical type.

"When possible, give the make of the machine. It is important to know the construction, whether light, or heavy and rigid, for the following reasons: A heavy machine will absorb vibration and for this reason a softer grade of wheel may be used, thereby increasing production, whereas a harder grade wheel would be required for the same work on a light machine, due solely to the construction of the machine. If the machine is light and vibrates, production is sacrificed on account of the necessity of furnishing a harder grade wheel.

"Strong rigid machines, set on firm foundations, allow the grade of wheel to be used that will produce the best results.

"To determine the proper grit and grade, it is necessary to know the kind of material to be ground. With this information, the correct abrasive can be selected. If steel, is it hard or soft? If malleable iron, is it hard or annealed? If iron, is it cast, wrought or chilled? In the grinding operation, it is necessary to know whether there is line or surface contact. To describe fully what we mean, the following illustration will suffice: If the operation was grinding balls, there would be line contact, and, in such a case, it would be necessary to furnish a hard grade wheel. If the operation was internal grinding, there would be a large surface contact, thereby requiring a softer grade wheel, and in most cases a coarser grit.

"Whether the work is to be ground wet or dry largely determines the grade of wheel to be furnished. In many cases, a harder grade of wheel can be used if the grinding is done wet, as this practice prevents the work from overheating.

"Wheels are, under ordinary conditions, recommended to run 5,000 to 5,500 surface feet per minute, although in many kinds of grinding, they should be run much slower. If a wheel is too hard for the operation, good results can often be obtained by reducing the speed, and if too soft, this condition may be rectified by increasing the speed. It is seen, therefore, that wheels at slow speeds tend to act softer, whereas wheels at high speeds appear to act harder. In stating the speed, the number of revolutions per minute should be given. Wheels used on cylindrical grinders are operated at about 5,500 peripheral feet per minute, while for automatic knife grinding, they are run as slow as 2,500 feet per minute surface speed. It is seen, therefore, that speed plays an important part in a successful grinding operation.

"If the operation for which wheels are to be ordered is cylindrical grinding, the diameter of the pieces to be ground should be given, also the R. P. M. of the work. This enables the grinding-wheel manufacturer to determine the work speed. It is also necessary to know the quality of finish desired, as this is largely determined by the grit of the wheel.

"If the operation is surface grinding, the speed in linear feet should be given. It is important also to know the table traverse, or cross feed, which is the speed with which the wheel is fed across the work.

"If the wheel is other than regular, a blue print or sketch should accompany the order. Oftentimes the work to be done is of a special nature, thus a sketch of the work will also materially aid in the proper selection of the wheel. The user who is careful to give required information is generally the one who is getting the best results from his grinding wheels."

CHAPTER THIRTEEN

DESIGN OF DUST-COLLECTING SYSTEMS

(Reprinted from *American Machinist.*)

State law requirements—Design of wheel hood—General design—Size of exhaust pipe for different size wheels—Elbows—Collars—Method of erection—Clean-out—Fan—Dust-collector—Exhaust systems.

IN the majority of states where manufacturing is carried on to any extent, laws have been passed compelling the manufacturer to equip grinding and polishing departments with a suitable system for carrying away the dust. The different state laws vary greatly as to what constitutes an effective dust-collecting system; some being very rigid, while others are quite liberal.

This legislation is good for several reasons. In the first place, it protects the workman's health. The removal of dust from any manufacturing plant affords better fire protection. It saves quite an amount of material in cases where brass, copper, nickel or other comparatively valuable metals are ground or polished. It is a fact that in many cases where dust-collecting systems have been installed, enough metal has been saved in the course of a few years to offset the cost of the installation.

The first point to consider in any dust-collecting system is the design of the hood that covers the wheel. Fig. 38 illustrates an effective hood made by the B. F. Sturtevant Co., Hyde Park, Mass. The lower part of the hood forms a receptacle for containing the heavier part of the material removed from the work, and is provided with a swing clean-out gate. It is important to collect as much metal and abrasive as possible in the hood, as this saves wear on the piping, fan and collector. By referring to Fig. 39, it is seen that the hood in question is hinged on one side to facilitate the removal of the wheel as occasion requires.

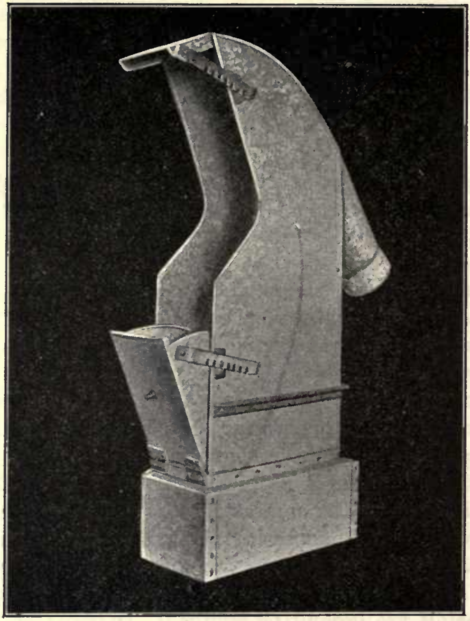


Fig. 38.—Wheel hood designed for catching dust.

The size of the branch pipes connected to the hoods is determined by the size of the wheels used. The following table gives the general rules recommended by the Sturtevant Company. These are general and open to modification in cases of special or wide-faced wheels.

Pipe Sizes	*Wheel Sizes*
2 inch	4 inch.
3 inch	4 to 6 "
3½ inch	8 to 10 "
4 inch	12 to 16 "
4½ inch	18 "
5 inch	20 "
6 inch	22 to 26 "

The elbows used in connecting the branch pipes with the main pipe collars are generally made in four sections for 45° elbows as shown in Fig. 40 A. This design allows a comparatively smooth interior, thus reducing friction to a minimum. As a further means of reducing friction, the radii of all elbows should at least equal the diameter of the pipe, and should exceed this when it is practical to have them do so.

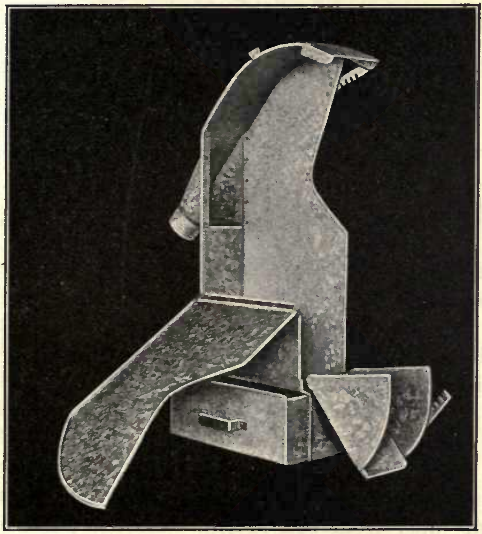


Fig. 39.—Wheel hood in opened position.

The collars that connect the branch pipes with the main pipe should intersect at an angle of 45°, or less, when measured from the center line of the main pipe. A greater angle than this creates unnecessary friction, which impairs the effectiveness of the system, and throws an unnecessary load on the fan.

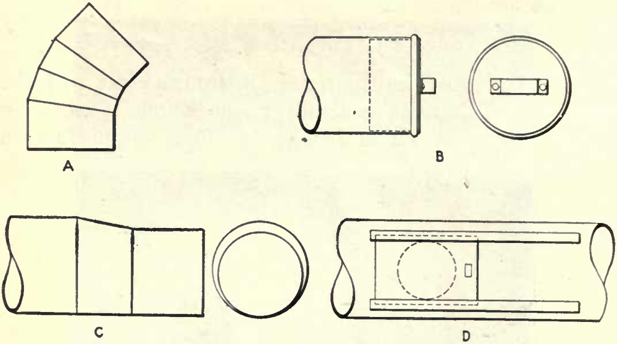


Fig. 40.—Piping details for dust-collecting system: "A," elbow joint; "B," cap cleanout; "C," main pipe joint; "D," main pipe cleanout.

The main pipes should be placed on the floor or between the ceiling and floor when possible. By referring to Fig. 41, which is a plan and end elevation of an exhaust system installed in a manufacturing plant, it is seen that the area of the main pipe increases for every two branch pipes added. This is essential in maintaining a uniform draft.

Without doubt, the ideal main pipe would be one having a constant taper from end to end. Such a pipe, however, would not be practical to construct, and, furthermore, would be unnecessarily expensive. The general rule, which by the way, is sometimes open to change, is to have the main pipe sections 25 per cent. larger than the sum of the openings that lead to it. Thus, in Fig. 41, the section marked A should be 25 per cent. larger than the combined areas of the two branch pipes opening into it. Section B should be 25 per cent. larger than the combined areas of its branch pipes, plus the area of section A, and so on. From this, it is seen that there is always a 25 per cent. increase to insure cutting down the air resistance to a minimum.

The joints of the main pipe should be formed as shown in Fig. 40 C the straight line always being at the lowest point. This is important, as it helps to keep the pipe free from obstructions.

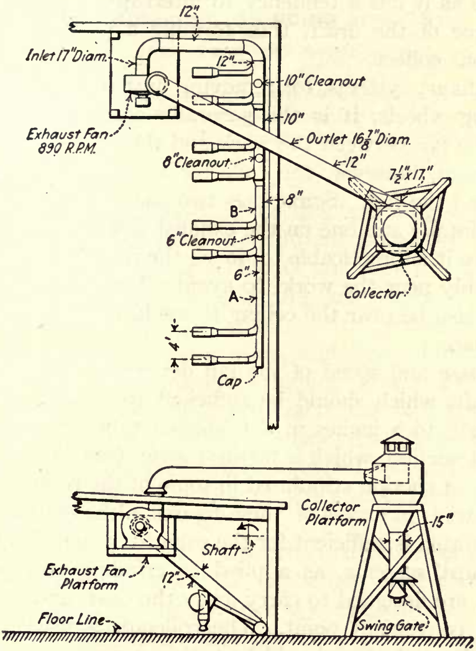


Fig. 41.—Plan and end elevation of a dust-collecting system.

A cleanout should be placed in every section of the main pipe, also at every elbow. This should be as air-tight as possible. Fig. 40 D illustrates the type of cleanout used for this purpose. It consists simply of a slide conform-ing to the curve of the pipe. The length of the slide should be twice its width to avoid cramping.

A cap cleanout, as shown in Fig. 40 B should always be located at the end of the main pipe. This type of cleanout is sometimes seen in main pipes. This, however, is poor practice as it has a tendency to interrupt the free passage and force of the draft, thus forming a pocket where obstructions collect.

In exhaust systems, for removing dust from grinding and polishing wheels, it is the generally accepted practice to place the fan between the work and the dust collector. In some cases, however, the collector is located between the work and the fan. Sometimes two collectors are used, one on the intake and one on the exhaust side.

Where it is practicable to do so, the fan should be placed reasonably near the work, to avoid a long intake pipe. It should also be near the ceiling to avoid taking up valuable floor space.

The size and speed of the fan determine the velocity of the draft, which should be sufficient to raise a column of water 1½ to 2 inches in a U-shaped tube at the point of weakest suction, which is farthest away from the fan. The amount of suction stipulated in some of the recently passed state laws is in excess of these figures, although the suction above stated is sufficient for the exhaust system in question.

Exhaust systems, as applied to grinding and polishing wheels, are designed to carry away the dust, and to deposit it at a convenient point. The collector is usually placed out of doors, but it should be within a reasonable distance of the fan to avoid a long exhaust pipe.

CHAPTER FOURTEEN

SAFEGUARDING GRINDING WHEELS

(Reprinted from *The Iron Age.*)

Why wheels break—Cause of accidents—How wheels are packed and tested before leaving factory—Wheel speeds—Mounting wheels properly—What causes wheels to burst—Safety flanges—Work rest—Wheel guards—Grinding on small wheels—Precautions for the workman.

WHEN we stop to consider that grinding wheels are used under all sorts of conditions, both good and bad, it is evident that serious accidents are bound to happen if precautions for proper safeguarding are not taken. From the writer's practical experience with grinding wheels, covering a period of many years, and from observation of the conditions under which grinding wheels are used in practically every branch of manufacturing, it is his opinion that fully 95 per cent. of the accidents due to the breakage of grinding wheels are wholly uncalled for and could be avoided by a little precaution on the part of both employer and employee.

The following is a list of the principal causes of grinding-wheel failures which will be explained, each cause being taken up separately for the sake of convenience.

Imperfect wheels.
Abnormal wheel speeds.
Faulty mounting of wheels.
Lack of attention to work rests.
Loose-wheel spindles.

The reliable manufacturer of grinding wheels, whose products are to be found in every city and town in the country, spares no expense to make sure that only perfect wheels are placed on the market. This has been explained under the head of grinding-wheel manufacture, and no further comment is necessary.

Extreme care is also exercised in packing wheels for shipment that accidents in transit may be avoided. The larger wheels are packed in individual boxes with sawdust. The smaller wheels, or rather comparatively thin wheels, receive the added protection of corrugated strawboard. Before a wheel is mounted for use, it should be lightly tapped with a small hammer. If it emits a bell-like sound, it is safe. If it gives out a dull sound, it should be condemned as unsafe. Accidents through defective wheels are, happily, very rare.

Reliable makers of grinding wheels always mark on the tags of regular wheels the proper operating speed, and the consumer, or in the case of a large concern, the millwright and the mechanical engineer, should pay a little attention to this important detail. The proper operating speed for a common wheel in vitrified or silicate bond is 5,000 feet per minute. This is a safe speed and it is productive of economical results. The thin, special wheels made by the vulcanite and shellac processes, can be run much faster with perfect safety, owing to the strong nature of the bond. As a matter of fact, a vulcanite wheel has to be run at a high peripheral speed to show efficiency.

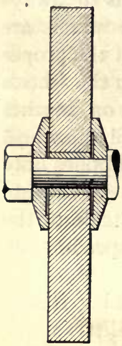
There are several reasons why grinding wheels are overspeeded. Indifference on the part of the millwright who installed the grinding stand is sometimes the cause. Not having just the proper-sized pulley for the line shaft, he is likely to substitute a different size, often larger than is called for, which of course overspeeds the wheel. Many grinding-wheel stands are equipped with a two- or three-step cone, the object being to speed up the wheel as it wears down. Neglecting to shift the belt to its lowest speed after installing a new wheel, results in overspeeding. While grinding-wheel stands of the above type are no doubt very convenient as regards speed adjustments, they are, at the same time, a source of constant danger, as an in-different or, in some cases, a green workman is liable to shift the belt to suit himself, ignoring limits of safety.

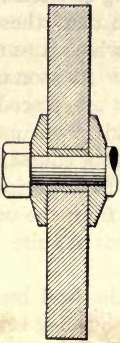
A safe and, at the same time, an economical way to use ordinary wheels, and one that is giving entire satisfaction in some of our largest manufacturing concerns, is to always buy wheels of a given size. When new, these wheels are mounted on a stand, the spindle of which runs at the proper speed for the diameter of the wheel. As soon as the wheels are worn down, say 2 inches, they are placed on another stand running at a higher speed and so on until the wheel is worn down to a stub. The above, of course, applies only to wheels having a constant grade from periphery to hub. Wheels having an increasing grade from the outside to the hole, as explained elsewhere, do not require speeding up as they wear away.

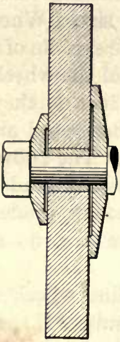
In mounting a grinding wheel, the lead bushing should slip readily over the spindle. If the bushing is a little small, as it sometimes is, the defect can be readily remedied by means of a bearing scraper or an old file. The operator who neglects this simple precaution and mounts a wheel by forcing it on the spindle, is taking a chance of meeting with a serious accident, as tight wheel bushings are the source of the majority of accidents.

The reason for this is quite apparent, as lead, the material with which grinding wheels are bushed, expands readily from heat. When the wheel spindle runs warm, as it invariably does after being in use a few hours, the spindle expands a little from the heat. The lead bushing readily absorbs a part of the heat which expands it several thousandths of an inch, owing to the fact that lead has a high co-efficient of expansion. The expansion of the lead throws an undue stress on the wheel, which, added to the stress to which the wheel is subjected from centrifugal force, is sufficient to cause it to burst.

Wheel flanges should be at least one-third of the diameter of the wheel, and should always be recessed as shown in Fig. 42. Plain flanges, as shown in Fig. 43, are dangerous, as they do not always grip the wheel properly, a slight crowning of either wheel or flange being sufficient to cause them to grip the wheel near the arbor only. Fig. 44 illustrates another source of trouble caused by wheel flanges







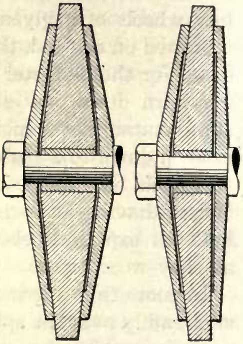


Fig. 42.—Proper design of wheel flanges.
Fig. 43.—Incorrect in design as recesses are absent.
Fig. 44.—Fruitful cause of accidents—two flanges of different sizes on one wheel.
Figs. 45 and 46.—Two types of safety flanges.

belonging to different grinding stands becoming mixed. The outer flange being smaller in diameter than the inner one, brings an undue side strain on the wheel.

Two types of safety flanges are shown in Figs. 45 and 46. While flanges of this type will prevent a split fragment of a wheel from flying, their use is not at all common. As a matter of fact, the average manufacturer considers them a nuisance. Generally speaking, safety flanges are not necessary with wheels made by a reliable maker, properly mounted and run at the speed recommended.

When the nature of the grinding will permit, it is a good plan to use wheels without a work rest. On comparatively heavy work, however, a rest is, of course, necessary as the workman has to utilize his strength in holding the work to the wheel. Rests are also necessary on tool-grinding wheels, and other wheels used for general purposes. It is with the last two classes of wheels that accidents occur by getting the work caught between the wheel and the rest. This generally results in a broken wheel and consequent injuries to any one who happens to be in the path of the flying fragments. The only way to avoid accidents is to keep the wheel true and the rest adjusted closely—within 1/32 inch of the face of the wheel. In justice to the manufacturer, it should be stated that accidents of this kind are in nearly every case caused by carelessness on the part

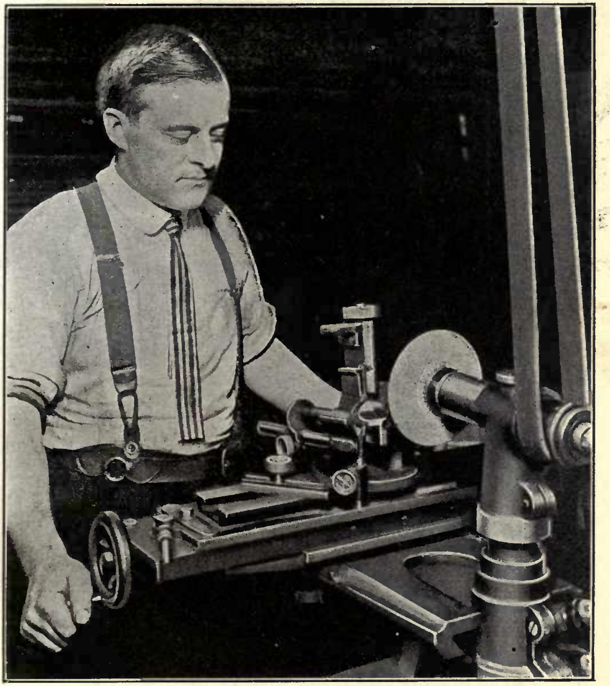


Fig. 47.—Sharpening a counterbore on an unguarded wheel.

of the operator. His common sense and mechanical instinct should tell him that he is taking desperate chances in allowing a wide gap between the wheel and the work rest.

Loose wheel spindles often cause wheels to break as they allow the wheel to run out of balance and also make it impossible to keep the rest adjusted close to the wheel. Babbitt metal, even of the highest quality, is cheap as compared to the consequences of injuries, and this is one reason why the spindles of grinding-wheel stands should be re-babbitted as soon as they show noticeable signs of wear.

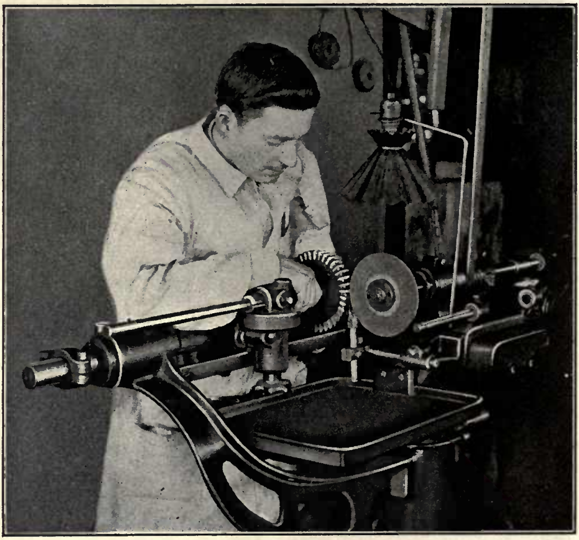


Fig. 48.—Sharpening the peripheral teeth of a milling cutter on an unguarded wheel.

Many states have passed laws requiring manufacturers to equip the grinding wheels used in their plants with guards, the object being to keep the pieces of the wheel from flying in case of accident; not to keep sparks out of the operator's eyes as one might judge from the flimsy guards sometimes seen over grinding wheels! While wheel guards are not necessary where reliable wheels, properly mounted, are in operation, their use is to be strongly recommended as they are the direct cause of preventing many fatalities from accidents caused by carelessness on the part of the operator.

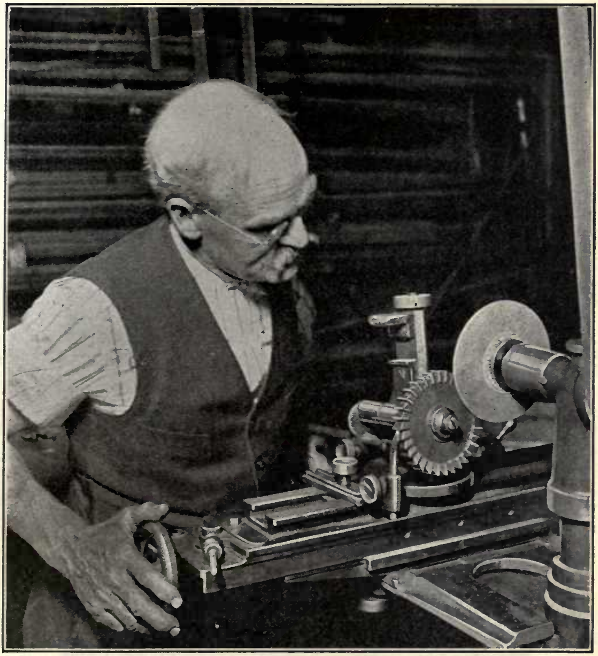


Fig. 49.—Sharpening the side teeth of a milling cutter on an unguarded wheel.

It is, however, not practicable to use guards over the smaller wheels used for cutter sharpening, and other work of like nature. Figs. 47, 48 and 49 illustrate cutter-sharpening operations, and to place guards over these wheels would be an impossibility, as the size of the wheels and their relative position to the work are different with every operation. Accidents with wheels of this kind are so rare as to cause no comment. There are two reasons for this: First these small wheels are comparatively strong for their size, seldom breaking unless injured by being dropped; and again there is no reason for standing directly in their path.

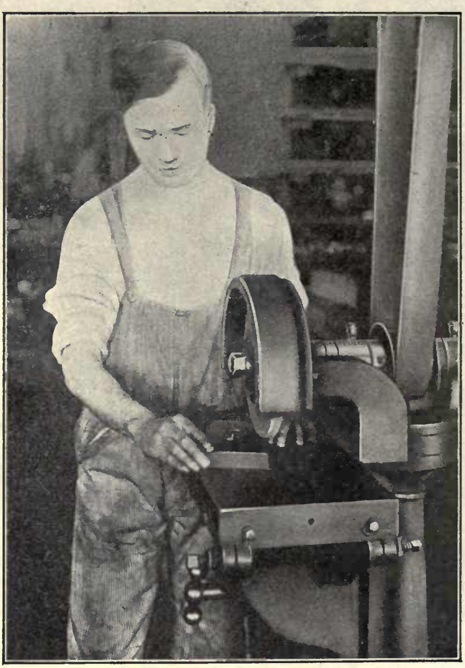


Fig. 50.—Correctly guarded surface grinding wheel.

The photographs referred to were taken by the writer for advertising purposes. In each case the operator was asked to assume a working position, nothing being said about standing out of the path of the wheel. However, the operator is out of the path of the wheel in each case, and as he assumed this position naturally, one would infer that a skilled mechanic prefers to keep out of the path of cutter grinding wheels. As a matter of fact he does—not because he is afraid of the wheel breaking but because he has learned from experience that to stand directly in the path of an unguarded wheel nearly always results in particles of the abrasive getting in the eyes; which in some cases requires the services of a skilled surgeon to remove.

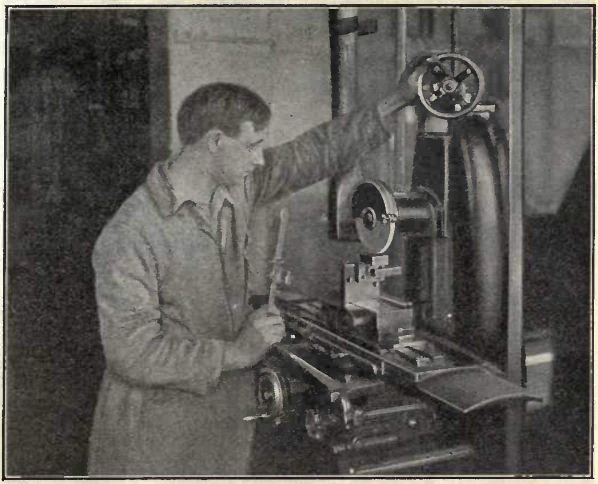


Fig. 51.—Guarded wheel on a Brown & Sharpe surface grinder.

Figs. 50 and 51 illustrate two types of surface grinding wheels, each of which is protected by a suitable guard. Guards over wheels used for surface grinding are generally considered necessary, the reason for this being that surface grinding wheels frequently break as they are of a soft, open bond. With guards of the types shown in the illustrations,

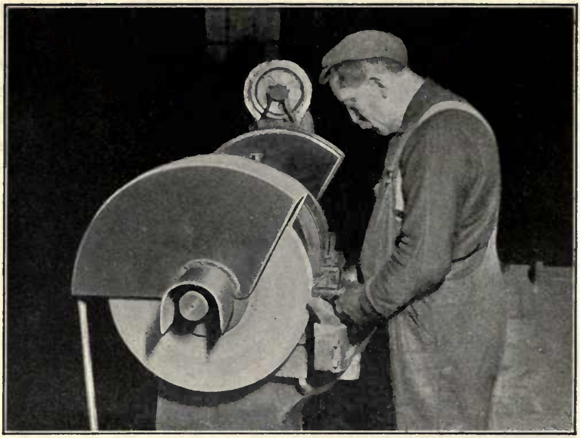


Fig. 52.—Sheet-metal wheel and spindle guard.

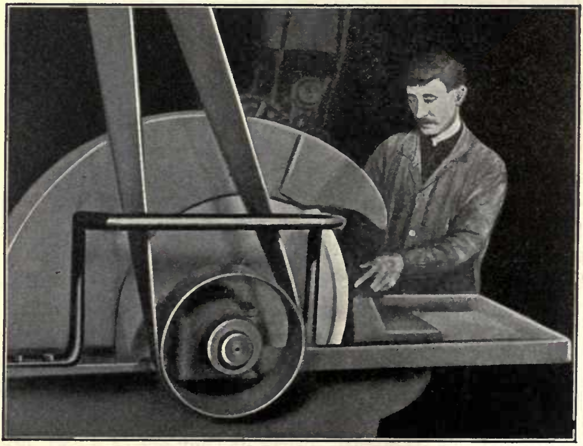


Fig. 53.—Wheel and belt both guarded.

serious accidents are an impossibility. With the modern cylindrical grinding machine, accidents from wheel breakage are almost impossible as the wheel is always protected by a heavy guard. While the operator generally stands directly in front of the wheel he runs no chance of being injured, as it would be practically impossible for a piece of the wheel to strike him. Machines of this kind are never used without wheel guards. In fact, a guard on a cylindrical grinding machine is a necessity in keeping water from flying all over the shop, as this class of grinding is invariably done wet.

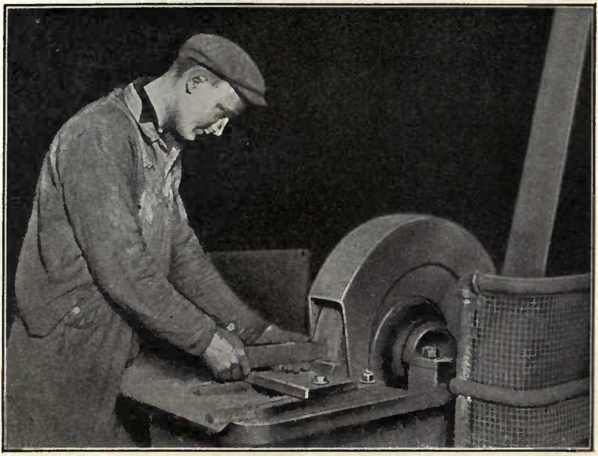


Fig. 54.—Sheet-metal wheel guard arranged for adjustment.

Figs. 52 and 53 are from photographs taken in the shops of two well-known railroad companies. By referring to Fig. 52, it is seen that the guard, which is made of sheet metal of sufficient thickness to withstand the shock of the wheel fragments in case of accident, is also provided with a hood to cover the projecting threaded end of the spindle. The object of this hood is to prevent the workman's clothing from being caught. While the workman in this illustration is grinding a comparatively small piece of work, he is taking no chances as the work rest is placed close to the wheel.

The tool grinder shown in Fig. 53 is of a type often seen in railroad shops. It is provided with a heavy hood; the work rest is properly adjusted, and a guard is provided to prevent the workman's clothing from being caught in the driving pulley. The reason that railroad-shop employees are so adequately guarded against accidents lies in the fact that the shop foreman and master mechanics in charge are fair-minded, conscientious men who have gradually worked up from unimportant positions to positions of trust and who, therefore, consider the workman's welfare from their own actual shop experience.

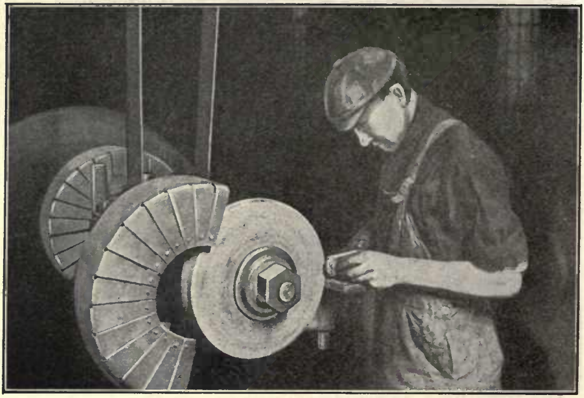


Fig. 55.—Novel form of sheet-metal wheel guard.

Fig. 54 illustrates another tool-grinding wheel that is properly guarded. The hood, which is made of 1/4-inch sheet metal, is securely bolted to the frame of the machine and is provided with an adjustment which allows it to be moved towards the wheel as the wheel is reduced in diameter. This is of importance as a guard should be placed reasonably close to prevent the wheel fragments from flying in case of breakage. The work rest in this instance is placed close to the wheel. Although the machinist in this illustration is standing in front of the wheel, he is taking no chance as it would be impossible for a section of a wheel guarded in this manner to get away from the hood. The guard over the driving pulley deserves mention. It is made of 1–1/2-inch iron pipe and covered with heavy wire netting.

Fig. 56.—These guards are inadequate and invite disaster.

Two sheet-metal guards are shown in Fig. 55. They are easily removed when it is necessary to change wheels, as the guard in the foreground shows. The working position of the guards is shown by the guard in the background. These guards are adjustable and can be moved toward the face of the wheels. They are novel in construction, the body being cut from one piece of heavy sheet metal.

Figs. 56 and 57 illustrate a wholly inadequate type of grinding-wheel guards that are, unfortunately, in common use. While guards of this kind are often passed by factory inspectors who are lacking in practical knowledge, they are worse than no guards at all, as a section of a burst wheel would crumple them up like so much cardboard.

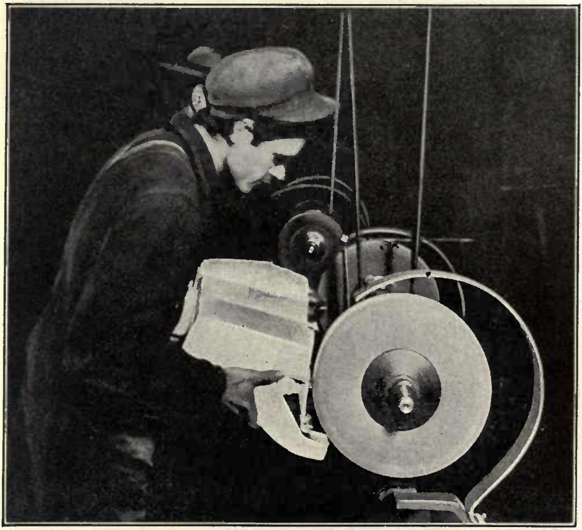


Fig. 57.—This guard is too flimsy to stop flying-wheel fragments in case of an accident.

In cases where grinding wheels burst, resulting in fatalities, it is sometimes a difficult matter to determine who is at fault, the employer or the employee. Is it justice to compel a manufacturer to pay heavy damages for fatalities brought about (as they often are) by wanton carelessness on the part of the operator? If the employer neglects to have adequate guards placed over grinding wheels, where there is a law requiring him to do so, it would seem that he was criminally negligent in cases where fatalities result from the bursting of grinding wheels. However, let it be assumed that the wheel is properly guarded and that the operator himself removes the guard for some reason and by so doing is injured. Should the employer be compelled to pay damages in this case? Assuming that one operator removes a wheel guard and neglects to replace it, another operator being injured on the same wheel a short time afterward, who is to blame in this case, the operator who removed the guard, the operator who afterward used the wheel without the guard or the employer who was ignorant of the whole proceeding? These are, of course, questions for the courts to decide, and decisions in cases of this kind are not easily reached by any means.

In questions where the safety of employees is concerned, labor and capital should co-operate. The working-man should bear in mind the fact that it is an impossibility for him to earn a living without assuming some risk, and where the employer provides all possible safeguards against accidents, the employee should see to it that these safeguards are not removed or destroyed.

CHAPTER FIFTEEN

ABRASIVE PAPERS AND CLOTHS*

Abrasive substances used in making abrasive paper—History of abrasive paper—How abrasive paper and cloth is manufactured—Grades of abrasive paper and cloth—Finding percentage of iron in garnet—Testing garnet paper—Paper and cloth abrasive discs—Testing discs for efficiency.

ABRASIVE papers and cloths, the abrasive coating of which is emery, Carborundum, garnet, flint, Aloxite, etc., are to be found in practically every branch of manufacturing from the small country planing mill or machine shop to the immense furniture factory or automobile plant. Large quantities are also consumed by tanneries and other leather workers. Comparatively little seems to be known concerning the manufacture of these staple articles, save from the meager accounts given now and then by salesmen.

All abrasive papers and cloths are made in the same manner, with the exception of abrasive discs, which will be considered later. We can explain the process followed by taking up the subject of garnet paper.

While the use of abrasive materials dates from remote times, the use of coated paper and cloth is a comparatively modern innovation. Some two hundred years ago it was common practice for New England cabinet makers who lived near the seacoast to use the dried skins of dogfish and sharks for smoothing wood. Any one who has had occasion to deal with the above-named fish in the live state will admit that their skins are excellent abrasives in a literal

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* The above chapter is a consolidation of two articles: "Abrasive Paper and Cloth," originally published in *The Iron Tradesman*, and "The Selection of Garnet Paper," which first appeared in *The Wood Worker*, to which the writer has added some further material concerning the testing of abrasive discs.

sense, as a single indiscreet rubbing contact, on the naked arm, for instance, invariably draws blood in a dozen places. However, as our forefathers could not always take the time to go shark fishing when the stock of this "natural abrasive" ran low, necessity prompted them to invent a substitute which resulted in the abrasive paper and cloth of the present day.

As near as we can ascertain, emery cloth and sand-paper were invented about two hundred and fifty years ago, the process of manufacture being very primitive, consisting of coating the backing with glue, liberally covering it with the desired abrasive, shaking off the superfluous material and hanging the sheets up to dry.

Wonderful improvements have been made in the manufacture of abrasive papers and cloths, the slow hand methods of a few generations ago being superseded by the modern coating machine, which turns out material by the mile. The process is practically the same for both paper and cloth backing and can be described as follows: The web of paper, traveling at high speed, passes under a printing attachment which imprints the brand, number, etc., at regular intervals. Next it passes through a series of rollers wherein the top side is given a coat of glue, which is distributed in much the same manner that ink is applied to the type in a large printing press. The glue-coated paper now passes under a large hopper from an opening in the base of which the grain flows in a steady stream, just a little wider than the width of the paper being run. The amount of running grain is regulated to allow slightly more to flow than will stick to the paper, the superfluous material being carried away by mechanical means, the exact nature of which most manufacturers wish to keep to themselves. By means of two endless chain belts, carrying cross sticks at regular intervals, the paper is caught up in long loops and carried to another coating machine where the sizing, or upper coating of glue, is applied. This covers the upper surface of the grain, and as it unites with the lower coat to a certain extent each grain is firmly embedded in a matrix. The paper is now caught up on more sticks, where it travels up and down the long drying room, the process of drying being hastened by carefully regulated blasts of warm air. The paper finally reaches the winding machine, where it is wound in rolls of about four feet in diameter. From there, it goes to the storage room, where it is thoroughly aged before being sent to the cutting room. It is of the utmost importance to age the paper before putting it on the market, as green paper, as it is termed by the manufacturer, is very short lived, owing to the fact that the glue is not set sufficiently to hold the grain firmly in place.

From the store room, the rolls go to the cutting room, where they are prepared in marketable sizes, consisting of 9 x 11 sheets, in quires and reams, and 50-yard rolls of various widths. Emery cloth is sold in 9 x 11 sheets and in rolls 9, 18 and 27 inches wide. The grits run from crocus to 3–1/2. Emery paper is sometimes sold in rolls, but there is more demand for this material in sheet form. Carborundum paper can be bought in both rolls and reams in all grits from 20 to F F. As this material is used extensively in the boot and shoe industry for heel scouring, heel breasting and fore-part buffing, it is also cut in odd sizes and shapes to fit various machines used for the above purposes. Carborundum cloth can be had in all grits from 4–1/2 to F F in 9, 18 and 24 inch rolls or 9 x 11 sheets.

There are four kinds of garnet paper, known to the trade as follows: Finishing paper, used for rubbing varnish, which is made in all grits from 1 to 6/0; double-faced finishing paper, in the same grits, which is coated on both sides and stripped apart as needed, the grits being the same as for ordinary finishing paper; cabinet paper (ordinary sheet garnet paper) in numbers from 3–1/2 to 6/0, and roll paper in numbers 3–1/2 to 4/0. Roll paper is furnished in standard widths of 18, 24, 30, 36, 40, 42 and 48 inches. Garnet cloth is always run in rolls of 28 inches wide, but can be had in any desired width. The bulk of garnet paper is used in the wood-working industries, but it also furnishes an excellent material for finishing comparatively soft metals such as aluminum, copper, very soft brass, etc. Ordinary sand-paper is made in the same sizes and numbers as garnet paper and is used principally for smoothing comparatively soft woods. In ream form, it is sold in every hardware and general store throughout the civilized world to customers who desire a few sheets at a time.

Abrasive paper and cloth are also made in disc form for finishing metals on the disc type of grinder. As the backing of this material is very heavy, and the coating extra thick, it is not practicable to run it off in mile lengths, thus it is coated in long strips of approximately 200 feet. After drying, the discs are cut from the strips by means of heavy dies in a hydraulic press. Some makers have processes for coating discs after they are cut to shape, the Besley discs with the spiral groove being a good example of this practice. The majority of these special methods are covered by patent.

Contrary to the general impression, there is very little profit in the manufacture of abrasive paper and cloth. This statement is not made at random, simply for the sake of filling up space, but from actual observation of the manufacture of the products in question. Therefore the writer's advice to the consumer who aims to use efficient material is to purchase standard priced goods. Owing to the fact that the margin of profit is small, the maker cannot cut prices to any extent and supply high-quality material at the same time.

The superintendent and the purchasing agent of any concern where garnet paper is used to any extent, are frequently interviewed by garnet-paper salesmen. As the salesman's duty is to sell goods, each and every one, of course, has just the material that will surely reduce production costs. Thus the question arises: "Whose paper is the most efficient?" It is impossible to answer this question offhand, but there are a few simple tests that any manufacturer can make in his spare time, and the data thus obtained is reliable.

Any one who is conversant with the working of a three-drum sander realizes that a machine of this type calls for a paper with a very strong backing; otherwise the paper is liable to tear before the grain is worn to a point of uselessness. To test the strength of the backing we can proceed as follows: First a frame as shown at (A) Fig. 58 is suspended from a convenient overhead timber. The cross

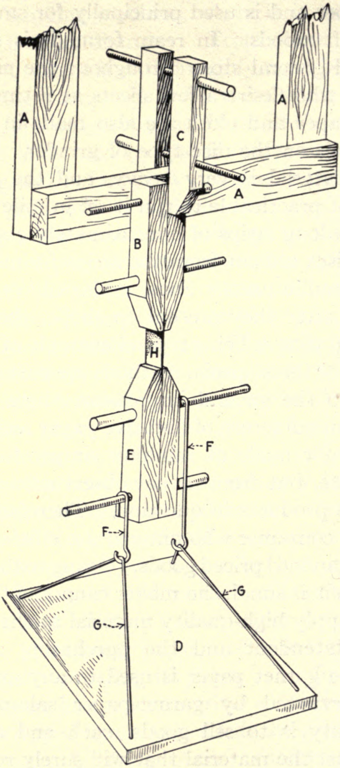

Fig. 58.—Simple device for testing the strength of abrasive papers.

piece should be about five feet from the floor. A common wood clamp (B) is fastened to the cross piece by means of another clamp (C). The tray (D) is suspended from the clamp (E) by means of short ropes (G) and two wire hooks (F). (H) is the sample of paper to be tested. This is cut lengthwise from a roll of paper and should be about 9 inches long and exactly 1 inch wide. The ends of the paper should extend about 2 inches in the jaws of the clamps, which must be fastened securely.

The next step is to place weights, one at a time, on the tray until the paper breaks; pieces of babbitt metal are excellent for this purpose. By weighing the amount of metal necessary to break the paper, we readily ascertain the breaking strain per linear inch. It is evident that the paper which supports the greater weight is the strongest. The results of these tests should be entered in a note-book, giving the make of paper, run number, grit number, and date of the test. It is a well-known fact that all garnet-paper salesmen lay great stress on the strength of their papers, but the practical man who takes the time to make the simple test here described, between several makes of papers, can readily determine for a certainty which is the strongest. Furthermore, the simple appliance used (which costs practically nothing) is as efficient for all practical purposes as the expensive paper-testing machines used by the paper manufacturers.

Oxide of iron, an impurity which is often present in garnet, is a detriment to fast cutting, and it generally indicates that the grain was not properly cleaned. To determine the amount of this impurity, a square foot of unused paper should be boiled for an hour or so in a clean receptacle; this will detach the grain from the backing. The grain thus obtained is carefully washed and dried, then spread out on a piece of paper and carefully gone over with an ordinary horseshoe magnet, which readily attracts the grains containing any amount of oxide of iron. These are placed in a little pile, and when the operation is complete, we have two samples of grain—one containing iron and another free from this impurity.

To obtain the percentage of iron, we must measure each pile by volume. This can be done with any small receptacle; an empty 38-caliber cartridge shell will answer the purpose very well. Suppose we find ninety shellfuls of grain that was unattracted by the magnet and ten that the magnet picked up. In this case, it is evident that the grain contains 10 per cent. of iron. If subsequent tests of grain taken from another make of paper yield 15 per cent. of iron, it is apparent that the first sample was of better quality. The results of these tests should also be entered in the notebook for future reference.

To test the working efficiency of any make of paper is also a comparatively simple operation. Here we can use what the salesman terms a "fifty fifty" test. Let it be assumed that we are using belts 18 feet long. We can make up a belt composed of 9 feet of one make of paper and 9 feet of another make. It is obvious that the paper that gives out first is of the poorer quality. A test of this kind causes the salesman who supplied the paper of poorer quality to scratch his head in perplexity. On these occasions it is up to the salesman to frame a good excuse or retire from the field as gracefully as possible. We can use the same kind of a test on the drum sander, provided it is of the type that takes straight paper—that is, not wound on the drums spirally. By covering half of each drum with one make of paper and the other half with another make, we can soon arrive at a definite conclusion.

The tests here described, which are not known to every user of garnet paper, were brought to the writer's notice while traveling as a salesman for one of the leading garnet-paper manufacturers and the data obtained from them can be relied upon. Any garnet-paper salesman can cite numerous instances where his goods have won out over those of his competitors, but he always keeps quiet concerning the instances wherein he has failed. This is one reason why it is a good plan for the consumer to work out his own tests in his own plant, ever bearing in mind the fact that crucial tests should result in cold, hard figures that have been obtained through actual common-sense tests.

The practice of disc grinding has become quite common during the last fifteen years and has led disc manufacturers to supply their products in many different abrasives and combinations of abrasives for various purposes. Flint, quartz, garnet, emery, corundum, Carborundum, Crystolon, Aloxite, Alundum and Adamite are the principal abrasives employed for disc grinding.

Notwithstanding this formidable array, the selection of suitable discs is a simple operation compared with the selection of grinding wheels. Grinding wheels are made in many different degrees of hardness to suit various classes of work. With grinding discs, however, the factor of grade as applied to grinding wheels is wholly eliminated. All that is necessary, is to select an abrasive that proves satisfactory, the character of the finish desired determining the grain of the disc.

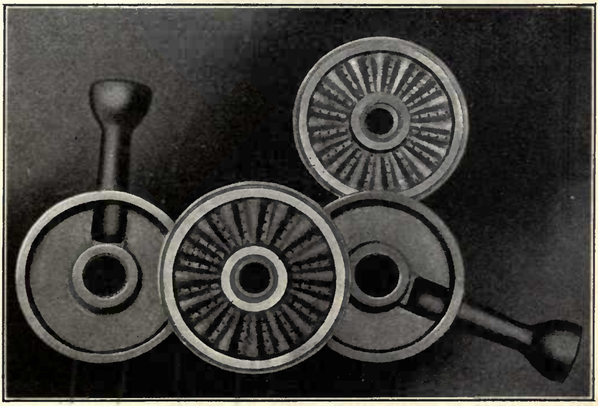

Fig. 59.—Gas-burner parts finished by disc grinding.

To illustrate the principle used in testing discs for efficiency, we can consider the pieces shown in Fig. 59, which are gas-burner parts, made of cast iron, measuring 5 inches in diameter. The finished surfaces measure 3/8 inch across and the grinding is done from the rough, the object being to make a good joint in the shortest possible time. The grinding operation is shown in Fig. 60.

Here it is seen that the pieces to be ground are held by a retaining device and also that they are weighted. The object of the weights is to insure a good contact. The final finishing is sometimes done by hand as shown.

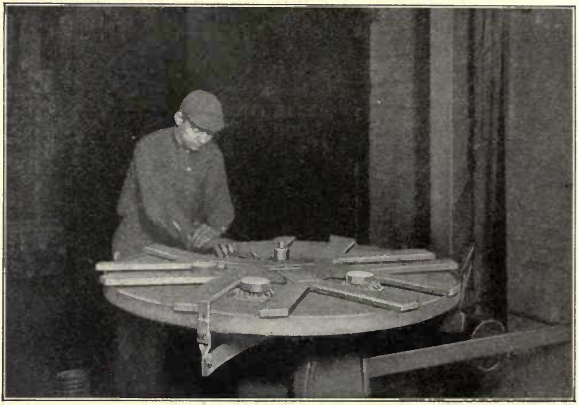

Fig. 60.—Grinding gas-burner parts on a horizontal disc-grinder.

To determine the grinding cost with a given make of disc, it is only necessary to note the cost of the disc, its life and the number of pieces ground. From this data the grinding cost per hundred pieces is easily computed.

To obtain the best results, the abrasive must, of course, be suited to the work, and while it is a well-known fact that flint and quartz are suitable for soft wood, garnet for hard wood, emery for rough-steel grinding where a durable disc is required, corundum, Aloxite and Alundum for steel, and

Carborundum and Crystolon for cast iron, the actual selection is often controlled by the makers as the majority of them designate their discs by numbers, preferring to keep the actual character of the abrasives to themselves. The object of this practice is to enable the disc manufacturer to be reasonably sure of securing repeat orders, relying on the consuming trade to order by number. This method is not without advantage to the consumer, as it enables him to order the material desired without having to resort to a list of abrasives, which, at best, are confusing to those not engaged directly in the abrasive lines.

Modern disc grinding is a comparatively new branch of engineering practice, and when we stop to consider that it originated from a sheet of sand-paper glued to a wooden disc for the convenience of the wood-worker, the present-day possibilities of this class of grinding reflect no small degree of credit on the experimenters who made this practice a commercial possibility.

CHAPTER SIXTEEN

SURFACE GRINDING

Finishing work by surface grinding—Development of the surface grinding machine—Finishing locomotive guide bars—Rotary grinding fixture—Wheel speeds—Cuts—Die grinding—How dies are held—Grinding punches—Care of wheels—Magnetic chucks—Demagnetizers—Proper wheel selection for surface grinding—Types of surface-grinding machines—Standard wheel list.

MANY years ago, after the grinding wheel became a commercial possibility, one of the first uses to which it was put, aside from tool grinding, was a simple kind of surface grinding called in shop language "spot grinding."

This operation, while comparatively simple, is productive of accurate results and is used at the present time in finishing certain kinds of gauges and other work where extreme accuracy as regards parallelism is desired. The operation is illustrated in Fig. 61. The operator is grinding a die by passing the work back and forth under the wheel. If the plane upon which the work slides is a flat surface, it follows that true planes will be ground on the work.

Fig. 62 illustrates a set of accurate size blocks as used by tool-makers and machinists who work to close limits. After hardening, gauges of this kind are often finished parallel by spot grinding, leaving a very small amount for final lapping on each surface. The amount left for the final finishing is generally 0.0002 inch on each surface.

At the top of the illustration is shown the fixture used for holding the blocks while grinding. This consists of a flat base equipped with two pinch clamps for firmly holding the work and forcing it downward at the same time. The slot

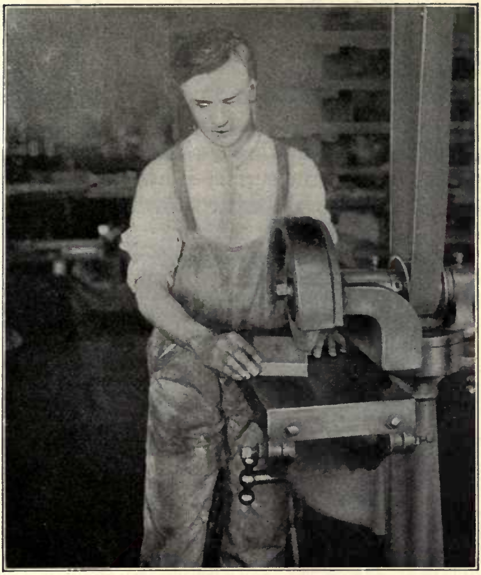

Fig. 61.—Spot-grinding a blanking die.

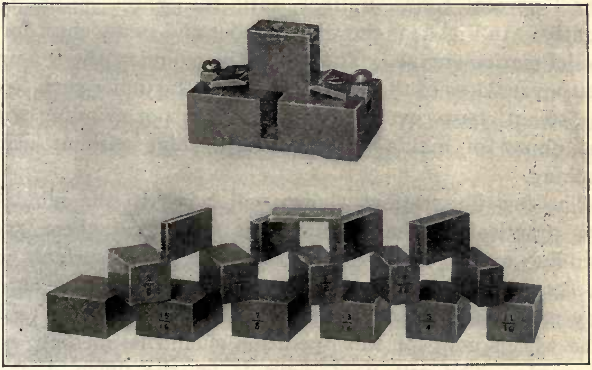

Fig. 62.—Accurate size blocks finished by spot grinding and fixture for holding them in the grinding operation.

seen at the front is for the accommodation of the micrometer so that the operator can measure the work without taking it out of the fixture.

Fig. 63 illustrates a tool-maker's square, the base of which was finished by spot grinding. The wheel marks are plainly seen on the work. The wheel marks left by this process are very slight and a true surface is assured if the operator takes time enough to pass all parts of the surface under the wheel several times, in fact until the wheel sparks but faintly. In Fig. 64 is shown a cylinder and steam chest for a model marine engine. The top of the cylinder, the top and bottom surfaces of the steam chest and the under surface of the steam chest cover were finished by spot grinding with the object of making a steam-tight joint without using packing.

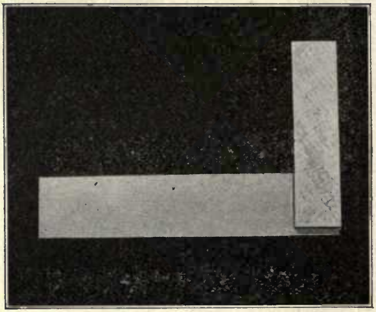

Fig. 63.—Spot-ground tool-maker's square.

The few illustrations shown will bring to the mind of the practical mechanic numerous instances where spot grinding can be used on work where accurate surfaces are necessary. The process is simple and can be carried out on any machine equipped with a grinding wheel and a table. The wheels used for this operation should be medium soft in grade. The grit used depends on the finish desired. For die grinding, as shown in Fig. 61, a grit as coarse as 36 can be used, while for size-block grinding, wheels as fine as 80 grit give good results.

Another early adaptation of surface grinding consisted of finishing locomotive guide bars after they were hardened. Formerly, guide bars were invariably made of wrought iron and case hardened to insure them against wear. As may be imagined, these pieces were often sprung in hardening, thus means were sought for correcting this error.

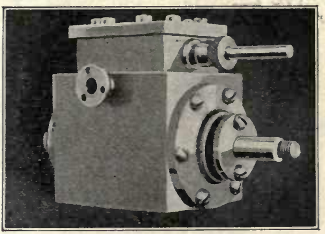

Fig. 64.—Cylinder and steam chest for model engine on which the flat surfaces were finished by spot grinding.

An early-developed machine for guide-bar finishing is shown in Fig. 65. This is not a grinding machine in the strictest sense of the word because it carries a circular lead lap instead of a grinding wheel. The work is securely held by the clamps shown on the platen and automatically fed back and forth past the circular lap which is charged with emery or other abrasive material. The roll seen at the extreme right of the platen is for the purpose of charging the lap.

The slide that carries the lap spindle is actuated by means of the handwheel which is plainly shown, while the wedge seen under the lap-slide ways is for the purpose of setting the lap square with the work. Lapping guide bars is a slow operation at best, but it is productive of excellent results.

Of late years, machines of this type have been equipped with grinding wheels in place of the lead lap. The writer observed such a machine modified in this manner at the Baldwin Locomotive Works, Philadelphia. The wheels used were Aloxite in shellac bond.

The machine just described is the forerunner of the present-day face-grinding machine, or side surfacer as it is often called. The side surfacer was first extensively used for grinding locomotive guide bars, but of late years it has been adapted to a large variety of surface-grinding operations. A modern face-grinding machine is illustrated in Fig. 66. This machine is a product of the Diamond Machine Co., Providence, R. I. It carries a ring wheel 30 inches in diameter, 6 inches wide with a 26-inch hole. This gives a working surface of 2 inches. The wheel is mounted in a substantial chuck, the body of which is cast iron; turned all over to insure a perfect running balance. The body of the chuck is tapered on the outside and is slotted so that it may be readily compressed by means of a steel ring which is drawn up on the taper by means of bolts. The chuck is equipped with a backing plate, back of the wheel. The object of the backing plate is to bring the wheel face forward as it wears away. By this arrangement, the wheel can be used down to a thickness of 1-1/4 inches with perfect safety. Chucks of this kind also insure the wheel against flying in case it is accidentally fractured. The machine is equipped with a circulating pump which floods the work

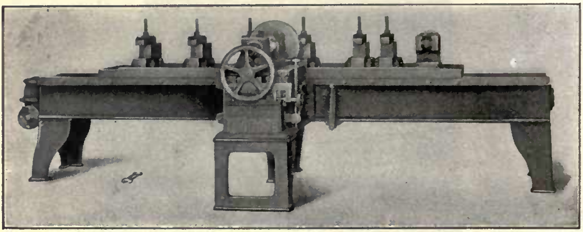

Fig. 65.—Locomotive guide-bar lapping machine.

with water, the object being to carry away dust and to keep down frictional heat.

The operation of grinding guide bars is comparatively simple. The work is strapped to the platen of the machine as shown in Fig. 67 and automatically fed back and forth under the wheel until the desired finish is acquired.

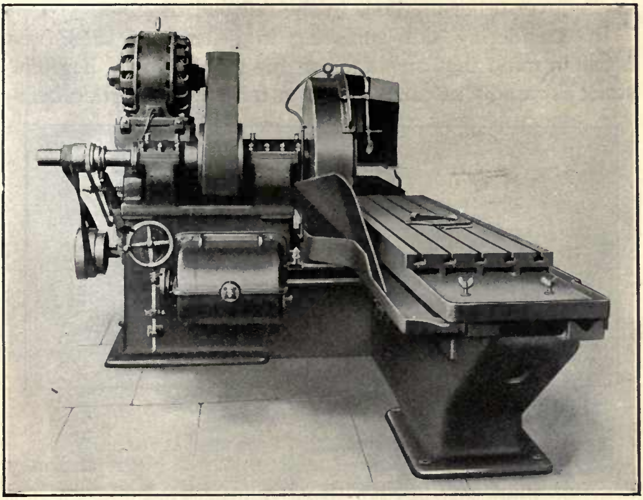

Fig. 66.—Modern face grinding machine or side surfacer.

New guide bars, as they come from the planer, are generally finished by grinding as the grinding wheel imparts a smooth surface for the cross-head gibs to slide upon. If the work is planed with a coarse feed, which leaves deep tool marks, so much the better, because this condition helps to keep the wheel true and free cutting.

By the time a locomotive comes to the shop for a general overhauling, the guide bars often require refinishing, owing to the fact that the pressure brought to bear on them through the cross heads, by the action of the main rods, wears them out of a true plane. This wear, in some cases, is as great as

1/32 inch. They are carefully lined up on the platen of the guide-bar grinder and ground until the wearing surface presents a true plane. Guide-bar grinding is one of the first instances where the grinding wheel showed a distinct saving over other methods in the railroad shop.

In considering side surfacing in general, it should be borne in mind that machines of this type cannot "hog off" stock as rapidly as can a planer or miller. On certain operations, however, the side surfacer shows high efficiency over machines equipped with cutting tools.

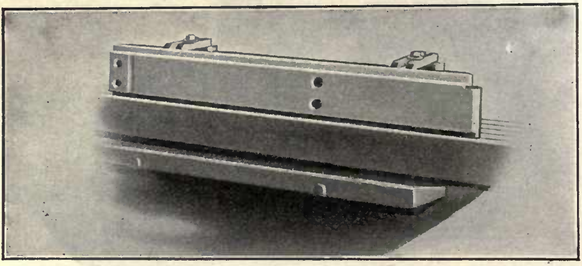

Fig. 67.—Locomotive guide bar in position for grinding.

In Fig. 68 is shown a variety of work that is admirably adapted for finishing on the side surfacer. The pieces shown are flasks, flask sides, heads, cases, covers, hoods, lathe legs, columns, guards, etc. From the design of these pieces, it is readily seen that they do not lend themselves readily to milling or planing operations. It is on work of this kind that the side surfacer shows efficiency. In finishing work of this kind on the miller or planer, it is necessary to strap the pieces securely in place. Pieces of comparatively thin section are often sprung out of shape by this procedure, caused by the strains, set up in clamping, adjusting themselves after the clamps are released.

On the side surfacer, conditions are more favorable because work does not have to be held as securely for grinding operations as it does when it is to be finished with cutting tools. Where work is to be finished regularly on the side surfacer, a smaller allowance for finishing is recommended which causes quite an annual saving in metal at the foundry.

A rotary grinding fixture designed for use on a side surfacer is illustrated in Fig. 69. This is a self-contained unit driven by a 3/4-horsepower motor running at a speed of 1,800 revolutions a minute. Power is transmitted to the chuck spindle through a chain drive and a worm and worm wheel. A clutch is provided to throw the power in or out and a crank in the foreground is for rotating the spindle by hand, as occasion requires.

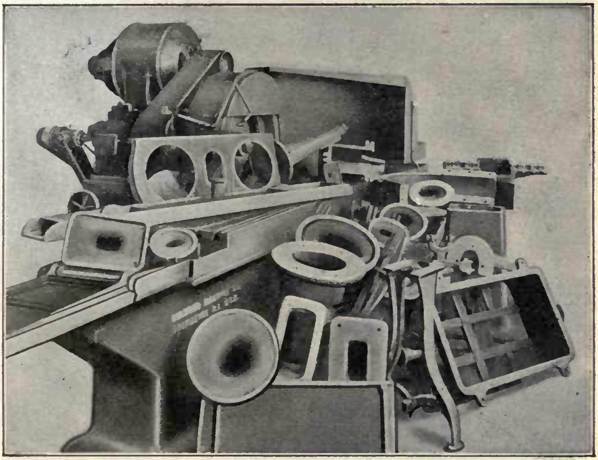

Fig. 68.—Type of pieces readily ground on the side surfacer.

This fixture was designed for finishing work that heretofore was done in the lathe and it is readily seen that if the fixture is properly aligned on the platen of the machine, surfaces that are square with the spindle of the attachment will result. Finishing the faces of round work by this method offers the advantage of combining the roughing and finishing operations, to say nothing of imparting an excellent finish.

Side surfacers are now used by many of the leading automobile manufacturing concerns for finishing a diversity

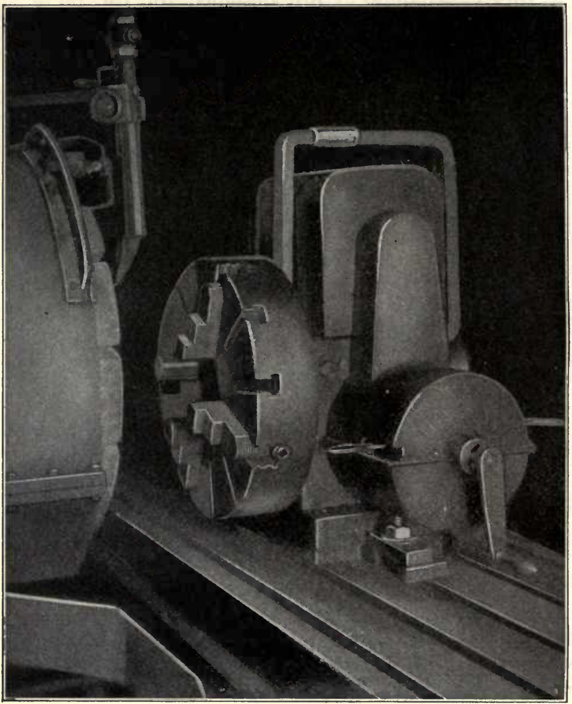

Fig. 69.—Rotary grinding fixture for use on the side surfacer.

of pieces. In Fig. 70 is shown the operation of facing gear-case covers. These are made of aluminum and 3/32 inch is allowed for finishing. As the illustration shows, four covers are set on the machine at one setting, being held in special fixtures.

An interesting grinding operation is illustrated in Fig. 71. This work consists of finishing aluminum crank cases for airplane engines. The work is clamped in special fixtures and 1/8 inch is allowed for finishing. The surfaces thus finished require no scraping and in assembling they are put together with a thin paper gasket and shellac.

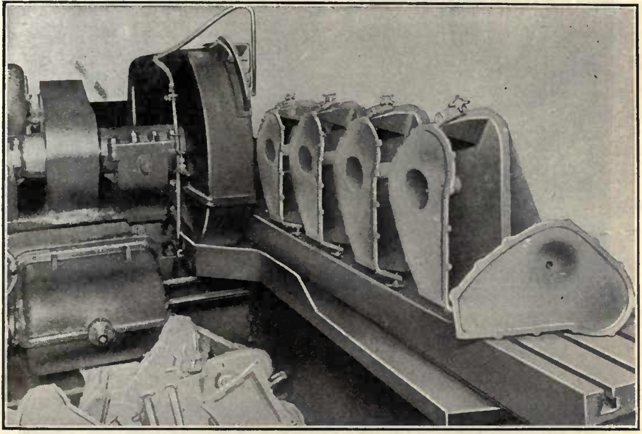

Fig. 70.—Finishing gear-case covers on the side surfacer.

A piece difficult to machine by ordinary methods is illustrated in Fig. 72. This is a gear-case cover used on tractors. It is held in the fixture shown and rapidly finished in a satisfactory manner.

To successfully finish work on the side surfacer is not a difficult operation if the operator pays due attention to a few simple factors. The wheel should be run at the speed recommended by the grinding-machine manufacturer. In the case of the 30-inch wheel on the machine shown in Fig. 66, the correct speed is 500 revolutions per minute. Plenty of water should be used as this keeps down the frictional heat and aids materially in imparting a good finish. Also, the wheel should be kept "sharp" by frequent

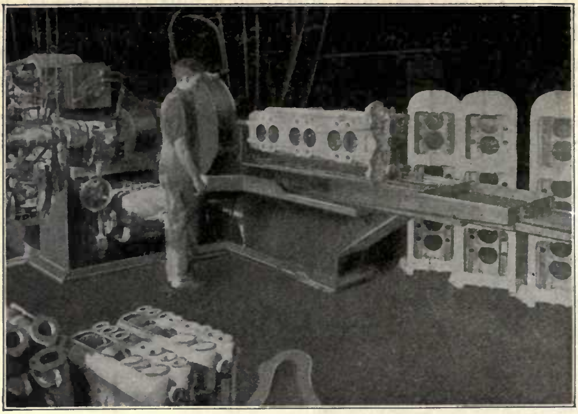

Fig. 71.—Surfacing airplane engine-crank cases on the side surfacer.

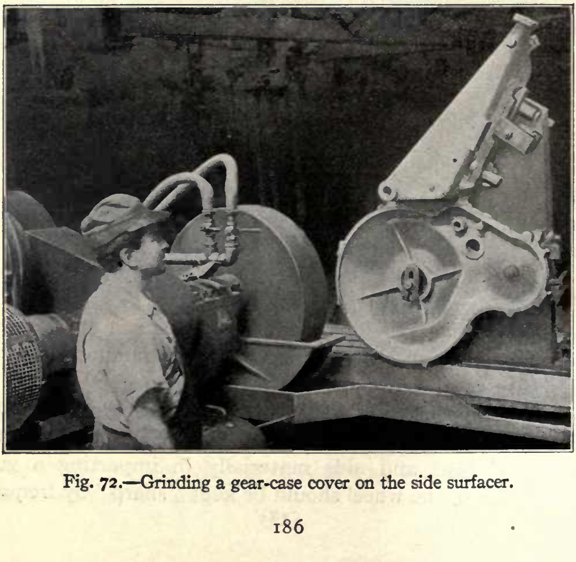

Fig. 72.—Grinding a gear-case cover on the side surfacer.

dressing, preferably with an ordinary wheel dresser of the star-wheel variety. The correct table speed for side surfacing depends on the amount of material to be removed. The machine illustrated in Fig. 66 is equipped with three table speeds of 10, 17 and 22 feet per minute respectively. A slow speed should be used when taking heavy cuts, otherwise the wheel is not given a chance to cut properly. In taking light finishing cuts, a fast table speed can be used to advantage. After the wheel has ceased to spark heavily, it is a good plan to let the work feed past the wheel several times without further cross feeding, especially with work of comparatively thin section. This practice produces accurate results as any undue pressure caused by the grinding-wheel which might spring the work is automatically avoided.

In selecting wheels for the side surfacer, it should be borne in mind that no one wheel can be depended upon to produce efficient results on all classes of work. Wheels made of carbide of silicon abrasives give excellent results for the surface grinding on cast iron, but they cut slowly and cause undue heating when used on steel. For malleable iron, steel castings or pieces made of machine steel, alumina abrasives should be selected. All grinding-wheel manufacturers carry wheels in stock for the grinding machines in question, but in ordering wheels, the manufacturer should state clearly for what purpose and under what conditions the wheels are to be used. This information enables the grinding-wheel manufacturer to make the proper selection.

DIE GRINDING

Die grinding is one of the earliest and, at the present day, one of the most common practices. When we stop to consider the numberless articles seen in the home, office, and factory that are the products of punches and dies, it is readily seen that die grinding is a very important branch of present-day machine-shop practice.

As previously stated, dies are often ground by spot grinding as shown in Fig. 61 and this practice produces good results where the die grinding is of an intermittent nature. The wheel used for this work, assuming that the die is made of hardened steel, should be made of an alumina abrasive, and should be run at a surface speed of approximately 5,000 feet per minute. The grade should be medium soft and, for ordinary purposes, 36 grit gives good results. Where an extra-nice finish is desired, on small dies for example, a wheel in finer grit can be used to advantage.

As Fig. 61 shows, the work is ground dry. For this reason, the cut taken is generally comparatively light, about 0.001 inch. The work seldom becomes unduly heated owing to the fact that the platen of the machine absorbs the heat from the die nearly as fast as it is generated. Punches are ground in the same manner as dies with the exception that they must be held in a special holder in cases where their shanks are made integral.

The use of the machine just considered is somewhat limited, as it produces flat planes only, whereas many kinds of dies, especially those used for punching comparatively thick metal, should be ground to give a shearing cut. To accomplish this it is necessary, from a practical point of view, to utilize a machine on which the work can be firmly fastened and fed back and forth under the wheel.

The machine illustrated in Fig. 73 is a Brown & Sharpe number 2 surface grinder—a machine that is widely used for sharpening dies and for the general run of surface-grinding work. It will accommodate work 18 inches long, 6 inches wide and 9-1/2 inches high when using a wheel 7 inches in diameter. The longitudinal travel of the platen is controlled by dogs that actuate the reversing lever and the platen saddle can be fed in from 0.001 to 0.009 inch at each reversal of the platen.

The simplest manner in which to hold a die for grinding, in cases where a flat surface only is desired, is to grip it in the vise with which the machine is provided. This practice, however, is not always productive of the best results because it is sometimes almost impossible to hold the work level in this manner.

For this reason, many mechanics prefer to strap the die directly to the platen of the machine, as illustrated in Fig.

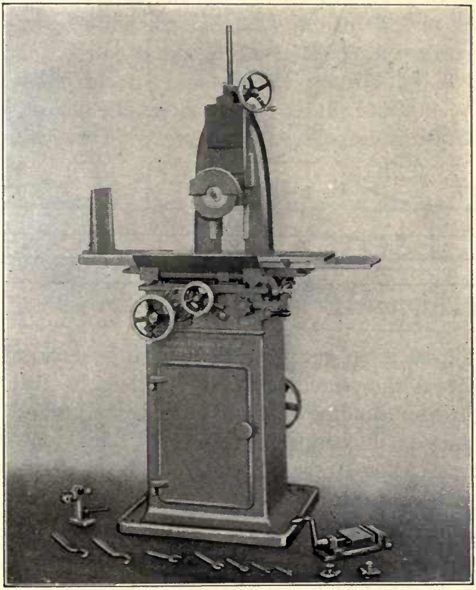

Fig. 73.—Brown & Sharpe automatic surface grinder.

74. If the bottom of the die is ground flat after hardening, it is obvious that this surface can be used for locating in subsequent grinding operations to bring about accurate results. In Fig. 74, A is the die, B the platen of the surface grinder, C the grinding wheel, D the straps that grip the work, and E the backing straps against which the straps D bear. The straps D act as pinch clamps and their downward thrust seats the die firmly against the platen of the machine.

Where comparatively thick metal is to be pierced, it is common practice to shear the face of the die as shown in Fig. 75, wherein A is the die, B the punch, and C the metal to be pierced. The double taper imparted to the face of the die allows it to cut the metal with a shearing action which relieves the punch press of considerable strain.

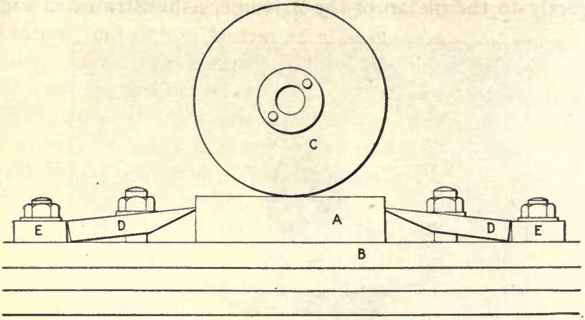

Fig. 74.—Holding a blanking die in position for grinding.

A fixture for holding dies that are to be ground with a sheared face is illustrated in Fig. 76. This consists of a base casting (A) and a die holder (B). The holder swivels on the pin (C) and is locked in the desired position by the bolts (D). One of the lugs on the base is graduated in degrees for ready setting as shown at (E). The recess in the holder is machined at an angle to correspond to that of the die

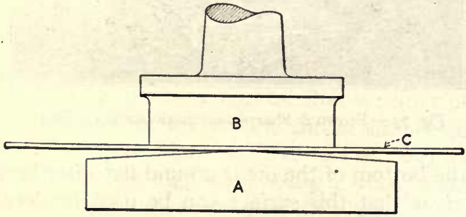

Fig. 75.—Blanking die with a sheared face.

which facilitates ready setting. This fixture is easily made by any tool-maker of ordinary ability and its use saves considerable time that is usually spent in setting up by other methods.

Punches are ground in the same manner as dies, with the exception that other means are usually employed in locating them on the grinding machine. A punch that is set in a holder having a flat upper surface, the upper member of a sub-press for instance, is readily ground by strapping it directly to the platen of the grinding machine. Many punches, however, are made with integral taper shanks, thus, means must be provided for locating them. The simplest method consists of a square block of cast iron, generally machined all over, with a taper hole bored through it to accommodate the punch shank. A block of this type is illustrated in Fig. 77, wherein A is the block, B the punch to be ground, C the grinding wheel and D the straps that hold the block in place on the grinding-machine platen. These are finger straps and holes are drilled in the block to accommodate them.

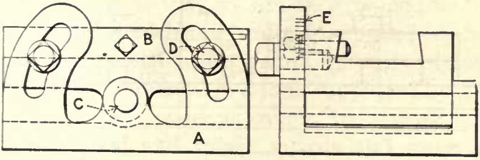

Fig. 76.—Fixture for holding dies while grinding sheared faces.

By referring again to Fig. 75, it will be seen that the punch will punch out a comparatively flat piece as its cutting surface is flat, while the stock that is perforated will be distorted to a certain extent by the action of the die face. In some instances, we do not care whether the punches are flat or not, as in perforating operations where the punchings constitute the scrap, but we do desire to preserve a flat surface on the stock that is perforated.

In this case, the punch is ground to give the shear instead of the die. The lower part of the punch holder shown in Fig. 77 is machined to accommodate the fixture shown in Fig. 76. This is for the purpose of grinding sheared faces on punches, the punch block being held in the position usually occupied by the dies, and the base of the fixture swiveled to impart the desired shear to the punch.

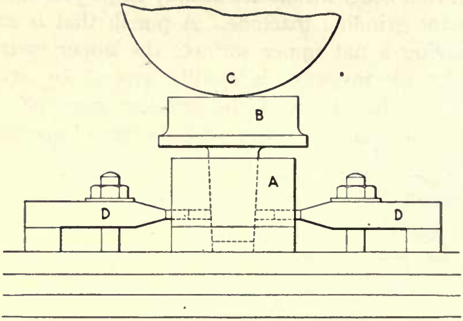

Fig. 77.—Fixture for holding tapered-shank punches for grinding.

Die grinding in itself is a comparatively simple operation that does not call for the services of a skilled tool-maker. As a matter of fact, at the present time, die grinding is done in many plants by women who do not pretend to be skilled mechanics. All that is necessary is to understand the fundamental principles of surface grinding and to exercise due care to see that the depth of cut and the cross feed is not heavy enough to cause the wheel to burn the edges of the die.

In ordinary die grinding, if done dry, which is the usual custom, the depth of cut should be from 0.001 to 0.002 inch and the cross feed 0.010 inch for each reversal of the platen. This is a general rule.

The wheels used for die grinding should be made of alumina abrasives and they should be quite soft and coarse.

Grades 3, 4 and 5 in the writer's proposed grade scale are generally furnished in grits from 36 to 46.

At the first sign of glazing, the wheel should be trued with a diamond tool. The easiest method for truing the wheel on a surface-grinding machine is to clamp the diamond tool in the vise with which the machine is equipped, and feed the diamond past the wheel by means of the cross feed.

Die grinding is sometimes done wet, which practice, of course, expedites production as the water keeps down the frictional heat. In wet grinding, both the depth of cut and the amount of cross feed can be materially increased. The machine illustrated in Fig. 73 can be equipped with a wet-grinding attachment wherein water is supplied to the wheel by means of a special wheel guard, through piping, by a centrifugal pump immersed in a tank supported by a bracket from the floor. The water is caught by a work tank provided with a hood and splash guards and returned to a settling pan through a flexible discharge pipe.

On the larger types of surface-grinding machines, the work should be ground wet under practically all conditions. The reason for this lies in the fact that the comparatively large wheels used create more friction in proportion than do smaller ones. A surface-grinding machine of the type in question having provision for an ample water supply, is illustrated in Fig. 78. Machines of this type give excellent results on heavy die work such as sections of large blanking dies, which, owing to their nature, cannot be made from a solid piece of steel, and for grinding large sub-press dies such as are used for blanking armature discs. These large surface-grinding machines give economical results as the depth of cut and the traverse feed can be materially increased when compared with smaller surface-grinding machines. This is, of course, owing to the heavier construction throughout and also to the fact that a larger wheel is used. Surface grinding in general was given a decided impetus some 25 years ago by the introduction of the magnetic chuck, by means of which flat work is readily located for grinding. The magnetic chuck offers the additional advantage of holding flat work securely without danger of springing.

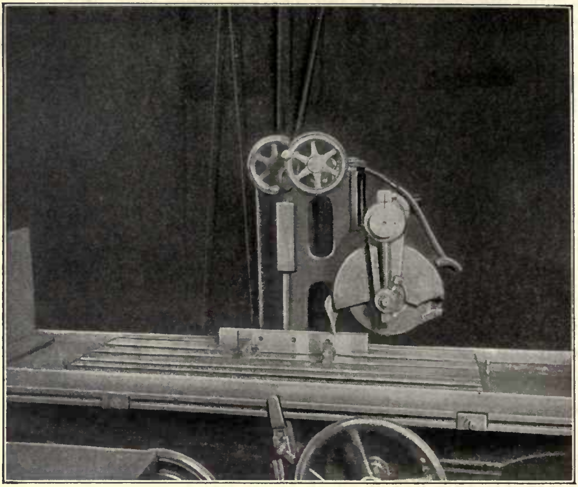

Fig. 78.—Surface-grinding machine having provision for wet grinding.

A magnetic chuck made by the Heald Machine Co. is illustrated in Fig. 79. It has a working surface 13 inches long and 6 inches wide, and is equipped with vertical adjustable side and end stops for locating the work. These prevent the thrust of the grinding wheel from forcing the work off the chuck. The front edge of the working surface is provided with a T slot, the object of which is to accommodate stops, fingers, retainer strips, etc., according to the nature of the work handled.

Figs. 80 and 81 illustrate special types of magnetic chucks designed by the Heald Company. The one shown in Fig. 80 has a taper base which is adjustable for finishing tapered work such as keys, wedges, etc. The base plate is pivoted at the left-hand end and has an adjusting screw, clamping

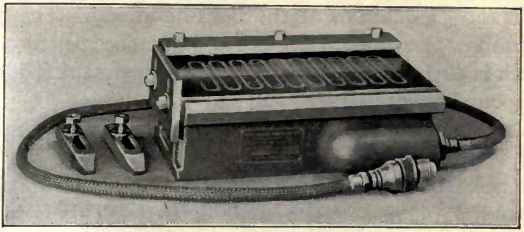

Fig. 79 —Heald magnetic chuck for use on the surface grinder.

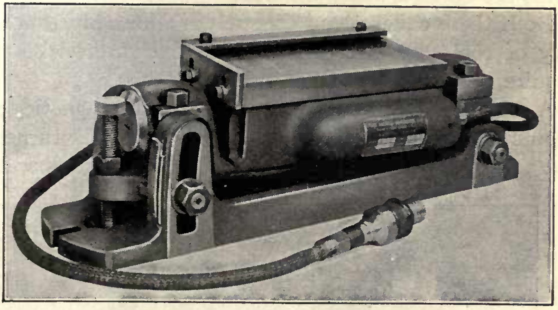

Fig. 80.—Heald magnetic chuck with adjustable taper base.

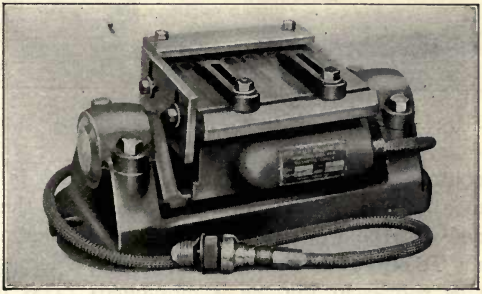

Fig. 81.—Heald magnetic chuck with adjustable swivel base.

bolt, and graduations at the right-hand end. The graduations show the taper in degrees and in inches per foot. This chuck is also provided with a swivel adjustment for grinding compound angles.

The chuck shown in Fig. 81 has a swivel base, the axis of which runs lengthwise through the center of the chuck. The swivel plate is provided with trunnions which are clamped to hold the chuck at the angle desired. This is indicated by graduations at the right-hand end. The base plate is in one casting which supports the chuck at both ends. Thus the outfit is self-contained.

Both these chucks lend themselves admirably to a diversity of tool-room and other work which otherwise would require special fixtures or setting-up devices.

A properly designed and constructed magnetic chuck should demagnetize as soon as the current is turned off, but to assist in the removal of work having comparatively large contact surfaces, a demagnetizing switch is of great assistance. This is due to the fact that after the current is turned off, the work retains a certain amount of magnetism. To offset and neutralize this force, a demagnetizing switch as shown in Fig. 82 is employed. This device is fitted at one end with contact points which close the circuit and magnetize the chuck for operation. At the opposite

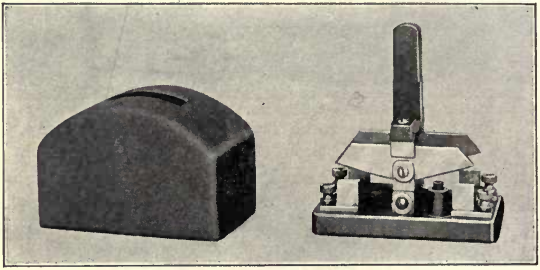

Fig. 82.—Demagnetizing switch for use with magnetic chucks.

end, it is provided with contact points having a reversing spring for demagnetizing purposes. By throwing the handle to the left, the chuck receives the current permanently and by throwing it to the right, making only an instant's contact between the blades of the switch, the demagnetizing effect is produced. After this, the work can be removed readily from the face of the chuck.

All work that is ground on a magnetic chuck is bound to retain a small amount of magnetism which often proves detrimental, owing to the fact that small particles of metal are thereby attracted. Magnetized pieces are readily demagnetized by the device shown in Fig. 83. The steel plates seen at the top of the case are the poles of magnets contained in the box. These electro-magnets are energized by connecting to an alternating-current circuit. The rapid reversals of polarity produced by this kind of current, remove all traces of magnetism by simply passing the work a few times across the steel plates.

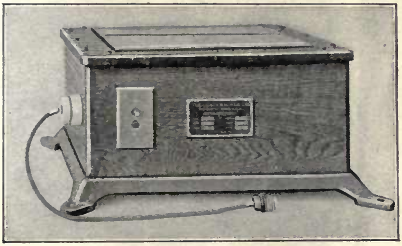

Fig. 83.—Heald demagnetizer.

In installing and operating magnetic chucks, two important factors should be borne in mind. First, the voltage for which the chuck is wound should correspond to the voltage in the circuit to which the chuck is to be connected. If the voltage in the line is too high for the chuck, the latter will be burned out and if the voltage is too low, the chuck will not retain the work.

Second, magnetic chucks cannot be operated on alternating current because the rapid reversal of polarity produced by such currents gives the poles or magnets of the chuck no permanent holding power. Thus, in cases where direct current is not available, it should be generated by a small generator driven by the line shafting.

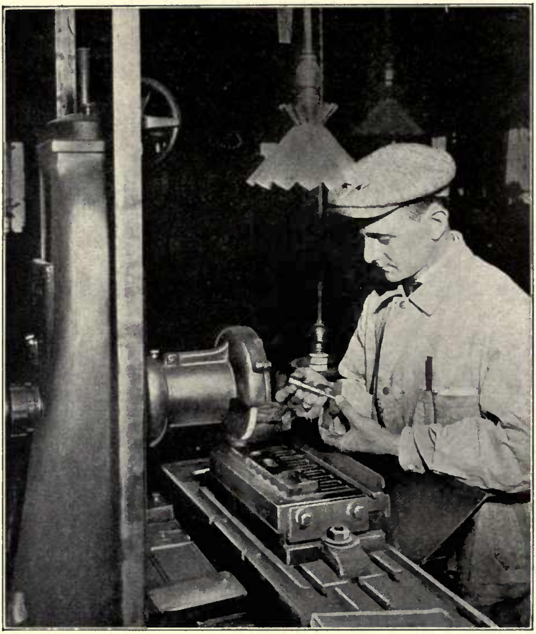

Fig. 84.—Grinding work with irregular contour on the surface grinder.

A Brown & Sharpe surface grinder equipped with a magnetic chuck is illustrated in Fig. 84. It is seen that the pieces ground are of irregular shape and it is on work of this kind in particular that the magnetic chuck shows efficiency when used on the surface grinder. The pieces shown enter into the construction of shoe machinery, which is very accurate work. These pieces are cast iron, the limit of variation allowed being 0.0002. The wheel used in this case is Carborundum 241 grit, M grade.

The ordinary run of surface grinding, as far as the method of procedure is concerned, does not differ materially from die grinding. With some classes of surface grinding, however (tool-room work for an illustration) more care has to be exercised to insure accuracy. Accurate surface grinding on machines of the type under consideration, depends a great deal on the "sizing power" of the wheel.

Let it be assumed that a tool-maker grinds a piece 4 inches long and 3 inches wide, locating the work on the magnetic chuck. He rough grinds both sides with a fairly coarse cross feed and then takes a finishing cut over one side with a finer feed. The work is then turned over and a finishing cut taken over the other side. If the wheel is sizing properly, that is, holding its shape and size, within close limits, the variation in the work should be very slight. In many cases, the work will be slightly tapered from 0.001 to 0.002 inch owing to the fact that the wheel wore away gradually while the cut was being taken.

The remedy for this is to true the wheel carefully and to see that a very slight depth of cut is used for finishing, not over 0.0005 inch. If, under this condition, the work still finishes tapered, the error is due to two causes. Either the wheel is too soft or it is run at too low a peripheral speed.

With machines having no provision for increasing the spindle speed as the wheel wears down, wheels often appear soft after they are half worn out owing to the fact that the peripheral speed is lowered considerably. The remedy in this case is to discard the wheel and mount a new one that is of the proper size. In nine cases out of ten, the new wheel will be found to size in a satisfactory manner. For this reason, it is poor economy sometimes to attempt to use wheels until they become too small.

If a new wheel fails to hold its size when run at a peripheral speed of 5,000 feet per minute, it is a sign that it is too soft.

In accepting this statement it is understood, of course, that the operator uses the whole face of the wheel. That is, he has not trued away part of it with the diamond, which practice, for some unknown reason, is followed in some shops.

If the full face of the wheel is used and the grade seems too soft, the remedy is to substitute a wheel one half or one grade harder or to use a wheel in combination grit. These combination grit wheels have remarkable sizing power and are preferred by many who have made a careful study of the underlying principles of grinding. The wheel used on the machine shown in Fig. 84 is in combination grit with 24 grit as a basis.

If, however, too hard a grade is used, the wheel will soon fill up and may burn the work. If the work appears unduly hot, so hot the hand cannot be held upon it, it is generally a sign that the wheel is overheating. In some instances, minute black spots are seen on the work, which is a sure sign of burning.

Some operators are under the impression that a fine-grain wheel is necessary for producing a smooth finish. This supposition, however, is erroneous. For the ordinary run of tool-room surface grinding, 46 grit is fine enough although wheels as fine as 60 grit are sometimes used on very small work. Fine grit wheels cut slow and for this reason are not economical in the long run. A wheel in coarser grit, with its full face utilized, will be found to give a satisfactory finish if it is trued properly.

When a wheel chatters, the cause can be traced to two sources. Either the wheel is too hard or the spindle bearings are loose. Chattering causes a wavy, speckled appearance on the work, readily detected by any mechanic. The remedy is, first to take up any slack in the spindle bearings and if chattering is still in evidence, attention should be paid to the grade of the wheel.

The machine shown in Fig. 85 represents another type of surface grinder. It is a product of the Heald Machine

Co. and is called a ring and surface grinder. In shop language, however, these machines are generally referred to as piston-ring grinders, owing to the fact that they are widely used for grinding the sides of piston rings.

Fig. 85.—Grinding piston rings on a Heald ring and surface grinder.

Briefly described, the main frame of the machine carries a vertical spindle upon which a magnetic chuck is mounted. The spindle is adjustable up and down to accommodate and size different thicknesses of work and is provided with micrometer adjustment for close setting. The upper part of the main frame supports a cross head which carries the wheel spindle. A novel feature of this machine is that an adjustment is provided to enable the wheel to grind tapered as well as flat surfaces. This adjustment is of great value in grinding such work as milling saws which should be thinner at the center than at the periphery to give the proper working clearance.

A larger machine built on the same principle is shown in Fig. 86. As the illustration shows, this machine is equipped for wet grinding. These machines will grind any kind of flat work within the capacity of the chucks, but are especially adapted for finishing round work such as piston rings, thrust collars, milling cutters, etc.

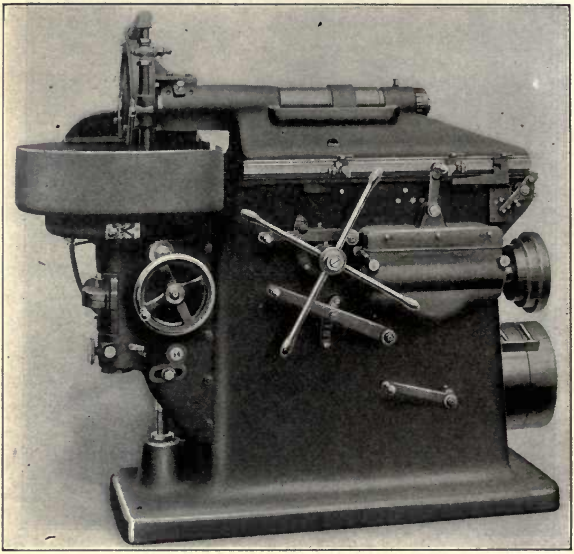

Fig. 86.—Heald rotary surface grinder arranged for wet grinding.

In comparing rotary surface grinders with surface grinders of the reciprocating type, it is seen that in the former, the wheel covers the entire surface of the work being ground in much less time than it does in the latter. For this reason, the sizing power of the wheel is materially increased.

A widely used type of grinding machine is illustrated in Fig. 87, the Pratt & Whitney surface grinder. In the language of the practical man, however, this machine is generally spoken of as a vertical surfacer. It furnishes a ready means for removing stock accurately and rapidly, not only on the regular work of surface grinding, but on roughing operations where very little metal has to be removed. In this work, it replaces the milling machine and planer to some extent.

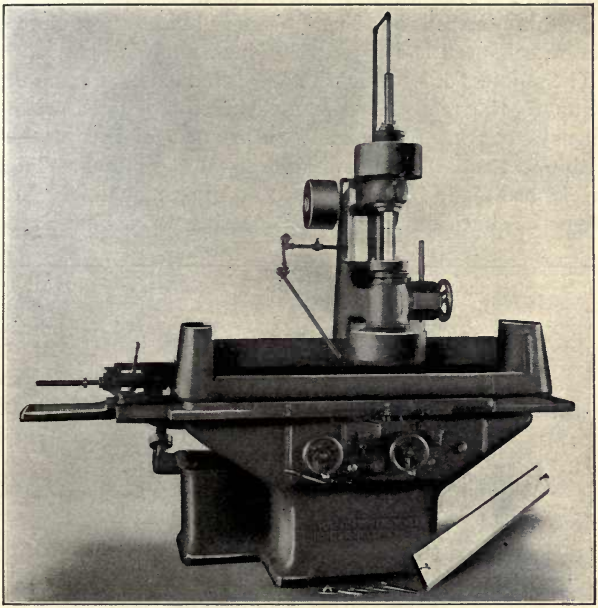

Fig. 87.—Pratt & Whitney surface grinder or vertical surfacer.

Briefly described, this machine consists of a rigid base, upon which the platen travels, and a substantial upright which carries the wheel spindle. The platen has a longitudinal movement only. A traverse movement is unnecessary owing to the fact that the diameter of the wheel used is sufficient to cover the whole width of the platen.

The machine carries a wheel 14 inches in diameter with a 4-inch face. The rim is 1-1/4 inches which gives a 11-1/2 inch hole. The wheel is mounted in a special holder, bedded in hot shellac and held securely by means of clamps. The wheel speed is 1,155 revolutions a minute.

The problem of locating the work is reduced to a minimum owing to the fact that the machine is equipped with a magnetic chuck. By means of rotary chucks, this machine is able to handle both plain and circular grinding. These chucks are made both magnetic and non-magnetic. Non-magnetic chucks are used for locating work that is not attracted by magnetism, such as bronze, aluminum, etc., while magnetic chucks are used for holding pieces made of ferrous metals. A plain rotary chuck with its driving mechanism is shown in Fig. 88. The base upon which the chuck revolves is clamped to the platen of the machine while the driving mechanism is located outside the water guard. An adjustment is provided for tilting the chuck, which makes possible the grinding of concave or convex

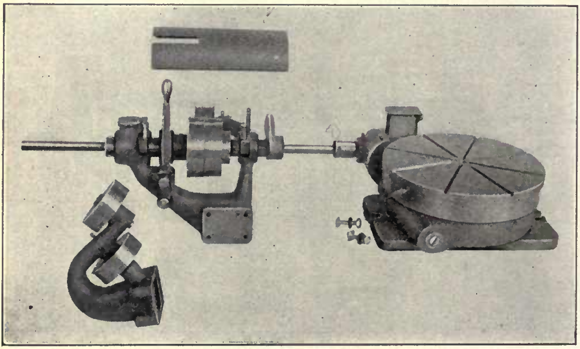

Fig. 88.—Plain rotary chuck for use on Pratt & Whitney vertical surfacer.

surfaces. The duplex and quadruple chucks shown in Figs. 89 and 90 are used on production work where they increase the output materially. The duplex chuck is adjustable for grinding either concave or convex, but the quadruple chuck does not possess this feature.

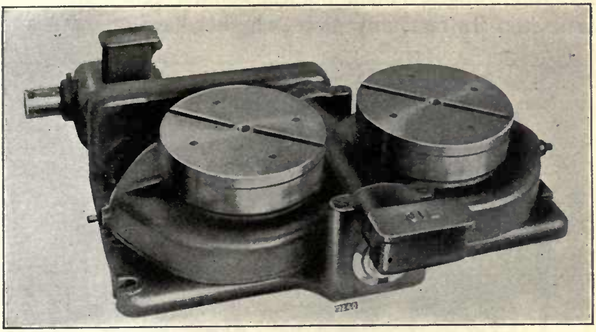

Fig. 89.—Duplex rotary chuck for use on Pratt & Whitney vertical surfacer.

Designed for a production machine, the grinder in question is thoroughly automatic. The table is provided with two feed speeds of 34 and 142 inches per minute. The feed of the table per revolution of the wheel is 0.029 and 0.123 inches.

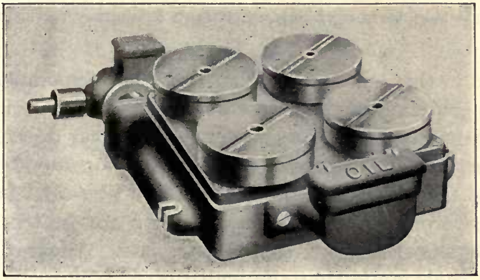

Fig. 90.—Quadruple rotary chuck for use on Pratt & Whitney vertical surfacer.

An endless variety of flat work, both rectangular and circular, can be finished on this machine as shown in Fig. 91. The pieces shown illustrate blanking dies, thread-cutting dies, ring gauges, chuck bodies, collars, gears, small-arms parts, etc. In fact, any piece, whether hard or soft, can be finished in this manner if its surface is of such a nature as to permit gripping on the magnetic chuck.

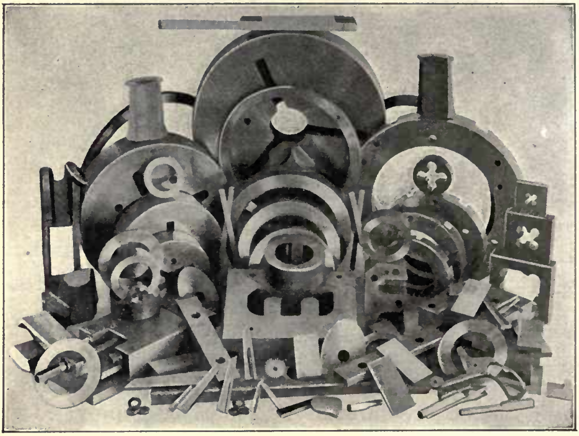

Fig. 91.—Samples of work finished on Pratt & Whitney vertical surfacer.

Successful grinding on the vertical surfacer depends more on the selection of wheels than it does on any one other factor. Carbide of silicon wheels should be used for grinding cast iron while alumina abrasives are better adapted for steel—both in its hard and soft state. A factor peculiar to this machine is that the width of surface to be finished determines the grade of wheel to use. Thus, when finishing comparatively wide surfaces softer wheels are necessary than those used for grinding narrow work. The following grits and grades have been found through practical experiment to give good results. On cast-iron and aluminum grinding; 16 to 24 grit, 1 to 4 grade. For soft steel; 16 to 24 grit, 3 to 7 grade. These wheels are also adapted for malleable-iron castings. For grinding hardened-steel parts 16 to 24 grit, 1 to 4 grade are used. These gradings are taken from the writer's grade scale.

To grind work successfully on a vertical surfacer, it must be borne in mind that one wheel cannot be expected to show efficient results on all classes of work; and for this reason several wheels for various purposes should invariably be kept in stock.

In grinding, the work should be held securely on the chuck, otherwise the action of the wheel will dislodge it. This sometimes results in a broken wheel, but accidents are readily avoided by placing backing strips around the work. The face of the chuck should be cleaned carefully before placing the work in position, if accurate results are required, because a small amount of dirt can cause an error of several thousandths of an inch.

While the wheels used with this machine are very free cutting, owing to their soft grade, they should not be crowded. That is, the spindle should not be fed down too great a distance at each reversal of the platen. To ignore this factor is to invite disaster for one of three results is bound to happen. The work will be burned, forced off the chuck or the wheel will be broken.

The wheel must be kept sharp and free cutting. It is readily trued by the device described for this purpose in Chapter X. An expert grinder can readily detect a wheel that needs dressing even if he cannot see its face. A wheel that needs dressing overheats the work, does not throw sparks freely and leaves a polished surface on the work.

Work should never be ground dry on machines of this type. A liberal supply of water is necessary for two reasons: It keeps down the heat caused by the cutting action of the wheel and it also carries away the metal particles removed from the work. Soda water supplied by the circulating pump should be used as plain water rusts both the machine and the work. If the machine is used intermittently, it should be cleaned thoroughly after using and oiled each time before starting up, while a machine that is used constantly should be oiled every day and cleaned thoroughly at least once a week.

Another type of surface-grinding machine is illustrated in Fig. 92. This machine is made by the Blanchard Machine Co., Cambridge, Mass.. and is called a high-power vertical surface grinder. The initial machine of this type was built by the Blanchard Company, some eight years ago, for their own use. The machine is built very rigidly to eliminate vibration and consists principally of a base carrying an upright on which the wheel head is mounted and a revolving platen on which the work is held.

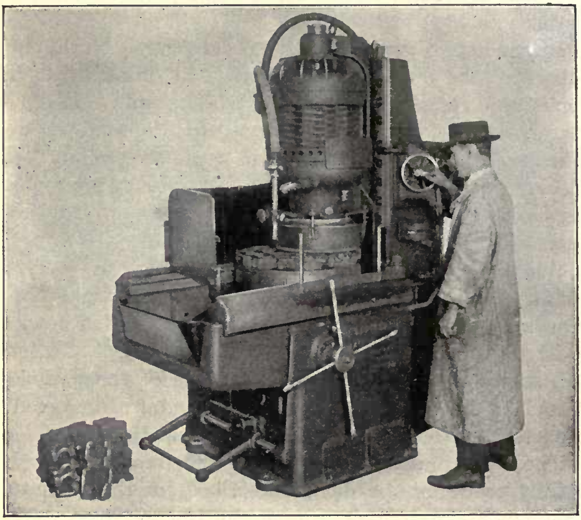

Fig. 92.—Blanchard high-power vertical surface grinder.

The wheel spindle on the machine shown is driven directly by means of a 20-horsepower motor although these machines can be arranged for belt drive. In the majority of cases, however, the direct drive is to be preferred.

The wheel used is a plain ring without flanges, thus clamps are not necessary in holding it in place. It is set in a cast-iron ring either with sulphur or Portland cement. The ring that carries the wheel is fastened to the face plate at the bottom of the driving spindle by means of six screws. To reinforce the wheel in guarding it against possible breakage, a wire banding consisting of two windings 1/2 inch wide of brass wire is applied to the outside.

A novel and valuable feature peculiar to this machine is the three-point column support. In turning out flat work of uniform thickness it is essential that the wheel spindle be exactly square with the chuck. While this alignment may be correct when the machine is new, it does not follow that any wear that may develop will be uniform. To correct errors due to wear, the three-point support is adjustable, which feature makes possible correct alignment at all times. This adjustment also furnishes a convenient means for setting the machine to grind concave or convex surfaces.

The work to be ground is held either magnetically or by clamps or by its own weight on the rotary chuck. The table body on which the chuck is mounted slides on the base and carries the chuck under the wheel where it is rotated by power and the wheel fed down gradually until the desired amount of metal is removed. Both hand and power feeds are provided, the latter having a wide range of feeds with automatic stops that can be set at any point.

The feed mechanism comprises a hand crank, a graduated rachet wheel and a pawl driven from the chuck motion and arranged to feed once at each revolution of the work. The feed is very sensitive as each tooth of the rachet wheel represents 0.0002 inch. The graduations on the wheel indicating thousandths of an inch are 1/2 inch apart.

Work on this machine is invariably ground wet and means are provided for insuring an ample supply of water which is supplied inside the wheel while guards are provided to prevent the escape of spray as it is thrown out by the centrifugal action of the wheel.

An idea of the wide range of work that can be handled on the machine in question is illustrated in Fig. 93. Here are included over one hundred different machine parts comprising units of fire-arms, rings, thrust collars, gears, connecting rods, flatirons, etc.

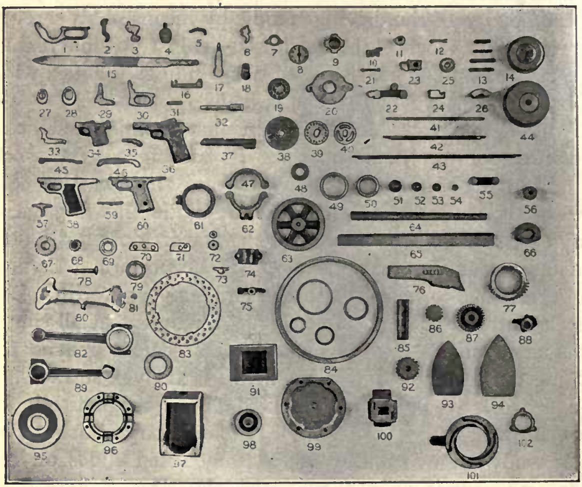

Fig. 93.—Samples of work ground on Blanchard high-power vertical surface grinder.

The machine is simple in operation, but it should be remembered that it is a precision machine in every sense of the word. All the bearings should be oiled once a day and the grease cups turned daily while the oil gauges should be kept filled to the center of the glass at all times.

The solution for cooling the work should consist of a nixture of 50 gallons of water, one to two quarts of cutting oil and three to five pounds of sulphate of soda.

In chucking work, the center of the chuck should be left open whenever possible. A practical method is to place the work in a circle around the chuck leaving an eleven-inch hole in the center. The work should be backed up against slipping by means of a loose steel ring placed around the outside of the work. This point is important and should never be overlooked. It must be remembered that each piece of work, to insure proper holding, must span one or more of the brass rings on the chuck face. Large pieces, the shape of which prevents the use of rings, should be securely blocked to prevent sliding. In grinding non-magnetic work, care must be exercised to block or clamp the same according to shape. As the pressure exerted by the wheel is always downward, danger of tilting the work is reduced to a minimum.

Soft wheels that wear away readily, thus constantly exposing new cutting grains, are to be preferred to harder ones that require constant truing. If the wheel refuses to cut freely and glazes or burns, the remedy can be found in one or more of the following factors: A softer and coarser wheel should be used, more feed with the object of keeping the wheel in cutting condition should be used, the width of the work surface of the wheel should be reduced, the face of the wheel should be roughened with a star-wheel dresser, and, if grinding broad surfaces, the amount of oil in the cooling solution should be reduced or left out altogether. The wheel speed must remain at 1,000 revolutions a minute for a 16-inch wheel, and 860 revolutions a minute for an 18-inch wheel.

The power feed should be used in preference to hand feeding. An average feed is 0.001 inch for each revolution of the work, but under some conditions, feeds as heavy as 0.002 and even 0.003 have been successfully used. The makers of the machine state that it is better to use too much rather than too little feed as fine feeds glaze the wheel readily.

The speed of the chuck should be from 13 to 17-1/2 revolutions a minute for the average run of work. This can be increased if a comparatively small piece chucked near the center is being ground. On the other hand, the speed should be reduced somewhat when grinding work that practically covers the chuck. To impart a very smooth finish, the chuck speed should be reduced to five revolutions a minute for the last few turns.

The proper method of operating the machine is first to locate the work, then close the switch and try the work to make sure that it holds. Next, with the wheel high enough to clear the work, the chuck is removed to its grinding position, as far as it will go under the wheel. The chuck is next started and the wheel fed down by hand until it starts to grind the work, when the power feed should be thrown in. The wheel should be raised before stopping the chuck or changing the chuck speed and the chuck should be stopped before it is moved from under the wheel.

The selection of correct wheels for vertical grinding machines should not be done haphazard if the best results are desired. Owing to the comparatively broad contact between the wheel and the work, a slight change in the grade of wheel often causes unsatisfactory work. In this respect, vertical surface-grinding machines are far more sensitive than other types of precision-grinding machines. The width of the surface to be ground often affects the wheel grading. Thus, narrow surfaces require harder wheels than do pieces with comparatively wide surfaces. After much experimentation, the Blanchard Machine Co. standardized the following wheel list, which gives the kind of wheel together with the proper grit and grade to use for various classes of work.

To provide means for readily measuring the work without taking it off the chuck, the Blanchard Company developed the continuous reading caliper gauge illustrated in Fig. 94. The attachment eliminates much of the time consumed under ordinary conditions when the work is stopped for the purpose of removing a piece for measurement with

SURFACE GRINDING

Material	Width of Surface	Finer Finish and Narrower Surfaces	Best Wheel for Average Work	Faster Cutting and Broader Surfaces	Finer Finish and Narrower Surfaces	Best Wheel for Average Work	Faster Cutting and Broader Surfaces
		Norton Crystolon			American Carbolite		
Cast Iron	Narrow	30 H	24 I		30 H	20 I	
	Medium	30 G	24 H	14 H		20 H	14 I
	Broad		24 G	14 H	30 G	20 G	14 H
Chilled Iron	Narrow		24 I			20 I	
	Medium		24 H			20 H	
	Broad		24 G		30 G	20 G	
Bronze	Narrow		24 I	14 I		20 I	14 I
	Medium		24 H	14 H		20 H	14 H
	Broad	30 G	24 G		30 G	20 G	
Aluminum	Narrow					20 I	
	Medium					20 H	
	Broad					14 H	
		Norton Silicate No. 38 Alundum			American Silicate Corundum		
Malleable Iron	Narrow		3824 I			24–1¼	
	Medium		3824 H			24–1	
	Broad	3830 G	3824 G			24–¾	
Soft Steel	Narrow	3830 I	3824 I		30–1	24–1¼	
	Medium	3830 H	3824 H	3814 I	30–1	24–1	14–1
	Broad	3824 H	3814 I		30–¾	24–¾	
Steel Castings	Narrow		3824 I		30–1	24–1¼	
	Medium		3824 H	3814 I	30–1	24–1	
	Broad	3830 G			30–¾	24–¾	
Hardened Carbon Steel	Narrow	3846 H	3830 H		46–¾	30–1	24–1
	Medium		3830 G	3824 H	46–½	30–¾	24–¾
	Broad		3830 G	3824 G		30–½	24–⅝
Hardened High-speed Steel	Narrow		3830 H			30–1	24–1
	Medium		3830 G			30–¾	24–¾
	Broad		3830 G	3824 G		30–½	24–⅝
WHEELS FOR BLANCHARD SURFACE GRINDER							

Revised to July 10, 1918.

the micrometer. The device increases the operator's confidence in grinding work accurately and rapidly as he does not have to feel his way toward the final finish. Thus, he can use a heavy feed until the last thousandth is to be removed.

As the illustration shows, the device consists of an upright and bracket for carrying a dial indicator. A hardened-steel contact point rests lightly on the work and is connected by means of a rod to the gauge head. The lower face of the contact point is of a flattened cone shape and as its vertical movement is slight, it readily passes over openings in the surface of the work or from piece to piece.

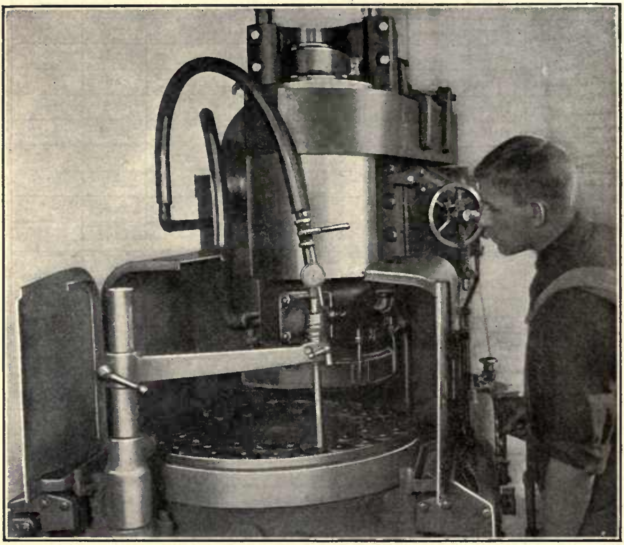

Fig. 94.—Continuous reading caliper gauge for use on Blanchard high-power vertical surface grinder.

In setting the gauge, the contact point is brought down on a size block or a finished piece of the desired size which is placed on the chuck and the dial of the gauge is revolved to bring the zero line to coincide with the pointer. The caliper is aligned to swing the contact point parallel to the surface of the chuck so that accurate readings can be taken at any convenient place on the work. It can be swung out of the way for placing or removing the work without destroying its setting.

In gauging the work, the caliper is swung to bring the contact point over the work while it is being ground. Each piece of work, as it is carried under the contact point, indicates on the dial the exact amount of oversize in thousandths of an inch.

CHAPTER SEVENTEEN

CYLINDRICAL GRINDING

Cylindrical grinders—Operation of grinders—Driving devices for work—Proper wheel speeds for various metals and work—Traverse feed—Depth of cut—Roughing and finishing cuts—Sparking—Backrest and steady-rests—Lubrication of work—Lubricating compounds and mixtures—Dressing and truing wheels while on the grinder—Chatter marks and their remedy—Selection of proper wheels for use on cylindrical grinders—Universal grinders—Grinding tapers—Various operations on universal grinder.

THE modern cylindrical grinder is one of the greatest aids to rapid production as it furnishes a convenient and accurate means for finishing a large variety of machine and other parts, both hard and soft. Cylindrical grinding is a trade in itself involving many factors that are intelligently understood only after many years of actual practice and patient experimentation. To be sure, any man who is mechanically inclined, or any woman, too, for that matter, can be taught to operate a cylindrical grinder in a few weeks' time, but to understand thoroughly the many perplexing problems of the grinding department of the average plant calls for knowledge that is acquired only through long practice.

In the foregoing chapter, it was seen that there are many types of surface grinders, but with cylindrical grinding the types of machines used do not differ materially except in one major point. That is the traverse movement of the machine which carries the work past the wheel. The oldest and most commonly used type consists of a stationary wheel with a movable platen while in a later type of machine, the platen does not move while the wheel carriage does.

As to the most efficient type there is a question. This has never been settled, even among abrasive engineers. However, both types give excellent results in actual practice. For the ordinary run of work, it is the writer's opinion that one type is as efficient as the other. It cannot be denied, however, that in grinding very heavy work (pieces weighing several hundred pounds) the traveling wheel offers a decided advantage, as the frequent reversal of motion of a unit weighing several hundred pounds is eliminated.

Grinding machines of the types before mentioned, that is those having traveling wheel heads and those having traveling platens, are again divided into two classes, plain grinders and universal grinders. A plain grinder is a machine designed to take the place of the engine lathe in finishing all kinds of turned work both straight and tapered, provided that the taper is not too abrupt. A universal

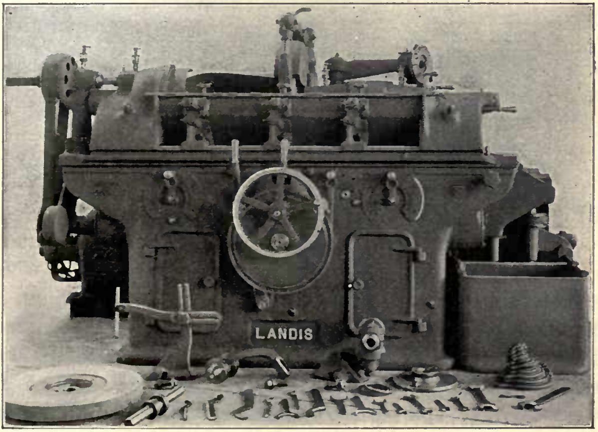

Fig. 95.—Landis 10x36-inch plain grinding machine.

grinder, as its name indicates, can be used for a wide range of work which includes besides plain grinding, internal grinding, face grinding, taper grinding, cutter grinding and in some cases, surface grinding. In the strictest sense of the word, the universal grinder is not a production machine and its usefulness is mostly confined to the tool-room.

Figs. 95, 96, 97 and 98 represent modern plain grinding machines as used on production work. The machine shown in Fig. 95 is a 10 x 36-inch plain grinder built by the Landis Tool Co., Waynesboro, Pa. It is thoroughly automatic in operation as regards traverse and cross feeds. The wheel carriage on this machine traverses while the platen is stationary. The reversal can be set at any desired place to suit different lengths of work and the cross feed can be set to feed either light or heavy at each reversal of the wheel carriage and also to cease feeding when a desired size has been reached. This feature is of great value in grinding routine work as the "cut-and-try" method is almost wholly eliminated. The work is driven on two dead centers. The machine illustrated in Fig. 96 is also a product of the Landis Company. It takes work up to 12 inches in diameter and 96 inches long. Its essential features are the same as those of the machine shown in Fig. 95, but it has an additional feature that is a decided novelty, the double

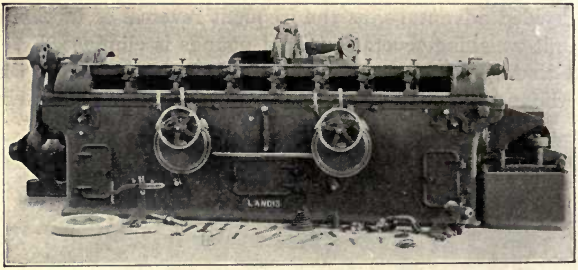

Fig. 96.—Landis 12x96-inch plain grinding machine.

control seen at the front. This is especially valuable in grinding long work as the machine can be fully controlled from either station. Both of the Landis grinders shown are arranged for individual electric drive.

The machine illustrated in Fig. 97 is a 10 x 36-inch plain grinder, arranged for belt drive. It is built by the Norton Grinding Co., Worcester, Mass. In this type of grinder, the wheel is stationary while the platen, which carries the head and tail stock, traverses. This is also a production machine and it is entirely automatic in operation. Fig. 98 shows another plain grinder built by the Norton Grinding Co. It is a much larger machine than the one shown in Fig. 97, but it operates on the same principles. It takes work 14 inches in diameter and 72 inches long. There are, of course, many other makes of plain grinding machines on the market, but they all work on the same basic principles. That is, they provide means for holding and revolving the work to be ground on dead centers, means for auto-

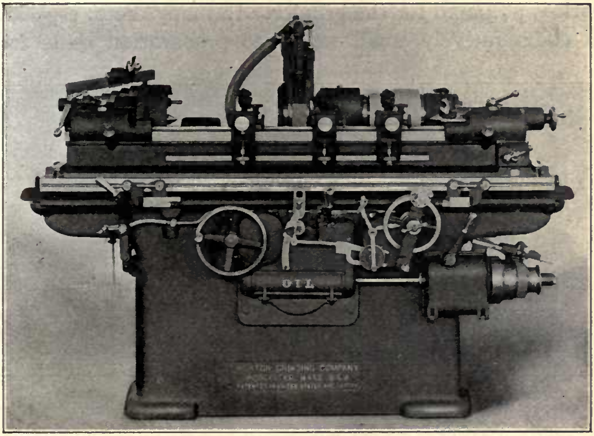

Fig. 97.—Norton 10x36-inch plain grinding machine.

matically traversing the work past the wheel, or *vice versa*, and means for actuating and controlling the cross feed automatically.

So much for plain grinding machines. Let us now consider the subject of cylindrical grinding itself. To permit the grinding machine to produce its maximum output, it is necessary to pay attention to the manner in which the work is prepared for the grinder. In many cases, especially on comparatively small work, no preparation aside from centering and squaring up the ends is necessary. This is especially true in cases where pieces are of a given size for their whole length, in which case the material is often cold-rolled steel 0.010 oversize.

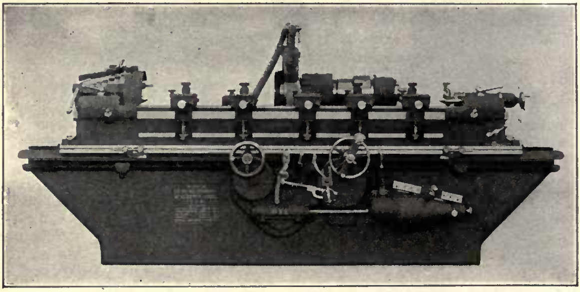

Fig. 98.—Norton 14x72-inch plain grinding machine.

With the majority of work, however, experience has proven that one roughing cut in the lathe is generally necessary. The rough feed marks made by coarse-feed, high-speed turning aid materially in the grinding operation as they help to keep the wheel in good cutting condition. When a rough feed is used for turning, 1/32 inch is a fair allowance to leave for grinding. This is a general rule and, of course, is subject to modifications. The Landis Tool Co. has compiled a table of grinding allowances for work running in diameter from 1/2 to 12 inches and from 3 to 48 inches long. The data were obtained from lengthy experimentation and the table follows:

DIAMETER INCHES	LENGTH IN INCHES 3	6	9	12	15	18	24	30	36	42	48
1/2....	.010	.010	.010	.010	.015	.015	.015	.020	.020	.020	.020
3/4....	.010	.010	.010	.010	.015	.015	.015	.020	.020	.020	.020
1....	.010	.010	.010	.015	.015	.015	.015	.020	.020	.020	.020
1-1/4....	.010	.010	.015	.015	.015	.015	.015	.020	.020	.020	.020
1-1/2....	.010	.015	.015	.015	.015	.015	.020	.020	.020	.020	.020
2....	.015	.015	.015	.015	.015	.020	.020	.020	.020	.020	.025
2-1/4....	.015	.015	.015	.015	.020	.020	.020	.020	.020	.025	.025
2-1/2....	.015	.015	.015	.020	.020	.020	.020	.020	.025	.025	.025
3....	.015	.015	.020	.020	.020	.020	.020	.025	.025	.025	.025
3-1/2....	.015	.020	.020	.020	.020	.020	.025	.025	.025	.025	.025
4....	.020	.020	.020	.020	.020	.025	.025	.025	.025	.025	.030
4-1/2....	.020	.020	.020	.020	.025	.025	.025	.025	.025	.030	.030
5....	.020	.020	.020	.025	.025	.025	.025	.025	.030	.030	.030
6....	.020	.020	.025	.025	.025	.025	.025	.030	.030	.030	.030
7....	.020	.025	.025	.025	.025	.025	.030	.030	.030	.030	.030
8....	.025	.025	.025	.025	.025	.030	.030	.030	.030	.030	.030
9....	.025	.025	.025	.025	.030	.030	.030	.030	.030	.030	.030
10....	.025	.025	.025	.030	.030	.030	.030	.030	.030	.030	.030
11....	.025	.025	.030	.030	.030	.030	.030	.030	.030	.030	.030
12....	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030

The majority of pieces that are to be finished by grinding are driven by means of a dog placed on one end. The dog engages a pin that projects from the face plate of the head stock. In cases where it is advantageous to traverse the entire length of the work at one setting (in grinding a piece of uniform diameter for its entire length for an illustration) the driving device illustrated in Fig. 99 is used in connection with Brown & Sharpe grinding machines. This consists of a special center (B), over which the driver (A) revolves. The driver is fastened to the dead-center pulley by the stud 68. The work is driven by the two pins (C). The holes in the work should be slightly larger than the pins and they should be drilled by means of a simple drilling jig to insure their slipping over the pins without interference.

Another device sometimes used is a square-shaped center. In this case, one end of the work is broached to fit the center. For taking comparatively light cuts, this method is satisfactory, but it possesses one disadvantage in that the center has to revolve, getting its motion from the headstock spindle. However, on special grinding machines such as used by twist-drill manufacturers, this type of center is often used as an inspection of the centers seen in some makes of twist drills shows.

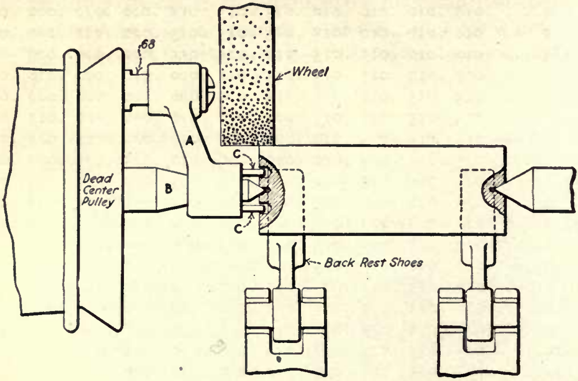

Fig. 99.—End driving-dog for use on Brown & Sharpe grinding machines.

After adjusting the tail stock to suit the length of the work, the machine must be set to grind straight by adjusting the swivel on the platen. In theory, this should not be necessary. In actual practice, however, it is found that the machine has to be "straightened up" every time the tail stock is moved. This is generally caused by small particles of dirt that work under the tail stock. It is a simple matter to straighten up the machine as all that is necessary is to take a few cuts over the work, caliper to find the taper, and adjust the swivel platen to offset this.

As a rule, when many pieces of the same kind are to be ground, it is the best practice to make two grinding operations, one for roughing and one for finishing. In the roughing operation, the wheel should be kept sharp and free cutting. This is done by passing the diamond past it with a quick motion. From 0.001 to 0.005 should be left for the finish grinding, the amount depending on the size of the work. In the finishing operation, the wheel should be carefully trued by passing the diamond over it with a comparatively slow feed.

Economical and efficient cylindrical grinding depends in a great measure on the speed at which the wheel is run. No hard and fast rule can be given for the correct wheel speed as it can range anywhere from 5,000 to 7,000 feet per minute surface speed. The rule is to slow down a wheel that shows a tendency to glaze and to speed up a wheel that wears away too readily. A little attention to this rule will save much trouble that is often laid to the wheel.

The speed at which the work is rotated has much to do with successful cylindrical grinding. If a wheel seems to be wearing away too rapidly, the fault can be overcome in many cases by reducing the work speed. On the other hand, if the wheel glazes readily, the fault is often overcome by increasing the work speed. The writer does not hesitate to state that it is impossible to lay down hard and fast rules for either wheel or work speeds. The skilful operator gets the result desired by a combination of both. The following approximate speeds, however, have been found to be satisfactory under general conditions in cases where the grinding wheel was run at a peripheral speed of 5,000 feet per minute.

Cast-iron roughing	40 feet per minute.
Cast-iron finishing	50 feet per minute.
Steel roughing	20 to 30 feet per minute.
Steel finishing	30 to 40 feet per minute.

On the subject of work speeds, the Landis Tool Co. says: "Our experience is that a surface speed of 30 to 60 feet per minute for steel and cast iron gives good results. However, the grade of the material, the quality of finish and the hardness of the wheel must be considered in determining the correct speed. Often when failure to produce good results is attributed to the wheel, it may be remedied by changing the speed of the work."

The traverse speed is another factor that must be considered in economical grinding. By traverse feed is meant the distance the platen travels for each revolution of the work. In roughing out work, this traverse should be very nearly the width of the grinding wheel for each revolution of the work. Thus, if a wheel with a 2-inch face is used, a traverse feed of 1-7/8 inches will be satisfactory. This practice causes the wheel to wear uniformly inasmuch as the work passes the wheel with a decided shearing action which helps to keep the wheel true. When a fine finish is required, however, the traverse feed should be reduced and the work speed increased. The above rules apply to the general grinding of steel. In grinding cast iron, the procedure is slightly different. For the rough grinding of this material a narrow traverse feed and a deep cut give better results than a wide traverse feed with a slight cut. In finishing cast iron, it is good practice to make as few passes over the work as possible as this has a tendency to prevent wheel glazing. It is seen that this is in direct opposition to the generally accepted rule for finishing steel, in which case an excellent finish is obtained by letting the work traverse back and forth past the wheel without cross-feeding until sparks are hardly visible. In shop language this operation is spoken of as "grinding out" and it is productive of excellent results, even when a comparatively coarse wheel is used.

To find the speed in feet per minute of the wheel or the work, multiply the diameter in inches by 3.14 and the result by the number of revolutions per minute; then divide the product by 12.

The depth of cut is understood as the amount the work is fed toward the wheel at each traverse. In cases where the work to be ground is of a substantial nature, that is, comparatively large in diameter for its length, a heavy cut can be taken; in fact the wheel can be forced into the work until the driving belt or motor, whichever the case may be, is working to its maximum capacity. This rule, however, applies to a hand feeding. When the automatic feed is used, a sufficient advance at each reversal of the platen should be made to keep the wheel cutting at its maximum capacity. Heavy cuts in roughing operations have a tendency to keep the wheel true and in cutting condition.

Sometimes in taking roughing cuts, it is noticed that the wheel sparks heavier on one side of the work than it does on the other. This is not the fault of the machine, but is caused by the internal strains and forces in the work adjusting themselves or, sometimes, by dirt working in the centers. It is needless to state that both the centers on the machine and in the work should be cleaned before placing the work in position which eliminates this cause of uneven sparking. When the uneven sparking is caused by the work adjusting itself to overcome internal strains, the evil corrects itself. The machine detects and corrects the error. When the work sparks uneven, the wheel should be kept sharp and slight feeds used until the work sparks evenly. A slight difference in sparking often leads the inexperienced operator to believe that the work is badly out of true. This, however, is seldom true, for in many cases an error of 0.0001 inch will cause uneven sparking.

To secure maximum production in the grinding department, the majority of pieces that are ground should be supported in the grinding machine by means of backrests or steady-rests as they are also termed. A visit to many grinding departments reveals the fact that this rule is often neglected. It takes a little time, to be sure, to set backrests, but the results obtained by their use amply pay for the small amount of time consumed in setting up. There is no hard and fast rule for the number of backrests to use on a given piece of work. One rest to a foot is sufficient, in most cases.

Backrests are of three kinds: solid, spring and universal. A difference of opinion exists among grinding-machine manufacturers as to what is the most efficient type of backrest, but all three types possess certain advantages. A solid backrest, as supplied with Norton grinding machines, is illustrated in Fig. 100. In this rest, the shoe forms a cradle for the work to rest in with a saddle or bearing point diametrically opposite the grinding wheel and another on the opposite side of the vertical center line close up to the point where the wheel comes in contact with the work being ground. This is plainly seen in the illustration. Howard W. Dunbar, in *Grits and Grinds*, a Norton Co. publication, has the following to say in regard to solid backrests:

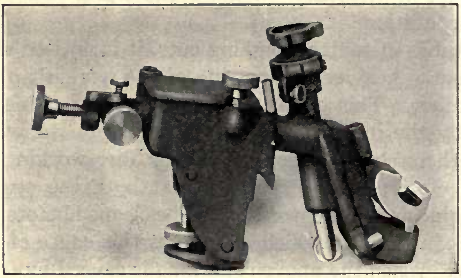

Fig. 100.—Plain or solid backrest for Norton grinding machines.

"The shoe should be exactly the same diameter as the finished ground work, and should be allowed to come in contact with the surface being ground immediately upon starting the grinding operation. The practice of attempting to true up the seat for the steady-rest shoe before bringing the shoe in contact with the work is wrong, as it allows the face of the wheel to break down, due to vibration of the work being ground. The support should be supplied immediately upon starting the grinding operation. It is a fact that work can be, and has been ground round and true with no support other than the steady-rests."

A spring backrest made by the Brown & Sharpe Mfg. Co. is shown in Fig. 101, and the following description of this rest and its use is from *Commercial Grinding by the Use of Plain Grinding Machines*, a shop handbook published by the Brown & Sharpe Mfg. Co.:

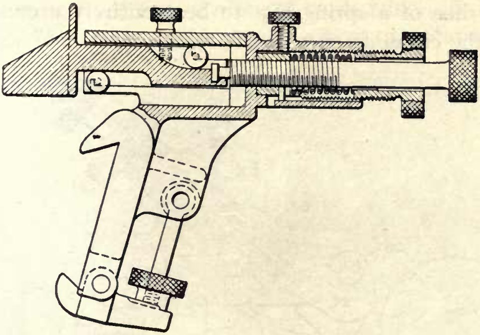

Fig. 101.—Spring backrest for Brown & Sharpe grinding machines.

"The shoe is of wood, brass or other soft metal, the end being made approximately to fit the work being ground. The spring keeps the shoe in close contact with the work and also allows the rest to conform to variations in the size of the work. The work, when revolving, tends to climb on the shoe, thus keeping the pressure on the lower roller and supporting the work on the under side. The shoes should be made of brass, soft metal, or wood, thus allowing the revolving work to wear the surface away sufficiently for it to fit the constantly varying size of the work. Brass or soft metal is best, but wood is also used. The shoe should have sufficient surface to last well but not enough to retard the wear mentioned. The shoe should move freely in the slide and be of sufficient mass to absorb slight vibrations. As the illustration shows, the spring holds the shoe in contact with the work and the pressure is regulated by the thumb screw. In fitting a shoe of this kind, it should first bear well on the under side of the work. The wear will quickly fit it to the work and the shoe will always have a firm bearing underneath. The shoes should never be made of hard metal or of a V shape. It is not always necessary for the shoe of a spring rest to bear entirely around one-half of the circumference of the work. A shoe of sufficient mass will prevent vibration, and, as it is of soft material, will soon wear to fit the varying circumference."

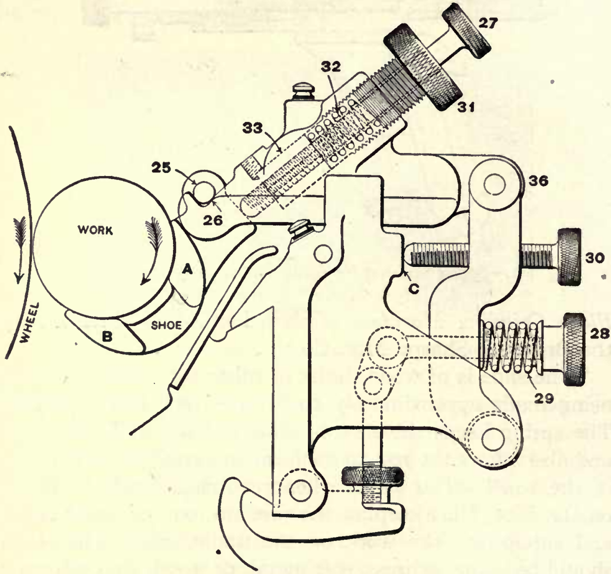

Fig. 102.—Universal backrest for Brown & Sharpe grinding machines.

A universal backrest is illustrated in Fig. 102. This device is a product of the Brown & Sharpe Mfg. Co. and is suitable for all kinds of work. It possesses the advantages of a solid rest combined with those of the spring rest. A

Brown & Sharpe grinding machine equipped with universal rests is illustrated in Fig. 103. The Brown & Sharpe Company give the following directions for the use of the universal backrest:

"One rest is required for each six to ten diameters of work in length. Thus, a piece of work 1 inch in diameter and 36 inches long would require six rests. Shorter work having different diameters, such as lathe spindles, require two or three rests. To place the shoe in proper position proceed as follows: First, select shoes the size of the finished work and hook the trunnions 25 into the Vees 26. Second, turn back the screw 27 far enough to allow the shoe to clear the work and loosen nut 28 entirely to relieve the pressure on spring 29. Then turn back screw 30. Third, turn forward the screw 31 until a light pressure is given to the spring 32. Turn forward the screw 27 and, if the spring 29 is wholly relieved and the screw 30 is far enough back, the shoe will come in contact with the work at both points A and B. Fourth, press lightly with the thumb, on 36,

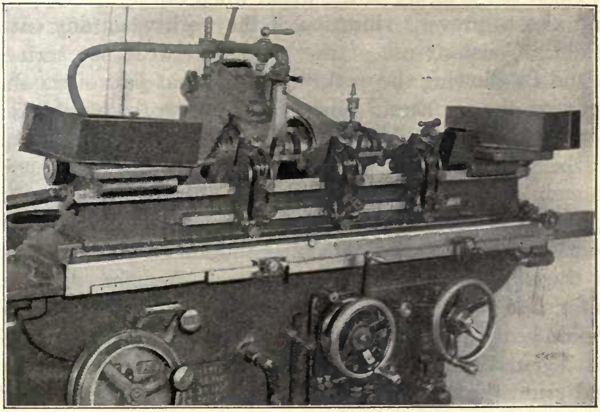

Fig. 103.—Brown & Sharpe grinding machine equipped with universal backrests.

holding the shoe in gentle contact with the work, and turn the screw 30 carefully, noting the slightest touch of the end against the stop C in order that none of the parts be moved, and, with this screw in contact with the stop, the shoe should bear equally at both points A and B. Turn nut 28 to give some pressure to the spring 29. The combined pressure of the springs 29 and 32 should be only sufficient to resist the pressure of the wheel when taking the last cut, and also to prevent vibration of the work when any cut is taken. Constant use of the shoes will wear the surfaces A and B, allowing the work to bear on that part of the shoe between the surfaces. When shoes are worn in this manner, clearance should be filed between the surfaces A and B. Fifth, grind the trial piece of work, moving the screw 27 to maintain the contact of the shoe with the work and the screw 30 to preserve the relative diameters at the various points. As the work approaches the finished size, measure at the different rests after each cut. After the trial piece is finished, with the diameter alike at all points, the shoe should bear equally at A and B and the sliding nut 33 should rest against the shoulder. Leave the parts in this relation and grind the other piece of work, adjusting screw 27 only as the shoe wears, and screw 30 for the delicate adjustment for diameter. Note the effect of the adjustment upon the sparks to determine the approximate position. When the work is to size, the nut 33 and the screw 30 are intended to rest against the shoulder and stop to prevent further pressure of the shoe upon the work. The shoe and wheel will be left in the proper position for sizing duplicate pieces. When unground work is placed between the centers and in the show bearings, the nut 33 and the screw 30 will be forced away from the shoulder and stop, thus compressing the springs 29 and 32. Should the shoe bear unequally at A and B, the screw 28 should be tightened to increase pressure at A and screw 31 to increase pressure at B. Do not make the combined pressure of these springs greater than necessary as long and slender work, although of uniform diameter, may not be straight when released from the shoe unless some allowance is made for elasticity."

Some twenty-five years ago, when grinding machines were few and far between, cylindrical grinding was often done dry. This practice is now considered unsatisfactory, except perhaps for light intermittent work as sometimes done in the tool-room on very small machines. To secure maximum production on routine work, it is of the utmost importance to cool and lubricate the work at the same time. To the layman, it may sound out of place to speak of lubricating the work on a plain grinding machine. We are apt to recall the all-round machinist of a quarter of a century ago who would, no doubt, hold up his hands in horror at the thought of bringing oil in contact with a grinding wheel.

Various compounds are now used in lubricating work while grinding. These consist of mixtures of water, soap, oil and sulphite of soda, commonly termed sal soda. Plain water is sometimes used and while this keeps down frictional heat, its use rusts both the machine and the work. Soda water is better than plain water as the soda prevents the water from rusting. The various compounds put up especially for the purpose, however, are efficient as they have been worked out by grinding engineers after much practical experimentation. The lubricant should be supplied by the circulating pump and should flood the work at the point of grinding contact.

To produce satisfactory work, it is necessary that the grinding wheel be in condition to perform its work rapidly when taking roughing cuts and smoothly when taking finishing cuts. A satisfactory cutting surface is produced on the wheel in two ways: by dressing and truing. These expressions are sometimes confusing, but the generally accepted meaning is that dressing consists of sharpening a wheel to make it cut fast, while truing consists of imparting a surface that will leave a smooth finish.

As explained in Chapter X, wheels on cylindrical grinding machines can be dressed to advantage with ordinary star-wheel cutters held in a suitable holder. For many years, the man who brought an emery-wheel dresser, as this tool is called, near a precision grinding machine was ridiculed, but latter-day experimentation has proven that grinding-wheel dressers of the Huntington type have their part to play in cylindrical grinding as well as for dressing wheels for rough grinding work.

There are several good reasons for using dressers of the kind under consideration, not the least of them being the present high cost of the bort diamonds generally used heretofore. It must be remembered, however, that the grinding-wheel dresser has its limitations. On the cylindrical grinder, its usefulness ends in preparing wheels for roughing operations. To true the face of the wheel for taking finishing cuts, the diamond should be used.

In dressing the wheel, the dresser should be held in a special holder, such as the one shown in Fig. 104, which shows a special Huntington dresser in use on a Norton grinding machine, and fed past the wheel with a rapid, even motion.

In truing a wheel to take smooth finishing cuts, the diamond tool should be held securely in the holder provided for it and fed past the wheel with an even motion, taking a very light cut. An expert operator knows how to use a diamond advantageously to bring about the desired results and this knowledge is gained by practice alone. In both truing and dressing operations, the wheel should be flooded with a liberal stream of lubricant.

Chatter marks on finished work are sometimes present and they can be attributed to a number of causes. Those not thoroughly conversant with the art of cylindrical grinding, often lay chatter marks to the gearing in the headstock. It is true, of course, that incorrectly fitted gears cause chatter marks. This cause, however, is not of common occurrence. The unskilled operator who desires to "wish" chatter marks on the headstock gearing generally cites the fact that an incorrectly fitted rack and bull gear on a metal planer leaves marks in the finished work and thus tries to establish a parallel case with the grinder. This comparison is not logical. The planer leaves marks in the finished work because the gearing is allowed to bottom either through wear in the ways or from chips and dirt that become imbedded in the bottom of the bull gear and rack teeth. With the grinder, there are no chips or dirt to work into the gearing and, furthermore, wear in the gears in question does not cause them to bottom.

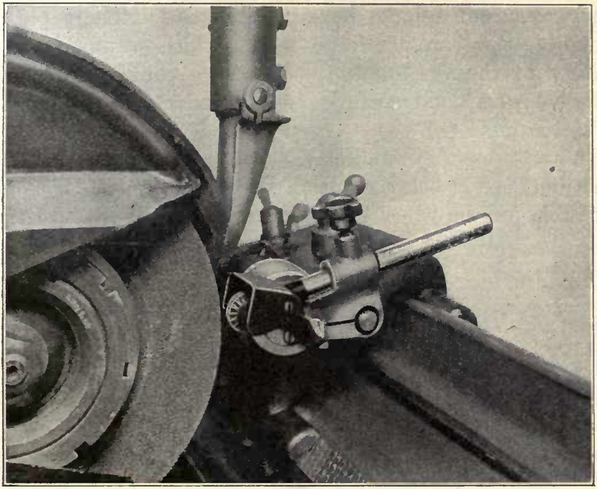

Fig. 104.—Dressing the wheel on a Norton grinding machine with a Huntington star-wheel dresser.

Chattering in connection with the plain grinder can be laid to many causes, among them being the following: Centers poorly fitted, wheel slide or spindle loose, head or tailstock loose, incorrect relation between wheel and work speed, lack of sufficient steady-rests, improperly trued wheel, wheel out of balance and end play caused by the work not being sufficiently supported by the centers. When chattering occurs, the first thing to do is to go over the machine carefully, inspecting all adjustments, and if this does not correct the evil, some of the other above-named causes should be investigated.

For the economical and efficient operation of any cylindrical grinding machine, it is very necessary that the wheel be in as perfect running balance as possible. Wheels that are out of balance cause vibration and chatter marks; they wear out spindle boxes rapidly and if badly out of balance, they are liable to burst, which means possible injury to the workman, the loss of a comparatively expensive wheel and curtailment of production until a new wheel is mounted.

Wheels, as they come from the grinding-wheel manufacturer, are in balance within very close limits. It is impossible for the wheel manufacturer to make a wheel that is in perfect running balance without some special treatment owing to the fact that the wheel texture is apt to vary slightly. Thus, one side of the wheel may be a little heavier than the opposite side.

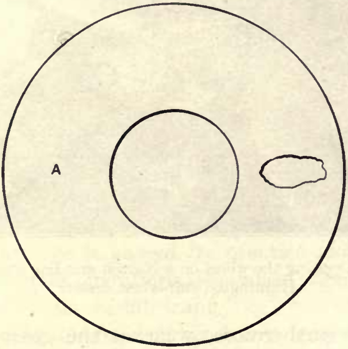

Fig. 105.—Balancing a grinding wheel by chipping the heavy side.

One method of balancing a grinding wheel is shown in Fig. 105. In this case, the light side of the wheel is at A and the opposite, or heavy side, is chipped away enough to counterbalance the unequal weight. This work is done with an ordinary cold chisel, but care must be used, otherwise the wheel will be broken. The Landis Tool Co. make use of the device illustrated in Fig. 106. This consists of two balancing blocks which have radial movement in an annular groove turned in the wheel holder. The blocks can be securely clamped in the desired position by means of screws. It is a comparatively easy matter to balance a wheel that is mounted on a holder of this type as all that is necessary is a simple adjustment of the balancing blocks.

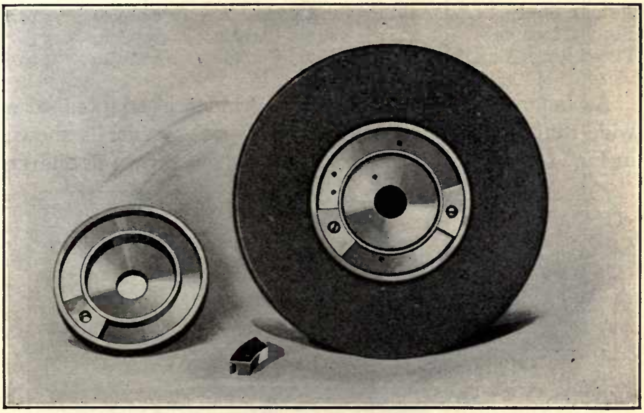

Fig. 106.—Landis wheel-holder equipped with balancing blocks.

In selecting wheels for use on the plain cylindrical grinder, it must be borne in mind that rapid production depends on the wheel used more than it does on any one other factor. It is impossible to give hard and fast rules governing the selection of wheels for various kinds of work owing to the fact that local conditions often have to be taken into consideration. The following grits and grades, however, have been found to give satisfaction for the various classes of work listed. The grades are given in the writer's proposed grade scale.

MATERIAL	ABRASIVE	GRIT	GRADE
Hard Steel	Alumina	30 to 40	5 to 7
Soft Steel	Alumina	30 to 40	5 to 6
Cast Iron	Silicon Carbide	30 to 36	4 to 7
Brass	Silicon Carbide	30 to 40	8
Chilled Iron	Silicon Carbide	36	8
Pistons, Cast Iron	Silicon Carbide	24 to 36	4 to 6
Pistons, Steel	Alumina	24 to 36	4 to 6
Pistons, Lyanite	Silicon Carbide	30 to 40	5 to 7
Piston Rings, Cast Iron	Silicon Carbide	36 to 40	4 to 6

As before stated, the universal grinder is adapted to a wide range of work. A typical universal grinder is shown in Fig. 107. This machine is made by the Brown & Sharpe Mfg. Co., Providence, R. I. The average universal grinder is somewhat smaller than the plain grinder ordinarily seen. The machine illustrated takes work 30 inches long and will swing 12 inches over the platen while the wheel used is 12 inches in diameter and from 3/8 to 1 inch thick.

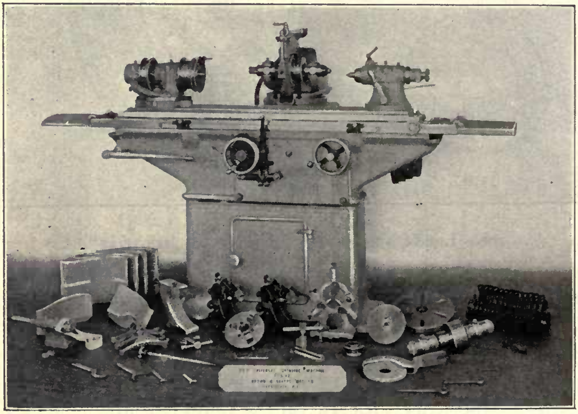

Fig. 107.—Brown & Sharpe 12x30-inch universal grinding machine.

The headstock of any universal grinder is supplied with a live spindle which can be locked when it is desired to grind on dead centers. The live spindle adapts itself to a variety of work, principally internal grinding, in which

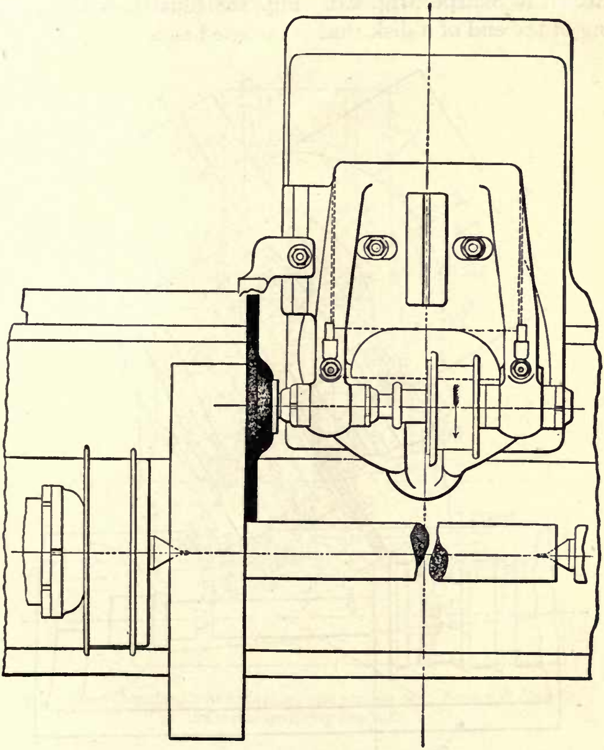

Fig. 108.—Grinding the side of a disc on a Brown & Sharpe universal grinding machine.

case a chuck for holding the work is screwed on the nose of the spindle. The base of the headstock on the machine shown swivels and this permits the machine to handle a variety of angular work. The wheel slide also swivels, which feature is often taken advantage of in grinding abrupt tapers on work that is held between centers.

The following examples, which graphically illustrate the adaptability of the universal grinder, are furnished by the Brown & Sharpe Mfg. Co. Fig. 108 illustrates the grinding of the end of a disk that is fastened to a shaft, the work being held between centers. The grinding wheel is placed on the end of the spindle.

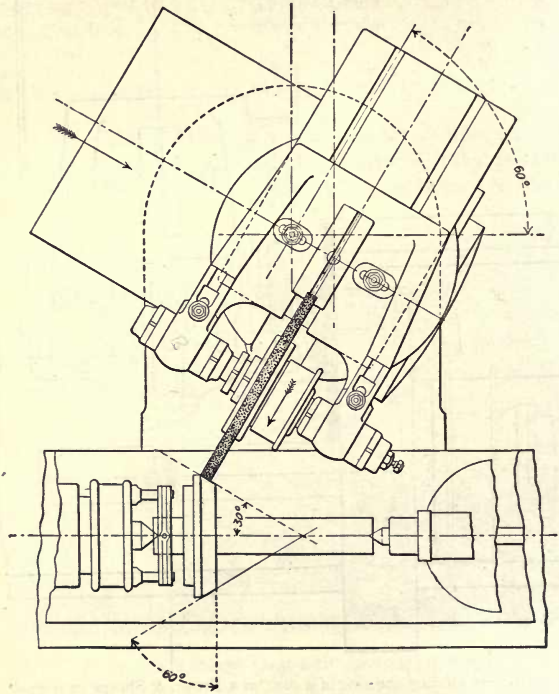

Fig. 109.—Grinding an abrupt taper on a Brown & Sharpe universal grinding machine.

In Fig. 109 is shown the operation of grinding an abrupt taper. In this operation, the swivel platen remains parallel with the ways of the machine as in plain grinding, but the wheel bed is set to the required angle which brings the line of motion of the wheel slide, when operated by the cross feed, parallel with the taper to be ground. The wheel platen is set at right angles with the line of movement of the wheel slide, indicated by the arrow, and the face of the wheel is thus brought parallel with the line of the desired taper. The work is revolved by the dead-center pulley as the illustration shows, and the wheel is traversed over the work by means of the cross feed.

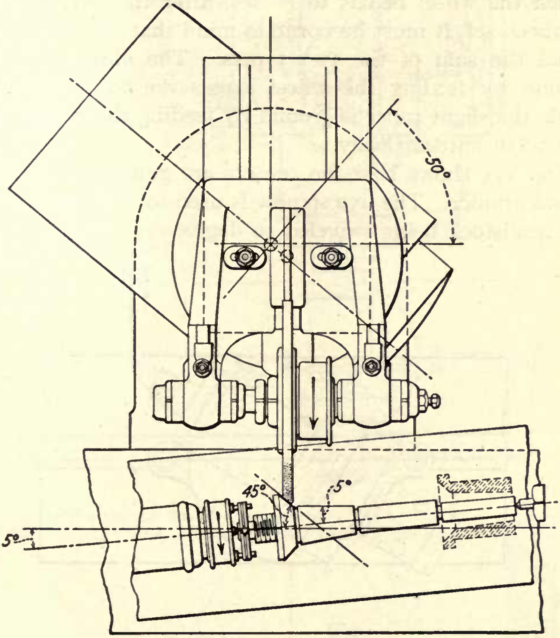

Fig. 110.—Grinding two tapers at one setting on a Brown & Sharpe universal grinding machine.

It is often advantageous to grind two tapers with one setting of the machine as shown in Fig. 110. The Five-degree taper is obtained by setting over the swivel plate while the forty-five-degree taper is obtained by setting the wheel bed to the desired angle. In obtaining the angle at which the wheel bed is to be set, after the swivel platen has been set, it must be borne in mind that the angle must equal the sum of the two tapers. The abrupt taper is ground by feeding the wheel across the work by hand, while the slight taper is ground by feeding the platen back and forth automatically.

Fig. 111 shows how the centers are ground on the universal grinder. The live spindle is used to drive the center, the headstock being swiveled 30 degrees.

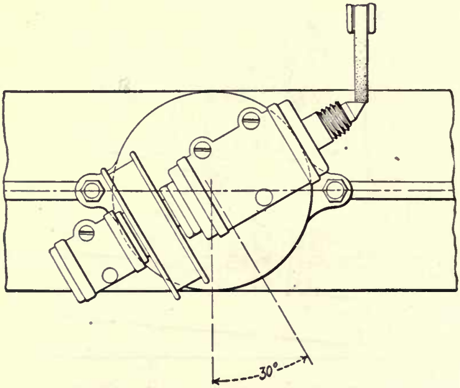

Fig. 111.—Grinding a center on a Brown & Sharpe universal grinding machine.

An interesting operation is shown in Fig. 112 which consists of grinding the sides of such work as hardened collars, washers, etc. The work is held in the chuck which is screwed to the nose of the spindle, while the headstock is set at 90 degrees with the travel of the platen. The wheel

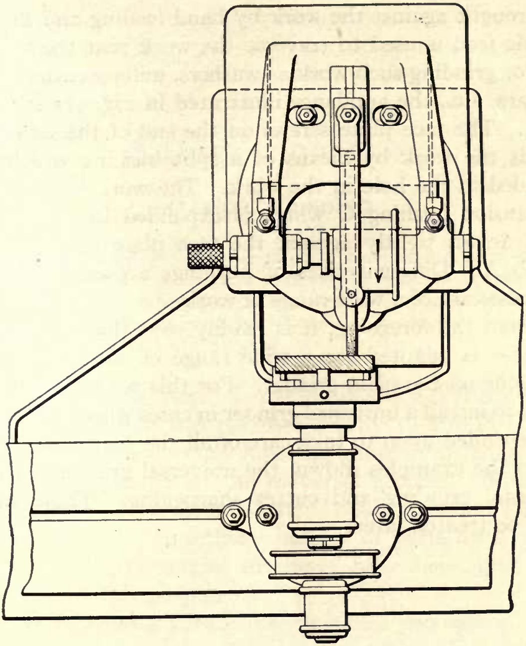

Fig. 112.—Grinding the side of a disc which is held in a four-jaw chuck on a Brown & Sharpe universal grinding machine.

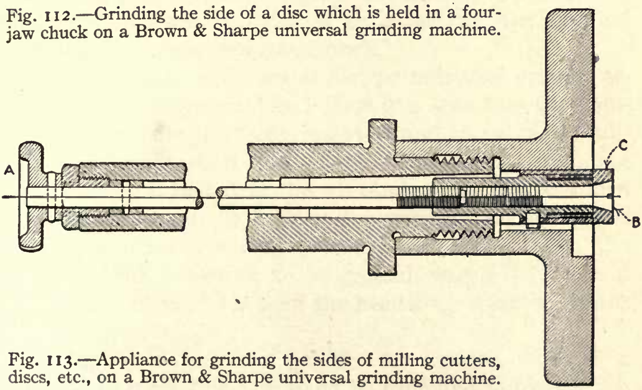

Fig. 113.—Appliance for grinding the sides of milling cutters, discs, etc., on a Brown & Sharpe universal grinding machine.

is brought against the work by hand feeding and the automatic feed is used to traverse the work past the wheel.

For grinding such work as washers, milling cutters, thrust collars, etc., the appliance illustrated in Fig. 113 is convenient. The face plate screws on the end of the spindle and holds the work by means of a split bushing which is expanded in the hole in the work. The work is held by the expansion bushing C which is expanded by the screw B and drawn tightly against the face plate by turning the knob A. Different sizes of bushings are readily inserted to take care of a wide range of work.

From the foregoing, it is readily seen that the universal grinder is adapted for a wide range of work that cannot be done on the plain grinder. For this reason, it is a good plan to install a universal grinder in cases where one machine is depended upon to take care of all the shop needs. Aside from the examples shown, the universal grinder is used for internal grinding and cutter sharpening. These subjects will be treated later.

CHAPTER EIGHTEEN

INTERNAL GRINDING

Internal grinding machines—Internal grinding on universal grinder—Setting up universal grinder for internal work—Grinding double tapers—Automatic grinders—Grinding holes in spur and bevel gears—Chucks—Wet and dry grinding—Proper speeds—Selection of wheels—Operating of cylinder grinders—Cylinder grinding.

BEFORE the advent of the automobile industry, internal grinding was confined chiefly to the tool-room and consisted of accurately finishing gauges, bushings, etc., the work being done on the universal grinder. With the growth of the automobile industry, however, came the demand for finishing countless numbers of parts by internal grinding and thus special machines have been gradually developed for this purpose.

Special internal grinding machines are production tools just as the plain cylindrical grinder is a production machine while the universal grinder is still used for the internal grinding of general tool-room work.

Fig. 114 shows a Brown & Sharpe universal grinder arranged for internal grinding. Here it is seen that the regular wheel spindle has been removed and in its place substituted a jack shaft that drives the internal grinding fixture which is bolted to the wheel platen. It is also seen that the wheel spindle bracket is reversed. As the arrows show, the grinding-wheel spindle rotates away from the operator while the work to be ground, which is held in a chuck screwed to the nose of the headstock spindle, rotates toward the operator.

Setting up a universal grinder for internal work is a simple operation, but care must be exercised in setting the headstock to bring its spindle in line with the travel of the platen if parallel work is desired. It is almost impossible to accomplish this by relying on the graduations of the headstock swivel and on the platen swivel and as the cut-and-try method is both slow and uncertain, other means to the desired end are generally used by the mechanic who desires to turn out accurate work.

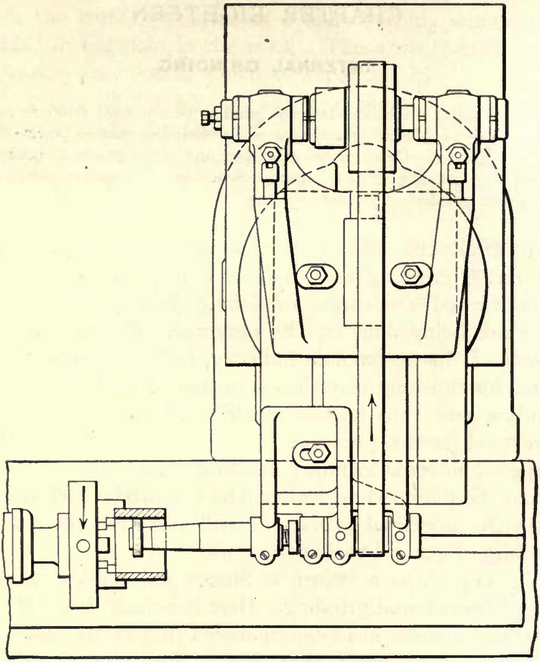

Fig. 114.—Brown & Sharpe universal grinding machine arranged for internal grinding.

The simplest and most practical method for accomplishing the desired result that has come to the writer's notice, is described below: First the chuck is screwed on the headstock spindle which is unlocked to allow it to rotate. Next a piece of round stock somewhat longer than the depth of the hole to be ground is clamped in the chuck jaws, allowing several inches to project. Then a relief is ground close to the chuck jaws. This is for the grinding wheel to dwell in during reversal in the subsequent operation. Then the outside of the piece is ground true and calipered carefully and the headstock reset until the wheel grinds the test piece parallel. When parallelism results, it is evident that the headstock spindle is parallel with the travel of the platen, which is the situation necessary for accurate internal grinding. The test piece is now removed and the machine set up for internal grinding. The operator need not pay attention to parallelism after this as it is assured. He is then free to concentrate his efforts to getting his work to the desired size.

In grinding tapers, the headstock is set over to the desired angle and the work, after being ground, is tested with a taper gauge on which a little Prussian blue is smeared. This furnishes a ready means of detecting any errors that exist. It is readily seen that it is a more simple matter to set up the internal grinding attachment to grind tapers than it is to grind absolutely parallel, that is by the cutting-and-trying method.

The machine shown in Fig. 115 is arranged to grind a double taper. The swivel platen is set over to give the five-degree taper while the wheel platen is set to impart the forty-five-degree taper. From these illustrations, it is seen that the universal grinder can be adapted to a variety of tool-room work. In fact, it can handle some varieties of work that are beyond the range of the production internal grinder. For this reason, internal grinding on the universal grinder will always be a part of tool-room work.

Special internal grinding machines are designed as production tools for rapidly and accurately finishing more work in a given time than it is possible to turn out on the universal grinder. Broadly speaking, these machines can be divided into two groups, those having hand feed and those equipped with automatic feed. This feature applies to the platen.

Machines equipped with hand feeds are adapted for grinding such work as transmission gears, bevel gears, pinions, bushings, or, in fact, any kind of short work. Experience has proven that on work not over three inches long, the average operator will turn out more work with a hand-fed machine than he will with a machine equipped with automatic feed.

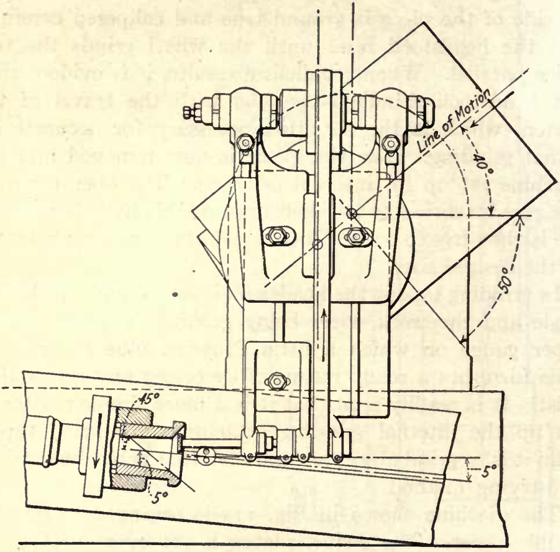

Fig. 115.—Grinding a double internal taper on a Brown & Sharpe universal grinding machine set up for internal work.

The machine illustrated in Fig. 116 is a product of The Heald Machine Co., Worcester, Mass., and is thoroughly automatic in all its operations. It swings work 15 inches in diameter and will grind holes 11 inches deep. The headstock is swiveled to permit grinding taper work and different speed changes are provided for roughing and finishing operations. The cross feed is automatic in operation and can be set to release when a given size has been reached. A novel feature of this machine is the protection guard over the wheel. This comes to the position shown in the illustration when the platen is moved away from the work and its object is to prevent the operator's hand from coming in contact with the swiftly revolving wheel should his hand slip while gauging his work.

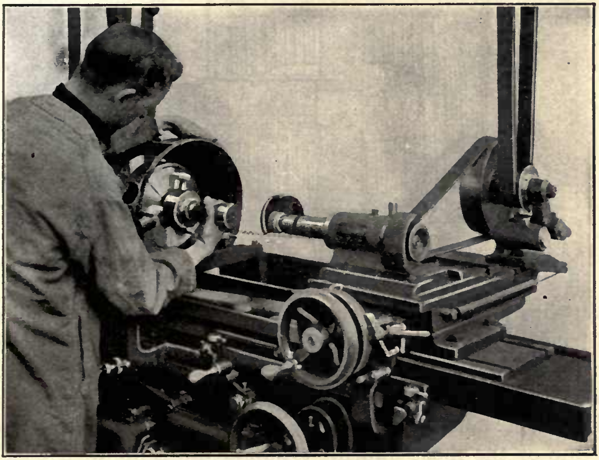

Fig. 116.—Heald automatic internal grinding machine.

By again referring to Fig. 116, it is seen that the work is held in a three-jaw chuck. This procedure is satisfactory in cases where the wall of the bushing, or other work being operated upon, is comparatively thick. With thin-walled bushings, the pressure brought to bear by the chuck jaws is apt to cause distortion if the work is gripped tight enough to hold it securely. To overcome this difficulty, many novel devices have been originated. One of these is shown in Fig. 117. This is a Heald universal bushing chuck. It consists of a body (1) which screws on the spindle, a movable cap (2), and adjustable threaded collar (8), and another collar (3) which centralizes the locating plug (4). The bushing to be ground is shown at 5. As the illustration shows, the part of the plug that engages the bushing is triangular in shape (6), while the end that engages the threaded collar is round as seen at 7. As this chuck grips the work at its ends, it holds it securely without danger of distortion.

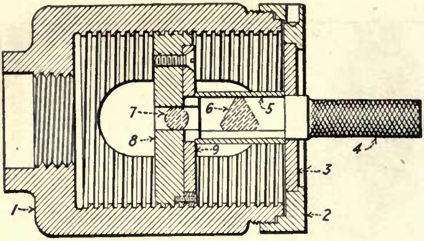

Fig. 117.—Heald universal bushing grinding chuck.

One of the most difficult grinding problems with which the production engineer has to contend, is grinding the holes in spur and bevel gears as used in automobile transmissions and differentials. These gears are hardened and heat-treated, thus they come to the grinding department in a slightly distorted condition. For smooth running, it is obvious that the pitch line of the gears must run as true as possible after assembling. To this end, special chucks have been developed for holding these gears in which the location is taken from the teeth at the pitch-line circle.

Fig. 118 illustrates three common methods for locating gears as described by the Heald Company. In A, the gear is held wholly by the outside diameter. In B, jaws of special shape are employed, which grip the gear at the bottom of the tooth space, while in C rolls are used which make con-

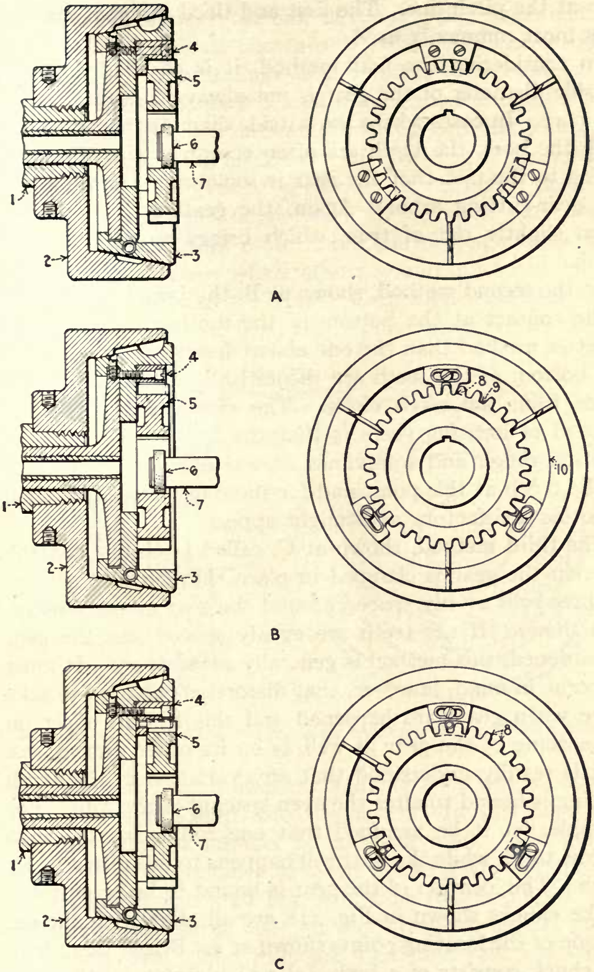

Fig. 118.—Three types of chucks used in grinding the holes in gears on a Heald internal grinding machine.

tact at the pitch line. The first and third methods are the ones most commonly used.

In considering the first method, it is obvious that the outside diameter of the gear is not always concentric with the bore. In cases where the outside diameter is concentric with the bore, the teeth are often eccentric with the hole, owing to the fact that the gear is sometimes a loose fit on the gear-cutting arbor. Again, the gear-cutting arbor is often slightly out of true, which brings about the same result.

In the second method, shown at B, the jaws of the chuck make contact at the bottom of the tooth space. This is a better method than the one above described inasmuch as the bottom of the teeth are theoretically all the same distance from the pitch circle. The disadvantages of this method of locating gears is that the bottom of the teeth is often rough and sometimes curved owing to the shape of the tooth at this point and for these reasons the method is not as satisfactory as it might appear.

The third method, shown at C, called pitch-line control, wherein the gear is clamped in place through the medium of three rolls evenly spaced around the gear as the illustration shows. If the teeth are evenly spaced and the gear unhardened, this method is generally satisfactory. It must be borne in mind, however, that distortion is bound to take place when gears are hardened and this has an effect on the spacing of the gear as well as on its other dimensions.

It is readily understood that any variation in the tooth spacing is bound to alter the even spacing of the rolls. For example, let it be assumed that one roll is located in a narrow tooth while the next roll happens to fall into a wider tooth. The location of the gear is bound to be eccentric.

The chucks shown in Fig. 118 are all alike with the exception of the locating points shown at 4. Briefly described, the chuck consists of a body (2) which screws to the nose of the spindle and a collet (3) which is split in three places and drawn into the chuck by means of a drawing rod which works through the hole in the grinding-machine head spindle. The gear is shown at 5, while 6 is the grinding wheel and 7 the grinding-wheel spindle. The body of the chuck is generally made of cast iron, while the collet is steel and insured against reasonable wear by case hardening.

For various work, aside from the grinding of gears, these collet chucks are to be preferred to ordinary three-jaw chucks because the latter soon fill up with particles of metal ground from the work which calls for frequent cleaning.

For grinding gears where accuracy and quiet running are paramount factors, the Heald Company have developed the chuck shown in Fig. 119. This chuck works on the multiple-roll system and has a single split ring which collapses as it is forced into the chuck. In this method of locating gears, a number of rolls are used. The number depends on the number of teeth in the gear. In the gear shown in the chuck in Fig. 119, nine rolls are used. The minimum number of rolls to use, however, should not be less than five. The rolls are hardened and are carried loosely in a retainer ring which keeps them in the proper position and in shape to be readily handled by the operator. In Fig. 119, the gear (7) and the rolls (6) are inserted in a

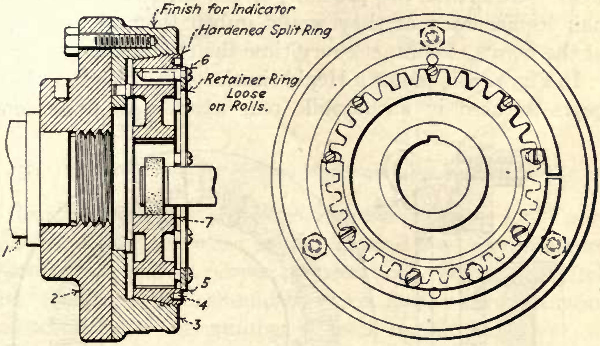

Fig. 119.—Heald multiple-roll chuck for holding gears for internal grinding.

split ring (4) made straight inside and tapering on the outside with a short thread to enable it to be screwed in and out of the body of the chuck. The body (3) is mounted on a face plate (2) which is screwed on the chuck spindle (1).

The object of making the chuck body in two pieces, 2 and 3, is to afford ready means for keeping the chuck running absolutely true. By referring to Fig. 119, it is seen that part of the outside of the piece (3) is ground cylindrical to make a path for the indicator to register on while truing up the chuck. This feature allows the operator to check up the running of the chuck as frequently as desired. The split ring (4) is hardened to insure it against wear. Otherwise the pressure of the rolls would soon impair its accuracy as they would imbed themselves slightly at the points of contact every time the chuck was tightened.

In Fig. 120, is shown a Heald chuck for locating large bevel gears as used in automobile rear axles. An unhardened gear (2) is mounted on the face plate, which is recessed slightly to center the locating gear so that it will run true at all times. The gear to be ground (3) is located with its face to the locating gear and is held in place by three clamps

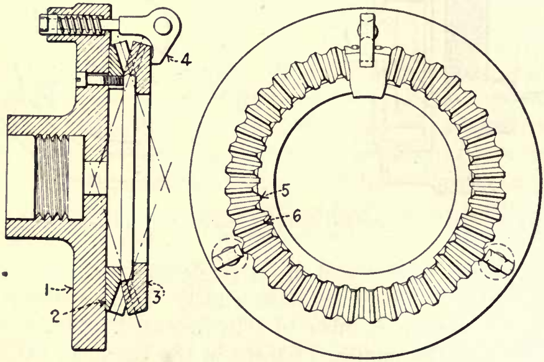

Fig. 120.—Heald chuck for locating large bevel gears for internal grinding.

shown at 4. As the illustration shows, a portion of the teeth of the locating gear are cut back as at 5 leaving full-length teeth (6) at three points of the circumference. This three-point contact insures the gear against rocking on its seat.

Another novel gear chuck is shown in Fig. 121. This chuck was originated by the Heald Company and is used for grinding bevel pinions. In reality it is a modification of the principle used in the chuck shown in Fig. 119. Taper rolls are used which are spaced around the circumference to locate the gear in proper position according to the pitch line. The taper rolls should be three, five or seven in number, according to the number of teeth in the gear.

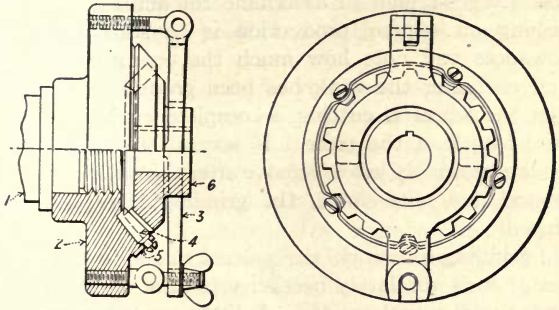

Fig. 121.—Heald chuck for locating bevel pinions for internal grinding.

The method of holding the rolls allows for a certain amount of play for the purpose of taking care of slight variations in the gears, due to hardening.

Referring to Fig. 121, 1 is the spindle, 2 the chuck body, 3 the clamp arms that hold the gear in position, 4 the locating rolls and 5 the retaining ring in which the rolls are mounted.

While the present-day internal grinder is a production machine in every sense of the word, it is not a tool for "hogging" off stock. It is a machine especially designed for finishing operations. For this reason, attention should be paid to the amount of stock left for grinding, especially in hardened work.

The amount to be left for grinding depends on the diameter of the hole and its length. In considering hardened work, it is very evident that comparatively long pieces will warp more than shorter ones. On short pieces with holes 1-1/2 inches in diameter and down to 1 inch, 0.008 to 0.010 inches is sufficient. On smaller holes, the allowance can be decreased. Larger holes require a more liberal allowance. A good plan to determine the amount to leave for finishing on regular production is to start with liberal allowances and note how much the operator has left to grind out after the work has been ground round, that is when the wheel is cutting a complete circle through the entire length of the piece. If several thousandths of an inch are invariably left to remove after the work has assumed a round and true shape, the grinding allowance can be reduced.

In grinding soft work, the general rule is to leave a little more than is absolutely necessary to true up the work and grind out the tool marks. A little experimentation will determine the correct amounts in all cases.

Internal grinding is done both wet and dry. The general accepted rule is to grind cast iron and bronze dry and to grind steel wet. However, this rule does not have to be adhered to without exceptions as steel is often ground dry with satisfactory results. In wet grinding, the hood over the chuck keeps the spray from flying. In dry grinding, an exhaust pipe draws away the dust through the hollow-head spindle. This protects the operator and keeps the machine clean at the same time.

Wheels on internal grinders are run at peripheral speeds ranging from 4,000 to 6,000 feet per minute while the work speed can vary from 25 to 100 feet per minute. There is no hard and fast rule to refer to, but the experienced operator judges the correct combination of wheel and work speed by the quality and quantity of the output and the performance of the wheel.

In selecting wheels for internal grinding, carbide of silicon is used for cast iron and bronze while alumina abrasives should be used on steel, both hard and soft. For the average run of work, grits from 36 to 50 are used in grades 4 to 6 on the writer's grade scale. For grinding cast iron, the grades are somewhat softer, from 2 to 5. As a general rule, soft wheels give the best results. The reason for this lies in the fact that there are comparatively few cutting points on these small wheels, and if they do not wear away readily, bringing new cutting points into action, the wheel glazes quickly.

Careful attention should be given to keeping wheels on internal grinding machines true. They should never, under any circumstances, be dressed with a star-wheel dresser although a carbide of silicon brick is a good medium to use, provided it is held securely in a holder that is fastened to the platen on the machine. The operator should never attempt to true the wheel by holding the brick in his hand as this gives poor results. The diamond is an ideal tool for truing these wheels, but the present cost of bort stones makes their use prohibitive in cases where another medium will serve the purpose equally well.

Because of their high rotative speed, internal grinding machine wheel spindles should be properly lubricated with a grade of oil that is especially adapted for the purpose. There is a great difference between ordinary slow-running bearings and those of a high-speed grinding spindle. The former takes a heavy oil which forms a thick film on which the journal rests. With the latter, the bearings are adjusted very closely and for this reason a light-bodied, high-grade oil should be used.

A special internal grinding machine that is widely used in the automobile and airplane engine industry is shown in Fig. 122. This is a cylinder grinder made by the Heald Machine Co. With the development of the automobile industry, considerable difficulty was experienced in finishing cylinders by ordinary methods, that is, boring or reaming. This was due to several factors, chief among them being the fact that cylinder walls are comparatively thin, thus they sprang away from the finishing tools which left the cylinder considerably out of true. Again, internal-combustion engine cylinders should be made of a comparatively hard, close-grained iron which is always difficult to machine accurately. With these factors in mind, engineers turned to the grinding machine for a solution of the difficulty.

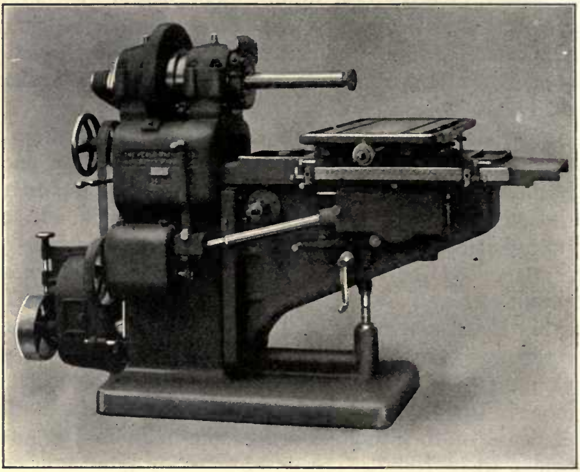

Fig. 122.—Heald cylinder grinding machine.

The ordinary single cylinder of other days was a difficult piece to grind inasmuch as it could not be rotated readily—a special grinding fixture was necessary which had provision for running and balancing each individual cylinder. Again, it would be impossible to rotate a cylinder of the type illustrated in Fig. 123, which is cast *en bloc*. Therefore the machine shown in Fig. 122 was developed. The base and upright of this machine are cast in one piece. The wheel spindle is mounted at the top of the upright and is of the planetary type. The main spindle revolves to carry the wheel around the wall of the cylinder to be ground while the supplementary spindle rotates rapidly to impart motion to the grinding wheel. A special adjustment, graduated in thousandths of an inch, determines the eccentric setting of the wheel spindle.

The platen can be adjusted at right angles to the wheel spindle by means of a screw feed equipped with a micrometer dial, which feature is made use of in grinding cylinders of the type shown in Fig. 123. The platen is fed longitudinally by means of an automatic feed, the movement being controlled by adjustable dogs that actuate the reversal at each end of the stroke.

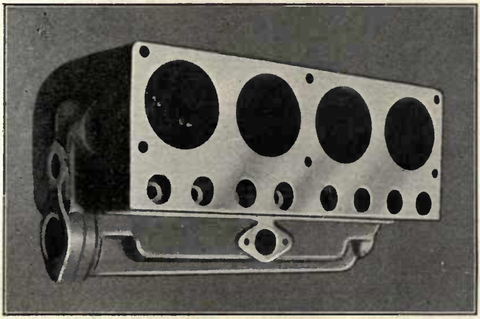

Fig. 123.—Multiple cylinder for an automobile engine as finished by grinding.

The operation of grinding the cylinder shown in Fig. 123 is shown in Fig. 124. The cylinder is mounted on a special angle-iron fixture that is clamped to the platen of the machine. One bore of the cylinder is ground at a time and completely finished before moving the platen to grind the next hole. The amount to leave for grinding depends upon the size of the cylinder and the condition in which the holes are left by the rough boring operation. Usually cylinders are rough bored with a coarse feed which leaves deep tool marks. This is advantageous as the tool marks exert a shearing motion of the wheel which helps to keep it true. If the holes are accurately spaced in the boring operation from 0.10 to 0.15 inches below the bottom of the boring tool marks are sufficient for finishing. This is not a hard and fast rule by any means as local conditions must be taken into consideration, thus experimentation is the only accurate guide. If the operator finds that he has a large amount of stock to remove after the holes show up true, the amount left for finishing should be reduced and, on the other hand, if the holes fail to "grind out" the allowance must be increased. It is best when first installing a grinder for this work to start with a liberal allowance which can be reduced if too much stock has been left.

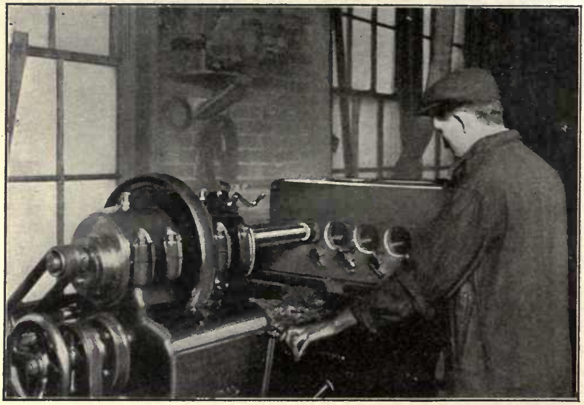

Fig. 124.—Grinding a four-cylinder unit for an automobile engine on a Heald cylinder grinding machine.

Cylinder grinding is a precision operation in every sense of the word, especially when finishing cylinders for aircraft engines. For this reason, the wheel must be kept true and in cutting condition at all times. By again referring to Fig. 124, it is seen that there is a bracket set at an angle under each cylinder location. These are for holding a diamond tool used for truing the wheel. In this illustration, the diamond tool is fastened in the bracket at the right of the cylinder being ground.

For grinding cast-iron cylinders, carbide of silicon wheels should be used. The grits commonly furnished run from 30 to 36 and the grades from 2 to 4 on the writer's proposed grade scale. For grinding steel cylinders, alumina abrasives should be used. The grits in this case run from 30 to 40 and the grades from 1 to 4.

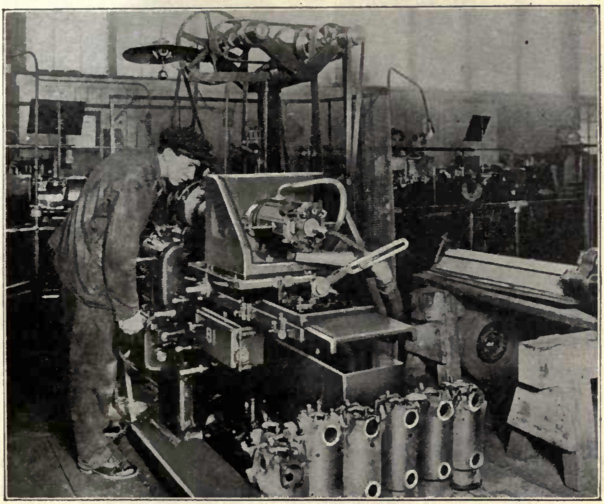

Fig. 125.—Grinding Hall-Scott airplane engine cylinders on a Heald cylinder grinding machine.

Two important factors involved in cylinder grinding are: keeping the work cool and carrying away the dust. It is needless to say that the work must be kept cool if accurate sizes are to be maintained while the dust must be disposed of to conform with the laws relative to grinding-room practice in force in the majority of states.

Excellent means to attain both these ends are illustrated in Fig. 125 which shows the operation of grinding cylinders for the well-known Hall-Scott airplane engines. The cylinder to be ground is held on a special angle-iron fixture which is clamped to the platen of the machine. Water supplied from the city mains is circulated through the water jacket by means of the connections seen at the top near the upright of the angle iron and at the end of the cylinder. The dust is exhausted by means of an air suction connected to the exhaust opening of the cylinder.

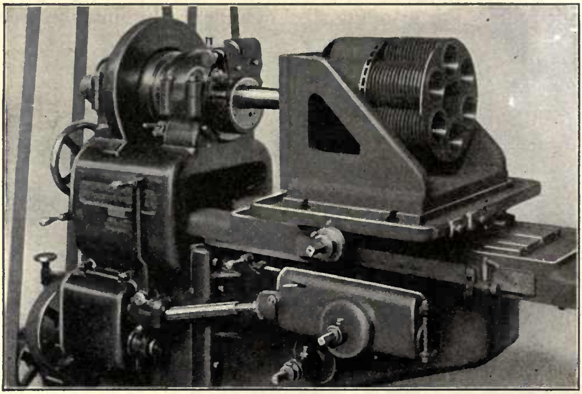

Fig. 126.—Grinding a special internal combustion engine cylinder on a Heald cylinder grinding machine.

Cylinders are often ground, however, with no provision made for water cooling, and, if the depth of cut taken is not too heavy, good results are obtained. Such a grinding operation is shown in Fig. 126. The work consists of grinding a special cylinder of the air-cooled type. The dust can be readily disposed of by placing a hood connected to the exhaust system over the end of the hole being ground.

The cylinder grinder has, without a doubt, gone a long way toward perfecting the present-day automobile and airplane engine. Ground holes are more accurate than it is possible to produce by boring and reaming and every hole can be made exactly the same size with very little trouble. Far less accuracy is required in boring, in fact, the boring operation is for roughing out only and the time spent in reaming is eliminated. Multiple cylinders are handled as easily as are single ones and interchangeability of cylinders, pistons and rings is assured. No time has to be spent in lapping a ground cylinder and a maximum amount of compression is always possible.

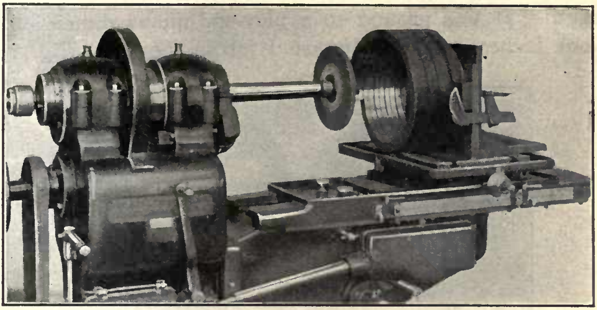

Fig. 127.—Grinding the hole in a coil spring on a Heald cylinder grinding machine.

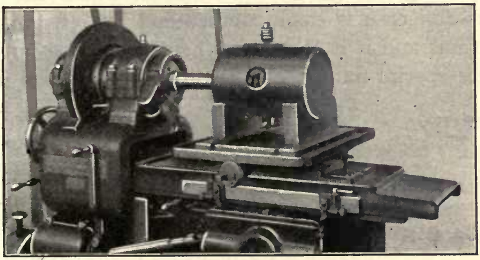

Fig. 128.—Grinding a hole in a piece of tile pipe on a Heald cylinder grinding machine.

Aside from cylinder grinding, the cylinder grinder lends itself readily to a number of operations that would be difficult to handle by ordinary methods. A novel grinding operation of this kind is shown in Fig. 127. This shows a flat, coiled spring 14 inches in diameter and 10 inches in length. It was ground to a plus-and-minus dimension of 0.001 inches. Another unusual job is shown in Fig. 128.

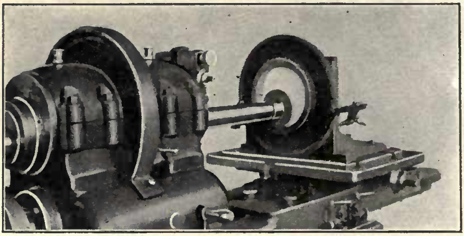

Fig. 129.—Grinding a hole in a large worm gear on a Heald cylinder grinding machine.

This is a piece of tile pipe 16 inches long and 8 inches inside diameter and was ground to within a limit of 0.001 inches, plus-or-minus. Fig. 129 shows a large worm gear mounted for internal grinding. The manner in which the work is held in each case is easily understood by referring to the illustrations and it is seen that these pieces did not require elaborate special fixtures for holding them in position.

CHAPTER NINETEEN

SPECIAL GRINDING OPERATIONS

Grinding calender rolls—Special grinding machines—Roll grinders and roll grinding—Corrugating flour-mill rolls—Grinding crankshafts—Grinding cam shafts—Locomotive valve gears.

IN this category can be included a number of grinding operations that are interesting because of the ingenuity shown in adapting the grinding wheel to unusual problems. They are also very important operations. One unusual grinding operation consists of finishing the calender rolls of Fourdrinier paper-making machines. The machine takes its name from Henry Fourdrinier who introduced the first paper-making machine into England. After the paper has been formed and partially dried, it passes through a series of calender rolls which impart a smooth finish. If paper were not calendered, it would have the appearance of a sheet of newspaper that had been wet and afterward dried. The largest stack of calender rolls in use at the present time in the United States or Canada is shown in Fig. 130. The relative size of the stack can be judged by the man standing at the left. When it is taken into consideration that these rolls are made of hard chilled iron and that they must have a mirror-like finish, to say nothing of fitting together so perfectly that light will not show between them, it is seen that roll grinding is indeed an exacting operation.

These rolls are in use at the Ontario Paper Co., Thorold, Canada, and are designated as follows: Bottom, next to bottom, intermediates and top. All these rolls are 196 inches long. The bottom roll is 30 inches in diameter and weighs 44,000 pounds. The next to bottom roll is 20 inches in diameter and weighs 18,000 pounds. The intermediate rolls are seven in number, 14 inches in diameter and weigh 9,000 pounds each, while the top roll is the same diameter and weight as the next to bottom roll.

As the work of calender rolls is nothing more or less than to press paper, it would appear that they should stay in shape indefinitely, but this is not the case. The constant rolling action gradually affects the mirror-like finish and, again, the "doctors," which are thin plates of specially tempered steel used for scraping them, sometimes leave scratches. What is termed a "plug" in paper-mill parlance often occurs. As the paper maker says: "A plug plays the mischief with the rolls." It occurs usually when the web of paper breaks and banks up and a large wad is pulled between the rolls. When this happens, one roll may stop

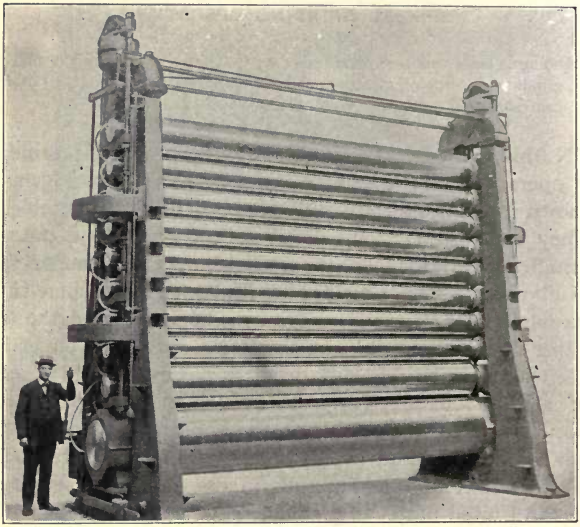

Fig. 130.—The largest stack of calender rolls on the American continent.

revolving while the next roll to it continues to revolve. Under these conditions, a flat spot is sometimes worn on the roll.

It will be seen that a special grinding machine is necessary to keep the calenders in condition. The majority of paper mills keep a few spare rolls in stock which are substituted for worn ones. Most paper mills also have a completely equipped grinding department which saves the time and expense involved in cases where rolls are sent to a distant point for grinding.

As stated in the introduction, roll finishing was one of the first attempts at cylindrical grinding. The rolls in use at that time, some 50 years ago, were, of course, much smaller than the ones shown in Fig. 130. A typical old-time stack, some 50 years old, is still running near Ansonia, Conn., and consists of the following: A top roll 10 x 50 inches weighing about 1,225 pounds, a bottom roll of the same dimensions and weight, and four five-inch intermediate rolls weighing a little over 300 pounds each.

Since the original paper machine, the prototype of the present-day Fourdrinier machine, was invented in 1798 by Louis Robert in France, it follows that the early calender rolls were not finished by grinding. The question naturally arises: "How were these hard rolls finished with the proper degree of smoothness to calender paper?" It is the writer's opinion that these old-time rolls were not chilled rolls but simply hard, charcoal-iron, sand-cast rolls. Thus, they could be finished with turning tools, just as roll turners in steel mills finish the passes on rolling-mill rolls at the present time.

It is definitely known that hard, chilled-iron rolls were made fifty years ago and that they were finished by grinding, probably with hand-made grinding wheels consisting of emery bonded together with glue or shellac. Who made the first grinding machine for this purpose, however, is a matter of conjecture. The writer has made diligent search, but is unable to throw any light on the subject.

A modern roll-grinding machine is shown in Fig. 131. This machine is a product of the Farrel Foundry & Machine Co., Ansonia, Conn., who are the makers of the rolls illustrated in Fig. 130. As the illustration shows, this machine differs radically from machines for cylindrical grinding as described in a previous chapter. Roll grinding is a trade in itself and its successful prosecution is possible only with machines built especially for the purpose.

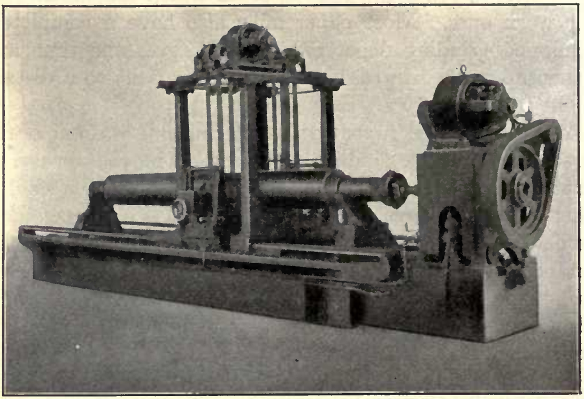

Fig. 131.—Farrel self-contained calender-roll grinding machine.

Briefly described, the roll-grinding machine illustrated consists of a massive bed upon which the carriage, carrying two wheel heads, traverses, deriving its motion by means of an automatic screw feed. The motor for driving the wheels is mounted on a superstructure over the carriage while the carriage-driving mechanism is actuated by means of the motor seen at the right. This motor also imparts the rotary motion to the roll.

Two grinding wheels, one on either side, work on the roll simultaneously. This is for the object of expediting production and insuring a straight, true roll at the same time.

The latter feature is assured by the swing-rest principle employed in mounting the grinding wheels. This principle has been in use for a number of years. On this plan, the grinding wheels, instead of being mounted rigidly like a lathe tool in a tool post, and each wheel independent of the other, are hung or suspended from "A" frames on the wheel carriage and the wheel heads are connected by a cross bar. One moves with the other. The "A" frames and the links on which the wheel carriages are suspended are plainly shown in the illustration. The swing-rest mechanism is supported on knife edges of tool steel bearing in links which, in turn, are supported on knife edges on a connecting cross bar. This allows free lateral movement and it insures a straight roll because the straight path in which the wheels are bound to travel is not influenced by any slight irregularities in the machine bed. To use a simple illustration, the wheels pass along the rolls just as a mechanic passes a pair of calipers along a piece of shafting or other cylindrical piece of work.

When a grinding wheel is in a fixed position, as the tool in a lathe, it follows that any slight error in the alignment of the ways will be duplicated on the face of the roll. On the other hand, the grinding wheels on the swing-rest principle hang like a plummet and maintain their relative position to each other on account of the cross bar that connects them. Thus, they traverse in a straight line, and, consequently produce straight work.

Another important factor peculiar to roll grinding is that comparatively long rolls are bound to sag of their own weight.

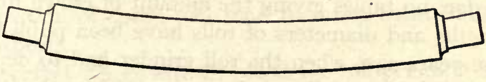

Fig. 132.—Calender roll sagged through its own weight. This illustration is exaggerated to illustrate the principle.

This is shown in Fig. 132 which is exaggerated to illustrate the principle. It is necessary to overcome this on bottom rolls, otherwise the next to bottom roll would not make contact without sagging and so on up the stack. The difficulty is successfully overcome by crowning the bottom roll so that in its deflected state its upper surface presents a straight line. This is illustrated in Fig. 133. This illustration is also somewhat exaggerated to illustrate the principle.

Fig. 133.—Crowned calender roll. The crowning compensates the error due to the roll's deflection. This illustration is exaggerated to illustrate the principle.

The mechanism for crowning is simple and easily understood. On one side of the roll grinder bed, extending nearly its whole length, is an arched plate called a master crown plate. This is not shown in Fig. 131 as it is on the other side of the machine. A toe piece on the wheel carriage travels over this master plate and, through the medium of levers, the wheel heads are moved away from the roll as the center is approached and toward the roll as the other end is approached. This imparts the desired crown. The mechanism is adjustable to impart the amount of crown necessary for different lengths and weights of rolls. It is obvious that a long, comparatively thin roll will deflect more than a roll of the same length, but of greater diameter, thus this adjustment is necessary. The amount of crown to give a roll to offset the error caused by sagging is determined by experiment alone. To the best of the writer's knowledge, no tables giving the amount of crown for different lengths and diameters of rolls have been published.

Some years ago, when the roll grinder had to depend on natural abrasives, roll grinding was a long and tedious operation. As a matter of fact, weeks were sometimes consumed in grinding a single roll in cases where it was badly out of shape. The discovery of Carborundum in 1891 proved a decided boon to roll grinding as this abrasive made it possible to accomplish in days what theretofore required weeks. At the present day, Carborundum and other carbide of silicon abrasives are used almost exclusively for grinding calender rolls.

Shellac-bonded wheels are generally used for this operation for two reasons: A shellac-bonded wheel imparts an exceedingly fine finish which is very desirable and, again, these wheels are quite durable. The grits used run from 24 to 80 in a medium soft to soft grade. For roughing operations, wheels in vitrified bond are sometimes used.

Roll grinding in itself is a comparatively simple operation. The roll is supported by its journals or necks and revolved by means of a flexible connection. The grinding should be worked wet under all conditions. The wheels are fed in until they spark heavily and enough passes taken over the roll to grind it true. It is then finished by means of light cuts, the wheels being allowed to traverse until no sparks are visible.

It is evident that a calender roll with imperfections on its surface will not finish paper satisfactorily and, for this reason, great care must be exercised in grinding and the least tendency to chattering promptly overcome. Chattering, in this case, is caused by one of three things or a combination of all three: Loose wheel spindle boxes, excessive work speed or hard wheels. When chattering occurs, the first thing to do is to see that the work speed is normal and then the wheel spindle boxes should be adjusted. If these adjustments do not overcome the difficulty, the wheel speed should be reduced slightly, and if the wheels are too hard the reduction of speed will tend to make them function as softer wheels.

The correct wheel-surface speed for roll grinding is 5,000 feet per minute. Regarding the work speed, however, there is no hard and fast rule. In visiting paper mills in all parts of the country, the writer has observed work speeds ranging all the way from 15 to 60 feet a minute and sometimes more, and in each case the operator was getting satisfactory results. Local conditions such as the grade and make of wheel used, the hardness of the roll, etc., have to be taken into consideration in determining the work speed. Roll grinding, in the strictest sense of the word, is not a production operation, thus the operator sets the work speed to suit himself and as long as he is getting a satisfactory finish he is not concerned whether the time taken to finish a certain roll is three days or a week.

Another important branch of chilled-iron grinding consists of finishing the massive rolls used in steel mills for rolling sheets and plates. This is exacting work as the faces of the rolls should be parallel in order that stock of uniform thickness can be rolled. Until a few years ago, these rolls were finished by the slower process of turning on a regular roll-turning lathe. The manufacturers of cylindrical grinding machinery, however, realizing that the steel mills offered a new field for the sale of grinding machinery, began a series of exhaustive experiments which ultimately resulted in the production of extra-heavy, specially designed machines for finishing these rolls.

The rolls in question are of various sizes ranging all the way from those used for rolling ribbon stock, which are from 8 to 12 inches long and from 6 to 10 inches in diameter, up to the massive rolls used for rolling heavy plates which are often 54 inches in diameter and 15 feet long. The small rolls can be readily ground in a regular cylindrical grinding machine and the process does not differ materially from any other cylindrical grinding job except, perhaps, that the wheel used is a trifle softer inasmuch as the amount of contact between the roll and the wheel prohibits the use of a hard or even of a medium grade wheel.

A massive grinding machine constructed especially for finishing steel-mill rolls is illustrated in Fig. 134. This machine is a product of the Landis Tool Co. and in general design it does not differ materially from a regular Landis plain grinder. As the illustration shows, the roll is located by its necks or journals and is driven from the face plate by a pin that engages the wobbler. The operator stands on the three-step platform plainly seen at the front of the machine, from which vantage point he has full control of the work at all times. He can look over the roll to observe the cutting action of the wheel without inconvenience. This machine is self-contained and electrically driven.

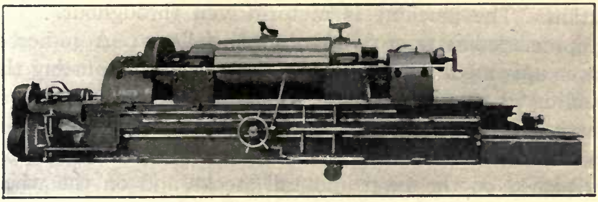

Fig. 134.—Landis grinding machine for finishing large steel-mill rolls.

Another heavy roll grinding machine is illustrated in Fig. 135. This machine is made by the Norton Grinding Co. and is somewhat more complicated than the first machine shown. In designing this machine, the principle of having the wheel traverse past the work is employed, which is a distinct departure from the Norton Company's practice. However, in grinding these massive rolls, it is readily seen that it is not practicable to mount the roll on a traversing platen. If this were done, the momentum of the massive moving body would present serious difficulties in reversing.

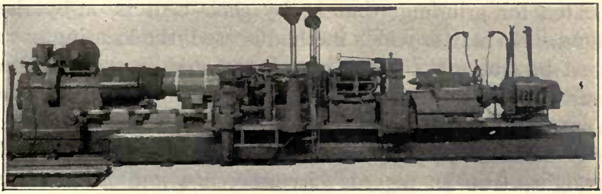

Fig. 135.—Norton grinding machine for finishing large steel-mill rolls.

The wheel is mounted on a carriage on which the operator stands. This position allows him to view the grinding operation at all times. The roll is mounted on its journals and revolved from the headstock. The wheel is fed toward the work by means of the upper handwheel shown in the illustration. The machine is motor-driven throughout. The equipment consists of five motors as follows: A 40-horsepower unit mounted on the wheel carriage for rotating the grinding wheel and traversing the wheel carriage; a 15-horse power motor mounted on the headstock for revolving the work and three 2-horsepower motors. These small motors are placed on the head and tail stocks and on the wheel carriage. The first two are for traversing the parts upon which they are mounted along the ways of the base, while the last drives the pump and traverses the grinding wheel at right angles to the work. This machine is said to be the heaviest grinding machine ever constructed. It weighs 100,000 pounds. After the first machine of this type was finished and installed in a steel mill for demonstration, it was found, after exhaustive trials, that it reduced the time required in dressing rolls from 50 to 75 per cent.

There always has, and probably always will be, controversy regarding the manner in which rolls should be located for grinding; that is, by their centers or by their necks. No matter which method is used, the locating points must be true. If the roll is to be located on centers, these must be true 60-degree centers; perfectly round at all points, and free from scores or imperfections. If the roll is to be located by its necks, it follows that these must be straight, true as regards circumference and in line with each other. If the necks are out of round, as they often are from wear, it follows that the imperfections will be duplicated on the face of the roll. It is a fact that the necks of these massive rolls are often out of true as they wear readily due to the excessive pressure to which they are subjected in actual use.

A good method, followed by many roll grinders, is first to true out the centers carefully; then mount the roll and grind the necks until they are round and straight. Then the roll is located by the necks and its body ground. On the other hand, many expert roll grinders have achieved excellent results by grinding rolls as large as 30 inches in diameter and 120 inches long by locating them on centers.

The surface speed of the wheels used for roll grinding is from 5,000 to 6,000 feet per minute. The surface speed of the work is comparatively high when compared to work speeds used in ordinary cylindrical grinding. In fact, it ranges from 100 to 200 feet per minute. The traverse feed is very nearly the width of the wheel for each revolution of the work. The depth of cut for roughing is all the wheel will stand, while for finishing the cut is comparatively light. It is obvious that rolls for rolling hot steel do not require the mirror-like finish called for on calender rolls. Steel-mill rolls, however, require a comparatively smooth finish as any imperfections would show up on the material rolled.

Steel-mill rolls are made of two materials—chilled iron and steel. For grinding the iron rolls, carbide of silicon is used and for steel rolls alumina abrasives. The same grits and grades apply to this work, in a general way, as given for grinding calender rolls.

Another important branch of roll grinding is the finishing of chilled-iron rolls used in flour mills. This applies to the smooth rolls as well as the corrugated breaking-down rolls. The corrugations of the latter wear down after a few years' service and before re-corrugating them, the worn corrugations are ground away. This work is done on the same type of machine illustrated in Fig. 131. As flour-mill rolls are comparatively small, ranging from 6 inches in diameter and 12 inches long to 12 inches in diameter and 60 inches long, a much smaller machine is used. These machines are generally provided with a swing rest for assuring straight rolls, but they are seldom equipped with a crowning attachment as the rolls are not long enough for their diameter to deflect from their own weight.

Large flour mills have their own grinding and corrugating departments in charge of an experienced operator, but many of the smaller mills send their rolls to repair shops that make a specialty of this work. There seems to be no good reason why this grinding could not be done on a regular cylindrical grinder after the method employed in grinding small steel-mill rolls, but the type of grinder shown in Fig. 131 seems to have the preference.

In grinding the worn corrugations from flour-mill rolls, carbide of silicon wheels in 30 to 60 grit and medium grade are used. Shellac-bonded wheels are always used for finishing operations, but for roughing some operators prefer vitrified wheels. The work does not differ materially from any other roll-grinding operation and the process followed is the same.

After the automobile had passed the experimental stage and began to be an industry in itself, one of the complex problems it brought about was the finishing of crankshafts. It goes without saying that the bearings and pins of this important member of the modern automobile must be accurately and smoothly finished if an easy-running motor is to result and, as may be imagined, abrasive engineers lost no time in adapting the cylindrical grinder for finishing crankshafts. In the early days of the automobile industry, the grinding of crankshafts presented many difficulties.

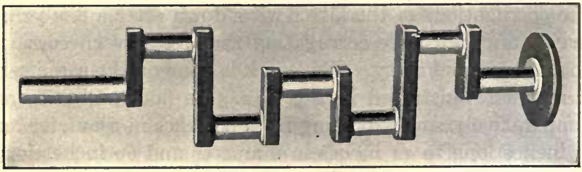

Fig. 136.—Typical crankshaft as finished by grinding.

The shaft was usually held between centers on offset blocks. This method when applied to a four or six throw crankshaft is not satisfactory as the shaft is quite liable to spring in the grinding operation, owing to the insecure support. Again, in the early days of four-throw crankshafts, there were no grinding wheels suitable for the work, that is, as we judge such wheels today.

A typical crankshaft, one that is easily finished by grinding, is shown in Fig. 136. This is an easy shaft to grind as it has but one intermediate bearing and four pin bearings.

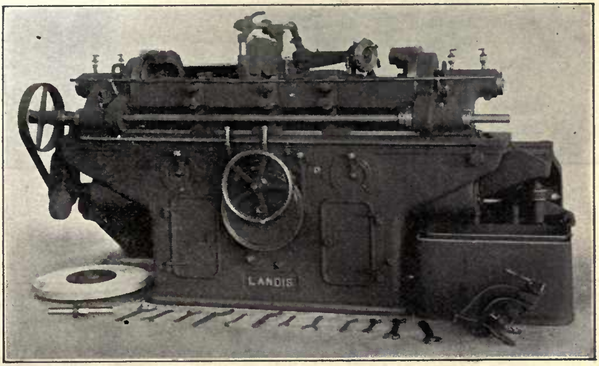

Fig. 137.—Landis crankshaft grinding machine.

A modern Landis crankshaft grinder is illustrated in Fig. 137. This machine does not differ materially from an ordinary cylindrical grinder with the exception that the crankshaft is rotated and driven from both ends while it is securely held in special indexing devices which are counterweighted to assure a satisfactory running balance to the shaft during the grinding operation. The double drive is derived from the shaft seen at the front of the machine.

The work-carrying fixture is shown in Fig. 138. These are attached to the face plates of the machine and carry the work while grinding the pins. The fixtures are equipped with two independent rotary adjustments, one an eccentric for obtaining different throws, the settings for which are

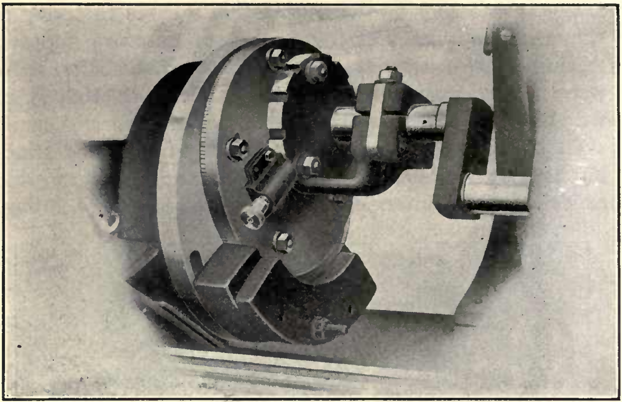

Fig. 138.—Work-carrying fixture for grinding crankshafts on Landis crankshaft grinding machine.

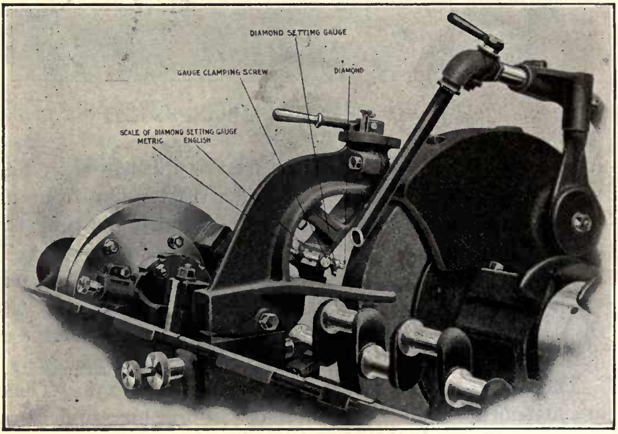

Fig. 139.—Special wheel-truing device for Landis crankshaft grinding machine.

indicated in English and Metric scales, and the other for locating the pins in their relative grinding positions. The setting for this is controlled by a division index which is of the tapered type to insure it against reasonable wear. The counterbalance weights are seen at the bottom of the face plate.

Another attachment peculiar to crank-grinding machines is the special radius truing device which is absolutely necessary in keeping the corners of the wheel at the correct radius to impart the desired fillets on the work. A Landis special wheel-truing device of this type is illustrated in Fig. 139. This is attached to the top of one of the workrests used in supporting the crank while grinding. The diamond tool is oscillated by the lever at the top. This fixture is also used for truing the face of the wheel and, as the illustration shows, the work need not be removed when the device is in use. As shown, the diamond-setting gauge is turned over and pushed back on its holder where it does not interfere with the truing operation.

Crankshafts are finished in two ways, grinding from the rough forging and finish grinding after a roughing cut in the lathe. There is some controversy as to which is the best method, but in actual practice both methods give excellent results. In grinding a crankshaft from the rough, it is first centered and the main bearings roughed out. Then it is held in the offset fixtures and the pins roughed out. Next the pins are finished carefully and last of all the main bearings.

In the other process, the roughing is done in the lathe and the grinding machine used for the finishing operation only. In this case, the main bearings are first rough ground to within a few thousandths of the finished size, then the pins are roughed. Next the pins are finished and last of all a finishing cut is taken over the main bearings.

Grinding from the rough wears out wheels rapidly, but as the turning operation in the lathe is eliminated, there may be truth in the claim that this method is the most rapid. However, many leading manufacturers prefer to take the roughing cuts in the lathe. Thus, it is seen that there must be factors in favor of both methods, otherwise one or the other would be adopted universally.

Crank grinding is an exacting operation and the speed with which the work is turned out is attained only by long practice on the part of the operator. It differs from ordinary grinding in several ways. In the first place, in working on the pins, the traverse feed is eliminated entirely and the work fed directly to the wheel by means of the cross feed. The face of the wheel must be kept true and straight in the finishing operation. Again, the operator has to exercise care in watching the fillets, for a true radius on the wheel corner is necessary in imparting the desired fillet on the finished work. Another point that requires close attention on the part of the operator is the spacing of the pins. Crankshaft grinding is a special trade in itself and in common with other exacting operations, skill is developed only through long practice.

As crankshafts are always made of steel, alumina abrasives are used for grinding them. Grinding-wheel manufacturers who cater to this class of trade have developed special wheels for the work. These wheels are generally in combination grits and great care has been paid to developing bonds that will insure the corners holding up well without danger of burning the work. The wheels used for grinding crankshafts from the rough are coarse and comparatively hard—from 16 to 24 grit in the writer's grades 11 to 14. For finishing, finer and softer wheels are used. The grits in this case run from 36 to 40 and the grades from 7 to 9.

Perhaps the greatest difficulty experienced in crankshaft grinding is keeping the work true. It is imperative that free-cutting wheels are used, but they must not be too soft, otherwise more wheel is wasted in keeping the fillets at the proper radii than is used in actual grinding. If the wheels are too hard, in the finishing operation, they heat the metal unduly which causes sprung work and burned spots in the fillets. Especial care must be exercised in taking the finishing cuts on the main bearings as these must test true, or at least within close limits, in the finished shaft. An expert can, of course, bend a sprung shaft until it runs true, but it is much better to have the work true as it comes from the grinder.

The finish left on the journals and pins is another important factor and the high degree of finish required by the government on crankshafts for airplane motors has caused more than one manufacturer much anxiety. There was a time when manufacturers of crankshafts used a final lapping with emery cloth and oil to impart a high degree of finish, but the government frowns on this practice.

The amount to be left for finishing should be determined by experimentation as it is impossible to set any definite rule. The accuracy with which the shafts are roughed out, both as regards dimensions and the spacing of the offsets are important factors bearing on this point. Again, the size of the shaft, whether long or short must be considered. On an average, however, 0.020 inch should suffice in the majority of cases where the operator who roughs out the work uses reasonable care.

Never under any conditions should it be attempted to grind a crankshaft without backresting it. Crank grinding machines are equipped with a special form of back rest that bears directly on the surface being ground and there is no excuse for not using these.

Another special grinding operation that has been developed by the automobile industry is that of grinding cam shafts. In the early development of the internal-combustion motor, in the days of single cylinder and two cylinder double-opposed type engines, individual cams were used. These were cut by methods used in cutting ordinary face cams after which they were hardened to eliminate wear. These early cams were not ground; for at that time rule-of-thumb methods were the general ones employed, thus after the cams were hardened, a polishing with abrasive cloth was thought sufficient.

As the automobile engine was gradually improved, the valve-actuating mechanism was given more attention and more accurately finished cams were demanded. Grinding-machine manufacturers turned their attention to the development of special attachments for cam grinding.

Present-day internal-combustion engine cams are of two kinds: Integral cams, in which several cams are made integral with their shaft, and individual cams. The former type is the one most extensively used. The latter type is sometimes used on multiple cylinder engines, in which case the cams are pinned or otherwise fastened permanently to the shaft. The majority of individual cams, however, are used on single cylinder engines of various types.

There are two types of cam-grinding attachments to take care of the two kinds of cams above referred to. An attachment made by the Norton Grinding Co. for finishing individual cams is shown in Fig. 140. Briefly described, it consists of a spindle which carries the cam to be ground and the master cam which, running over a roller, produces the desired contour of the cam face. It is driven from the headstock of the machine and a strong spring keeps the master cam in contact with its roller while the cam is brought to the wheel by means of the cross feed.

An attachment designed for grinding integral cams is shown in Fig. 141, while Fig. 142 is a close-up view of the attachment taken from the back of the machine. The gear guards are removed in this view to show the operating mechanism. A is the driving arm, B the master cams on their spindle, C the roll which is set in position before the desired leader by slipping along the shaft D. This is equipped with a locking device to hold it in place as occasion requires. E is the case that covers a stiff spring which holds the master cam in contact with the roll. F is the driving dog, G the steady-rests and H the tailstock. As the master cams are revolved their bearing against the roll causes the attach-

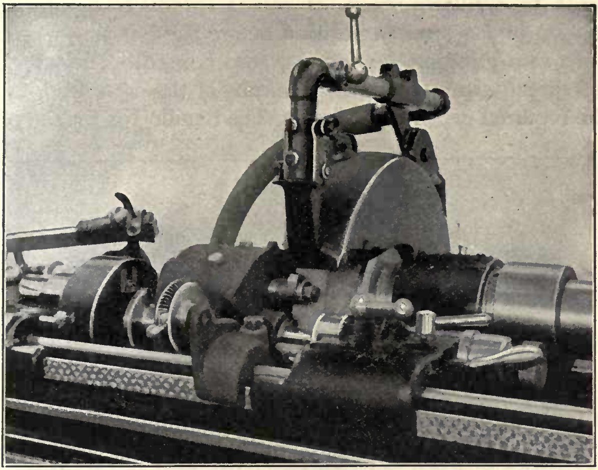

Fig. 140.—Norton grinding attachment for finishing individual cams.

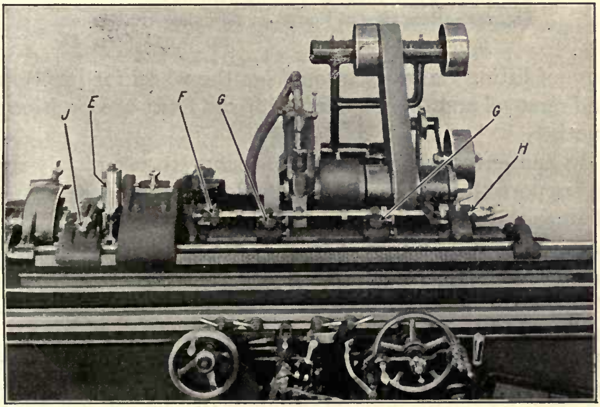

Fig. 141.—Norton grinding attachment for finishing cams made integral with their shafts.

ment to oscillate which, of course, produces a duplicate motion of the cams in position before the grinding wheel.

In cam grinding, no traverse feed is used. The wheel is fed directly into the work by means of the cross feed until the required depth is reached. The handle J is for the purpose of lifting the work away from the wheel for inspection and removal and to move the guide roll from one position to another.

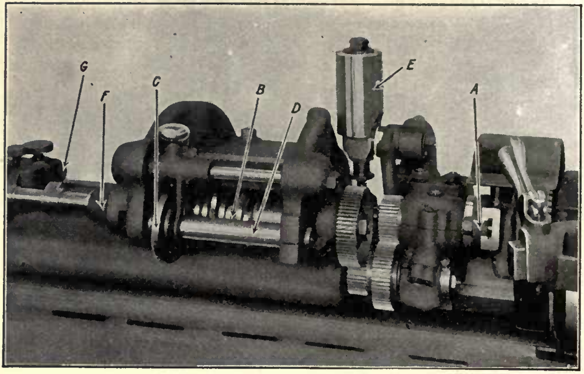

Fig. 142.—Rear view of Norton cam-grinding attachment.

In cam-grinding, it is very necessary to use steady-rests to support the work. These should be located reasonably close to the cam being ground and should bear on the round part of the shaft which is finished by grinding for this purpose. The Norton Grinding Co. provide two types of steady-rests, as illustrated in Figs. 143 and 144. Fig. 143 is an open type rest and Fig. 144 a closed type rest. It is obvious that the open type has the advantage of being readily handled in locating and removing the work. The closed rest is used in cases where great accuracy is demanded, for instance, on cams for high-class automobile engines and on aircraft engine work.

As the cams in question are made of steel, alumina abrasives are used in grinding them. The degree of accuracy demanded and the finish sought are important factors governing the selection of wheels for cam grinding. For roughing out the cams before they are hardened, which is common practice, wheels in 16 to 24 grit and 12 to 17 grades will be found satisfactory. It is seen here that the wheels used for this purpose are comparatively hard. For roughing out hardened cams 24 to 40 grit in grades 4 to 7 will give good results. For finishing hardened cams, grits 36 to 50 in grades 3 to 5 will be found satisfactory. The grades are according to the writer's grade scale.

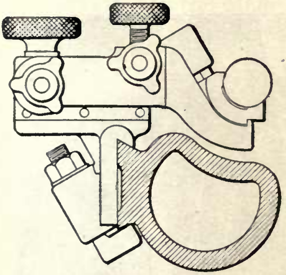

Fig. 143.—Open-type Norton steady-rest for camshaft grinding.

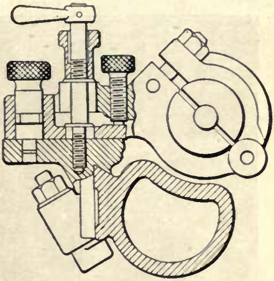

Fig. 144.—Closed-type Norton steady-rest for camshaft grinding.

One of the most interesting factors pertaining to cam grinding is the method followed in producing the leaders or master cams. It is necessary that these be accurate as regards contour if accurate results in the ground cams are sought. In grinding a cam, we use a leader of the desired form to produce the outline on the cam that oscillates before the grinding wheel. In making these leaders, we reverse the practice. This will be clearly understood by the following description. The operation is shown in Fig. 145. This is the same attachment used for cam grinding but set up differently. In place of the grinding wheel the disk (2) is used. This is made of cast iron and occupies the position taken by the grinding wheel in grinding operations. The model cam (4) bears against the disk and from it is produced the leader, several of which are shown at 5. This is ground by the grinding wheel (1). The spindle (6) carries the master cams. The master cams, which are hardened, were roughed approximately to the desired shape before hardening. The bearings of the master-cam spindle and the centers of the attachment must be exactly in line. As the grinding wheel and the master cam revolve, the model runs over the disk which produced the desired contour on the master. It looks simple, which in truth it is, but to assure satisfactory results two important factors must be borne in mind. The disk (2) must be the size of the grinding wheel that is to be used in grinding the cam on regular production work and the grinding wheel (1) must be exactly the same size as the roll that is to follow over the master cams when they are in use as producers for the finished cams.

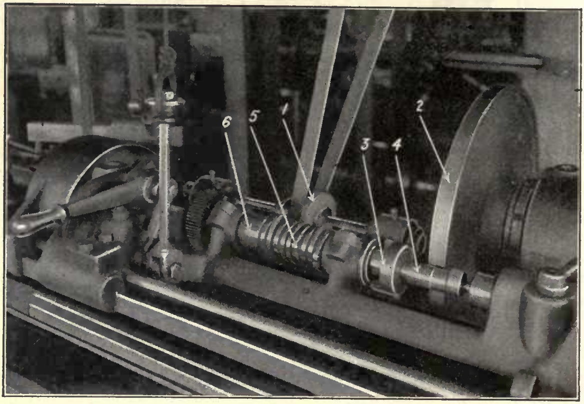

Fig. 145.—Grinding the leaders for a Norton cam-grinding attachment.

As previously stated the master cams are roughed out before they are hardened and a few words concerning a simple method to follow in marking the outline will not be out of place here. The blanks, while soft, are mounted on the roughing master-cam spindle, it being understood that in cam grinding two sets of masters are necessary, one for roughing and the other for finishing master cams. The machine is started up and the model produces the desired motion to the master cam shaft. The wheel (1) is brought to bear slightly against the side of the master where it marks the outline from which the toolmaker roughs out the cam.

As stated previously, the disk over which the model cam runs in making a master cam must be the same size as the grinding wheel to be used in grinding the cams later in production work. As all grinding wheels wear in use, it is evident that after the wheel is worn away somewhat it will not grind the same shape as it did when it was up to size. This is graphically illustrated in Fig. 146 which was prepared for explanatory purposes by Howard W. Dunbar, and illustrates clearly just what takes place in cam grinding. The model cam is in position bearing against the guide roll.

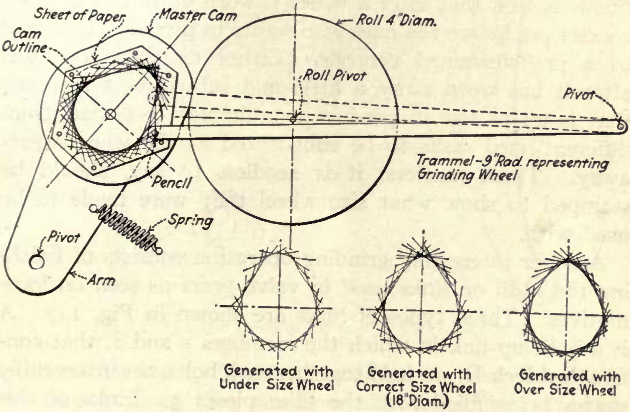

Fig. 146.—Effect of varying wheel diameters in cam grinding.

A piece of cardboard is glued to the master, this taking the place of the cam to be ground under working conditions. The pencil represents the periphery of the grinding wheel. A mark is made on the cardboard with the pencil, the master moved a little and another mark made and so on until the master has made a complete revolution. This gives the cam outline seen in the illustration. If the radius on which the pencil swings is changed to represent the periphery of a smaller wheel, a different shaped cam will be formed. As the three diagrams at the bottom of the illustration show, incorrect wheel sizes make a vast difference in the outline produced even though the same master is used. From this it is seen that after a wheel is worn down a little, two courses are before the man who wants to produce cams true to a predetermined contour. Either discard the wheel after it has worn away a little and substitute a new one that is up to size or produce a multitude of leaders from different-sized disks to be substituted as the wheel wears away. These masters, it is needless to say, should be stamped to show what size wheel they were made to be used with.

Another interesting grinding operation consists of finishing the radii on links used in valve gears as seen on locomotives. Three types of links are shown in Fig. 147. A is a built-up link in which the members 1 and 2, that confine the block D, are held together with bolts, the intervening spaces being filled with the filler pieces 3. Links of this type are generally made of wrought iron and protected against excessive wear by case hardening. A solid link is shown at B. Links of this type are generally made from steel castings. Sometimes they are case hardened, but in other instances they are left in their soft state. The link shown at C is the type used in the Walschaert valve gear.

Considering the link shown at A, it is evident that case hardening will distort it to a certain extent. If satisfactory working surfaces are desired, the errors must be corrected by grinding. Some years ago, links of this type were ground by hand on the face of a wide wheel. This practice, of course, called for the services of an expert workman and even under these conditions the results were not always satisfactory.

The machine shown in Fig. 148 was designed especially for grinding links and link blocks and is called a radial grinder. However, as these machines are used principally in railroad shops they are generally called link grinders. The machine is designed and built by H. G. Hammett, Troy, N. Y.

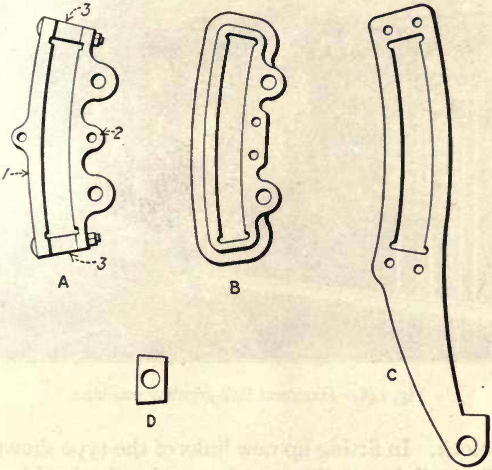

Fig. 147.—Three types of locomotive valve-gear links.

The fulcrum of the bar seen in the foreground is adjustable to accommodate links of different radii and causes the upper section of the platen to describe a curve as it traverses back and forth. The grinding wheel is carried on a vertical spindle and is fed downward as the grinding progresses. The link is lined up to the desired radius and securely strapped to the platen of the machine, although in some cases special fixtures are provided for locating the work.

In fitting up links of any kind, the first step is generally to grind the block which is then used as a gauge in grinding the link to the correct width. This is a much easier procedure than to attempt to grind the link first and then fit the block. In fitting up new links of the type shown at A, the built-up link, excellent results can be obtained by grinding the block and fillers at one operation and the other members next. In assembling, the clearance to allow the block to slide is obtained by means of paper shims or liners placed between the fillers and the members 1 and 2.

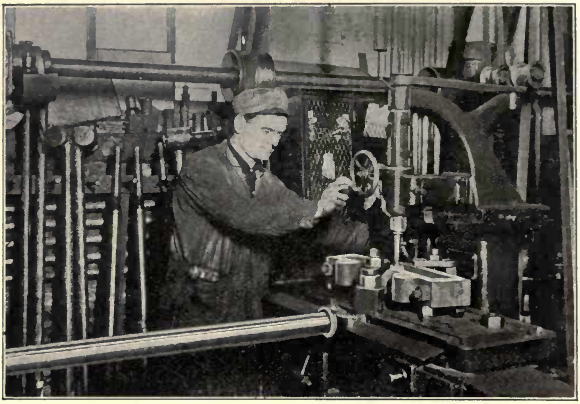

Fig. 148.—Hammett link-grinding machine.

Links wear quite rapidly, especially those used in connection with Stephenson link motions. This is due principally to the slip of the block caused, among other things, by offsetting the saddle pin to secure the desired cut-off motion. Built-up links can be readily re-ground and new blocks fitted, but with solid links the only thing to do is to grind them until the radii are trued up and then fit new blocks.

The operation of link grinding is simple after the link has been correctly located on the platen of the machine. The depth of cut should be comparatively light as this work is done dry and the wheel should be fed down by means of the automatic feed. The wheels generally used are from 30 to 40 grits in the writer's 12 grade. As the work is steel, an alumina abrasive should be used.

CHAPTER TWENTY

CUTTER SHARPENING

Machines employed for cutter grinding—Adjustments and attachments on cutter grinders—Grinding spiral cutters—General operation of cutter grinders—Selection of wheels—Speeds—Depth of cut.

TO insure maximum production on the milling machine, it is necessary to use properly sharpened cutters. Dull cutters throw an extra load on the machine, produce unsatisfactory surfaces and leave heavy burrs. Cutter sharpening is a comparatively simple operation that can be done by any mechanic of ordinary ability, provided reasonable care is exercised to see that the depth of cut is not deep enough to cause the wheel to burn the teeth. There are two kinds of machines used for cutter grinding, small universal grinders arranged for dry grinding and special cutter sharpening machines. A machine of the former type is illustrated in Fig. 149. This is a product of the Cincinnati Milling Machine Co. and is the result of many years' study and experimentation to produce an economical machine that could be adapted to cutter grinding and small tool-room cylindrical grinding.

On this machine the base, platen and head are all equipped with swivel adjustments while a vertical adjustment is also provided to enable the machine to take care of such work as grinding formed cutters without having to resort to the use of drop centers. Owing to its wide range of adjustments, this machine can be readily adapted to any kind of cutter grinding.

The machine shown in Fig. 150 is a Brown & Sharpe cutter grinder. It embodies a number of adjustments and, with the necessary attachments, can be set up to do any kind of cutter grinding. The operation shown in Fig. 150

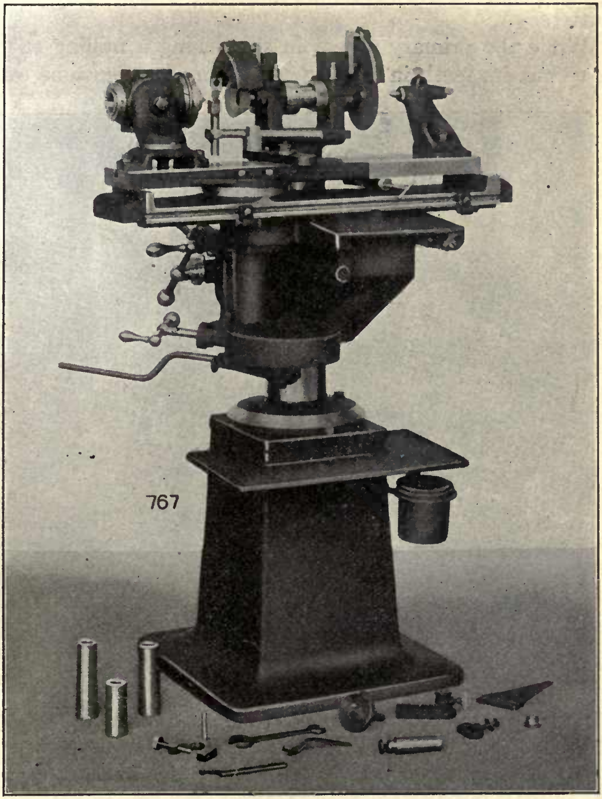

Fig. 149.—Cincinnati universal grinding machine adapted for tool-room and cutter grinding.

is that of grinding the peripheral teeth on an ordinary milling cutter. For grinding end mills, the work is located in a sleeve that fits the swivel head seen under the operator's hand. The attachment shown in Fig. 155, is for grinding the end teeth of cutters and similar pieces while the attachment illustrated in Fig. 163 is for grinding formed cutters.

While the primary object in sharpening a milling cutter is to put its teeth in cutting condition, care must be exercised to see that the cutter is kept round and that the teeth are ground straight with the axis of the cutter. If the cutter is not round, comparatively few of its teeth cut and if it is tapered accurate work cannot be obtained.

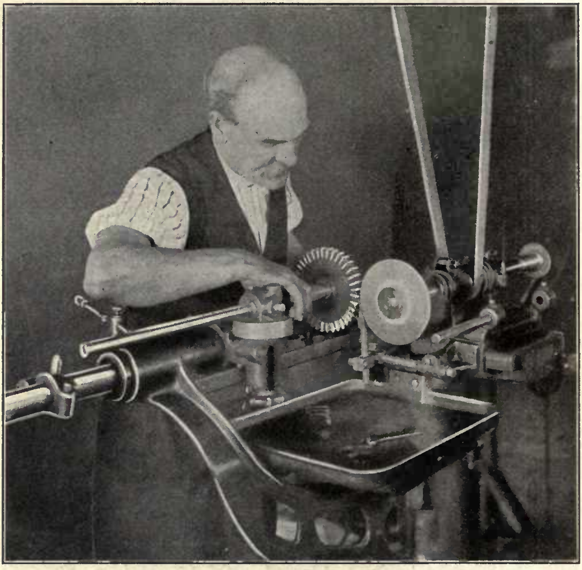

Fig. 150.—Grinding the peripheral teeth of a milling cutter on a Brown & Sharpe cutter grinding machine.

One of the most rapid and simple methods of sharpening a cutter properly, with the above factors in mind, is shown in Fig. 150. The cutter is mounted on a hollow work arbor as shown in Fig. 151 where it is held between two collars, A and B. These collars have several steps on them to accommodate cutters with different-sized arbor holes. This hollow arbor carrying the cutter is slid back and forth by hand along the bar C, which is also seen in Fig. 150. This bar is clamped in the swivel head. If the bar is straight, it naturally follows that the teeth of the cutter will be ground parallel, regardless of the setting of the swivel head, and if the work arbor is true, a round cutter will result. This method of cutter grinding is not new by any means, but it produces accurate results.

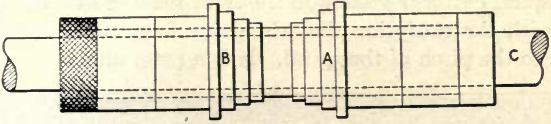

Fig. 151.—Hollow work arbor for locating milling cutters for grinding.

The first step in setting up the cutter grinder is to clamp the cutter on the work arbor, set the bar in place and then set the guiding finger under the cutter tooth nearest the wheel to impart the correct angle for clearance. This is generally from five to seven degrees. Too little clearance will cause the cutter to cut slowly, while too great a clearance makes the teeth dull quickly. In setting the guide finger to impart the desired clearance, the expert operator is generally guided by experience alone.

In grinding, the cutter should be fed past the wheel with a fairly quick motion and the depth of cut should be comparatively light as this work is generally done dry and thus it is obvious that a deep cut will burn the tooth. It is a good plan to mark the first tooth with chalk and grind the teeth evenly and carefully until all have been sharpened. It is generally found that the wheel wears a little in going around the cutter once and for this reason a very light finishing cut should be taken to insure the cutter not being out of round from excessive wheel wear. In connection with this point it may be well to mention the fact that comparatively wide-faced wheels give better results in cases where they can be used than do narrow ones, owing to the fact that the wide-faced wheel wears longer.

A spiral cutter is ground in the same manner as a straight one with the exception that the guide finger is set to conform to the pitch of the spiral. It is a more difficult matter to grind spiral cutters than straight ones as an inexperienced operator sometimes has difficulty in setting the guide finger properly and in keeping the cutter in correct contact.

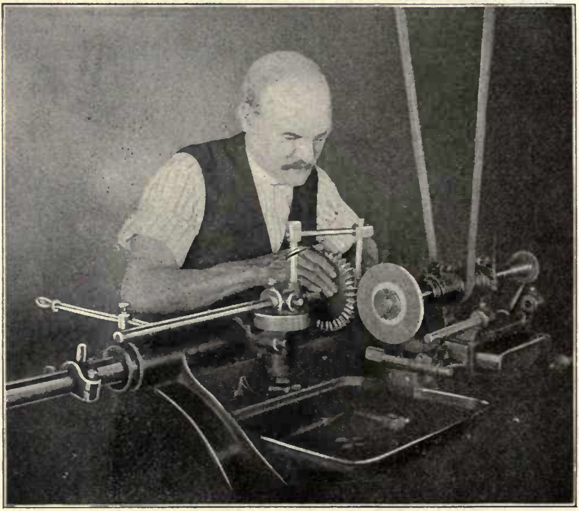

Fig. 152.—Grinding a milling cutter with the guide-finger over the tooth.

There are two ways to locate the guide finger in grinding milling cutters and both have their good and bad features. By again referring to Fig. 150, it is seen that the guide finger is under the tooth being ground. The wheel is running toward the operator. Thus the action of the wheel keeps the cutter tooth in contact with the guide finger. This is the safest way to grind a milling cutter, but it is more liable to burn the teeth than the method illustrated in Fig. 152 In the latter method, it is seen that the guide finger is placed just opposite to what it is in the former case and also that the cutter has been reversed. The operator must exercise great care to keep the cutter in contact with the wheel, the action of which has a tendency to pull the work away from the guide finger. Should the operator relax his diligence, the wheel might force the tooth away from the guide finger which would result in an injured tooth or perhaps a broken wheel. In grinding cutters by this method, the wheel is not as liable to burn the work, thus a deeper cut can be taken. For this reason, this method is used by many mechanics. In considering the best method to use, it is best for a green operator to use the first-described one while the latter should be left for more experienced operators.

In grinding the teeth of a straight or spiral milling cutter, the clearance is obtained by raising or lowering the guide finger. In grinding angular cutters, however, another method must be used. Correct and incorrect set-up positions for angular cutters are shown in Fig. 153. A illustrates the correct position in which the tooth makes a straight line toward the center. This is necessary in preserving the correct angle as given by the swivel head when

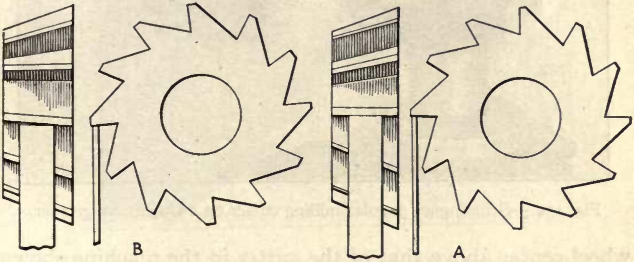

Fig. 153.—Correct and incorrect methods of locating angular cutters for grinding.

the machine is set up for the grinding operation. If the guide fingers were dropped to give the clearance angle, the result as shown in B would be had. Here it is seen that the tooth does not bear evenly on the guide finger.

In setting up the cutter grinder for grinding teeth on angular cutters, the clearance is obtained by raising the wheel center above that of the cutter in the machine shown in Fig. 154, which is a Cincinnati grinder set up for grinding the peripheral teeth of an angular cutter. The cutter is held on the end of the swivel head spindle and the angle for clearance obtained by raising the wheel head, while the swivel head is set over to the desired angle.

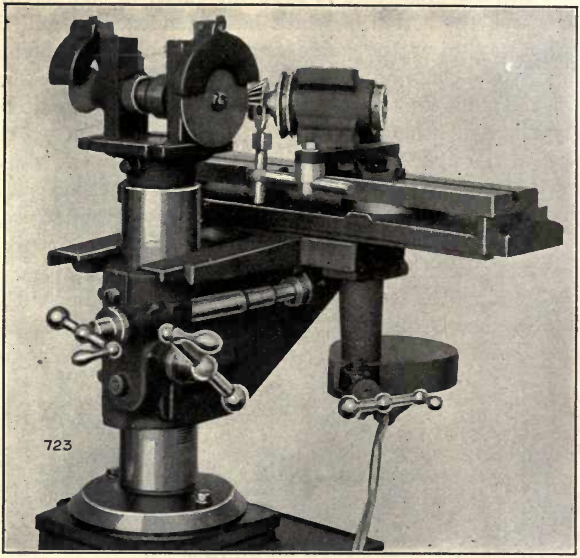

Fig. 154.—Grinding an angular milling cutter on a Cincinnati grinder.

As a general thing, the side teeth of milling cutters require grinding but seldom, owing to the fact that most of the cutting is done by the peripheral teeth. In some cases, however, the side teeth require sharpening, it being obvious that this is imperative with new cutters that have never been backed off.

Side teeth are sharpened in two ways, that is to say, with the face or the periphery of the wheel. For some milling operations, the periphery of the wheel is to be preferred as it gives a better cutting clearance. Grinding under these conditions is illustrated in Fig. 155 which shows an attachment for this purpose on the Brown & Sharpe cutter grinder depicted in Figs. 150 and 152. The cutter is held on the end of an arbor that fits in the head and is fed back and forth by the lever seen in the lower part of the illustration. The guide finger at the right locates the teeth.

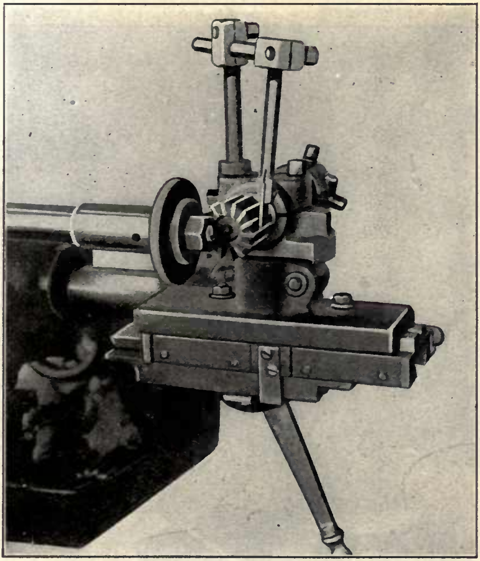

Fig. 155.—Grinding the side teeth of a milling cutter on the periphery of the wheel on a Brown & Sharpe cutter grinding attachment.

The operation of sharpening side teeth with the side of the wheel is illustrated in Fig. 156. The work is held on the end of an arbor which fits the swivel head and fed back and forth past the face of the wheel. The machine is a Cincinnati grinder and its makers give the following directions for setting up for this operation.

"After the cutter is placed in position as above described, the head should be set to zero and the cutter set central by means of the centering gauge. The tooth-rest is next adjusted and the head depressed to give the proper angle of clearance. The knee of the machine is next set to 90–1/2 degrees so that the grinding is done with the down side of the wheel, the upper side clearing. Should the tooth next

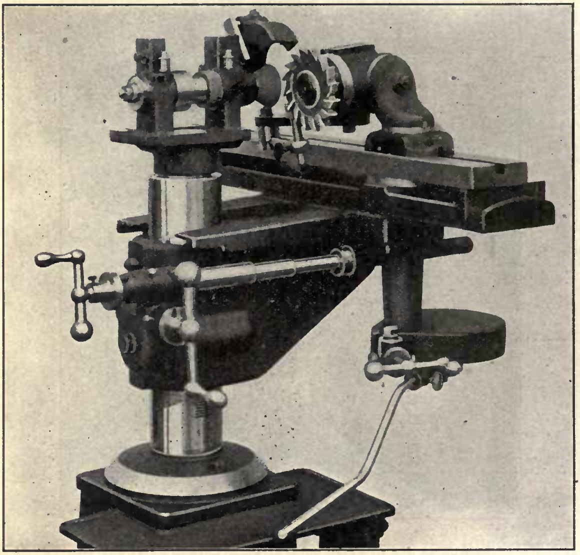

Fig. 156.—Grinding the side teeth of a milling cutter using the side of the wheel on a Cincinnati grinder.

to the one being ground strike the wheel, the table should be raised to make the clearance desired. The above applies to the grinding of right side teeth. In grinding the left side teeth, the operation is reversed and the knee set to 89–1/2 degrees so that the grinding is done with the up side of the wheel instead of the down side."

Another device often made use of in grinding the side teeth of milling cutters is shown in Fig. 157 and is called a universal head. These heads are very handy for a diversity of grinding operations. The machine shown is a Walker grinder and the operator is grinding the end teeth of a butt mill. This is held on a short arbor which is located in the vee block of the universal head. The head is tilted to impart the desired angle and the teeth are located by means of the guide finger which is strapped to the platen of the machine.

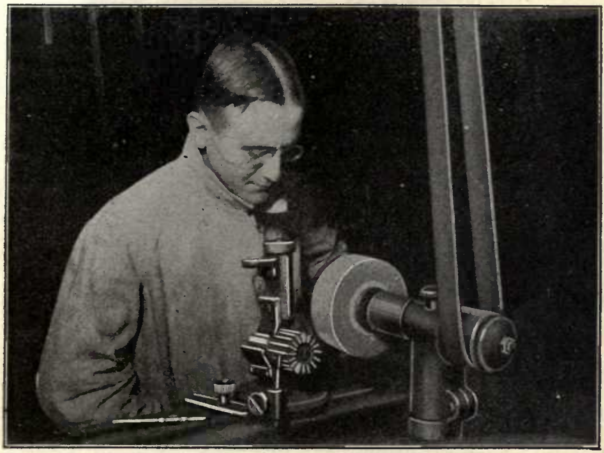

Fig. 157.—Universal head for grinding milling cutters, etc.

On first thought, it might seem that a large machine would be necessary to sharpen large inserted-tooth milling cutters. This is not the case, however, as they are readily sharpened on ordinary cutter grinding machines. Fig. 158 illustrates the operation of sharpening the face teeth of a large mill on a Cincinnati grinder. The cutter is mounted on a shank held in the swivel head spindle and the swivel head is depressed to impart the desired clearance. The face of the tooth should be brought to a horizontal position and the tooth-rest adjusted to bear on it.

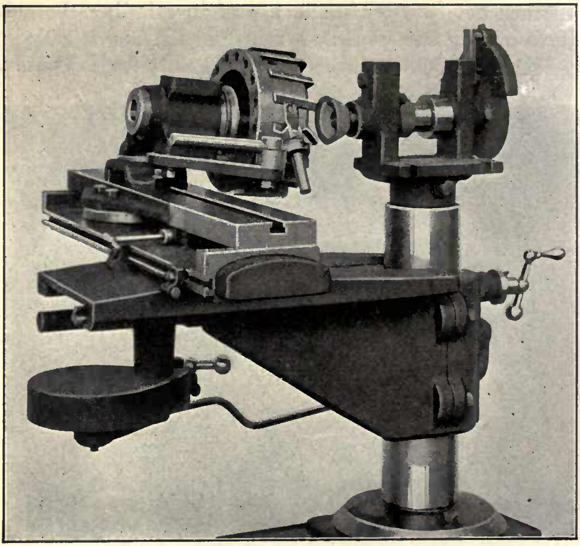

Fig. 158.—Grinding a large inserted-tooth milling cutter on a Cincinnati grinder.

It is a well-known fact that the corners of the teeth of any face mill wear readily and experience has proven that excellent results are obtained by rounding these corners. A corner relieved in this manner is illustrated in Fig. 159 and the operation of grinding it on a Cincinnati grinder is illustrated in Fig. 160. The cut is obtained by swiveling the head 45 degrees, 22-1/2 degrees and 67-1/2 degrees. While grinding large cutters, it is often necessary to swivel both the table and the head to allow for clearance. In this method the angle is obtained by a combination of both dials.

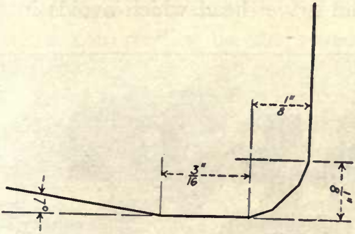

Fig. 159.—Relieved corners on face-mill tooth

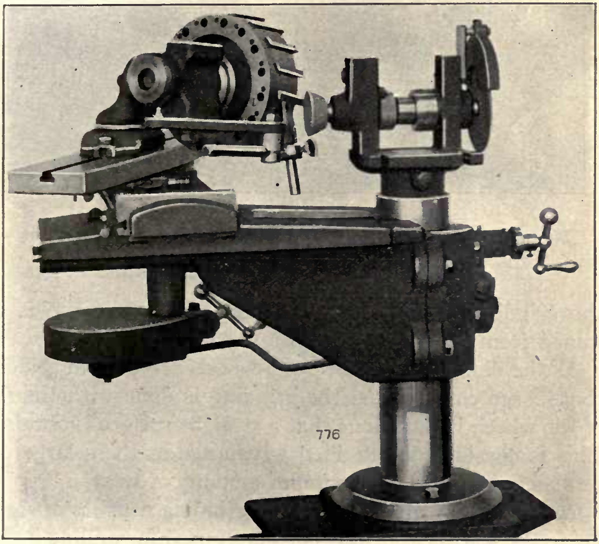

Fig. 160.—Cincinnati grinder set up to relieve corners of cutter teeth.

The operation of sharpening the peripheral teeth of large end mills is shown in Fig. 161. By referring to the illustration, it is seen that the tooth-rest is fastened to the top of the swivel head which avoids interference with the grinding-wheel head. The angle for clearance is obtained from the graduations on the swivel head.

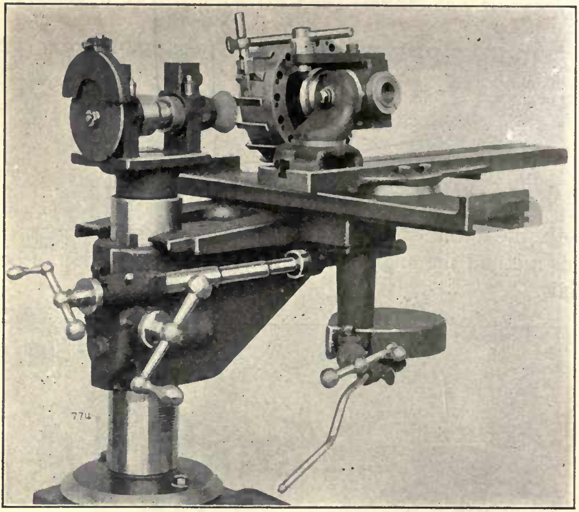

Fig. 161.—Grinding the peripheral teeth of a large milling cutter on a Cincinnati grinder.

As the illustrations show, cup wheels are used in grinding these large cutters. As the grinding is done with the face of the wheel, it is obvious that a straight surface is obtained. This is considered a decided advantage in these large cutters as it insures the maximum amount of wear.

An important branch of cutter grinding consists of sharpening the so-called formed cutters as used for milling irregular outlines. While an ordinary milling cutter is ground by cutting away its periphery, a different method must be followed with formed cutters as the outline is often of such a complicated shape that it would be impossible to grind it. The relief of these cutters is in the form of regular curves, and they can readily be sharpened by grinding away the dulled part of the tooth face. The principle is illustrated in Fig. 162, wherein A is the cutter and B the grinding wheel. In grinding formed cutters the dotted line C, which is a continuation of the wheel face, must pass through the center of the cutter. Otherwise the cutter will not mill exactly the form for which it was designed.

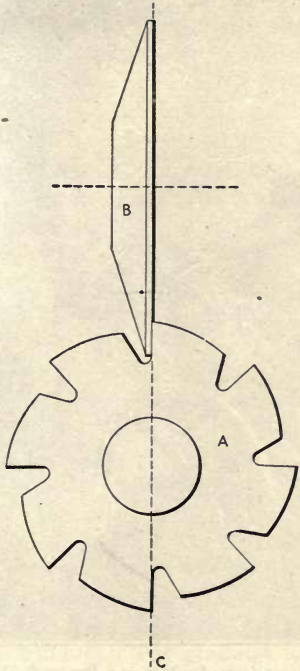

Fig. 162.—Principle involved in grinding formed cutters.

This is an important point in the grinding of formed cutters that is sometimes overlooked.

The operation of grinding a formed cutter is shown in Fig. 163. The work is done on a Brown & Sharpe formed

Fig. 163.—Grinding a formed cutter on a Brown & Sharpe formed-cutter grinding attachment.

cutter-grinding attachment that is fitted to the company's regular cutter grinder as shown in Fig. 150. The work is held on an arbor between two centers and the cutter is indexed around by means of the worm wheel seen in the illustration.

The first step in setting up the machine for grinding cutters of this type is to see that the face of the wheel is perfectly true. As a matter of fact, it is a good plan to true the face of the wheel every time it is placed on the spindle. Next, the center must be brought in line with the face of the wheel. After the cutter is in position on its arbor, the wheel is adjusted to the correct depth and one tooth fed around radially until it strikes the wheel. Then the index pin is located. The cut taken should be comparatively light as it is an easy matter to burn the teeth of the cutters in question, even with the best wheels obtainable. One tooth should be ground at a time with a fairly rapid reciprocating motion until the wheel ceases to spark heavily. After all the teeth have been ground enough to insure their being sharp, the cutter should be gone around once or twice with a slight cut to make sure that the grinding has left the teeth evenly spaced. Otherwise, only a few of the teeth will cut after the cutter is put in operation.

While the operation of sharpening milling cutters of any kind is comparatively simple, care should be exercised in the selection of the wheels used which should be free cutting and made of an alumina abrasive, since the work is steel grinding. It should also be borne in mind that wheels for sharpening high-speed-steel cutters should be somewhat coarser than those used for sharpening carbon-steel cutters. Again, the cup-and-saucer wheels used for sharpening both plain and formed cutters should be somewhat softer than the disk wheels so commonly used for sharpening peripheral teeth. The following wheels have been found to give good results in cutter grinding. The gradings are according to the writer's grade scale. For high-speed-steel cutters, 36 to 46 grit, 4 to 7 grade. For carbon-steel cutters, 50 to 60 grit, 4 to 7 grade.

After the peripheral teeth of an ordinary milling cutter have been sharpened several times, the tooth land becomes so wide that the clearance for chips is practically ground away, in which case the cutter is consigned to the scrap heap or annealed and re-cut on the milling machine. This process generally destroys the size of the hole, and, again, many cutters are lost in this manner through fire cracking.

Milling cutters can be successfully re-cut, without annealing them, on the attachment illustrated in Fig. 163 or on the surface grinder, in which case it is understood that

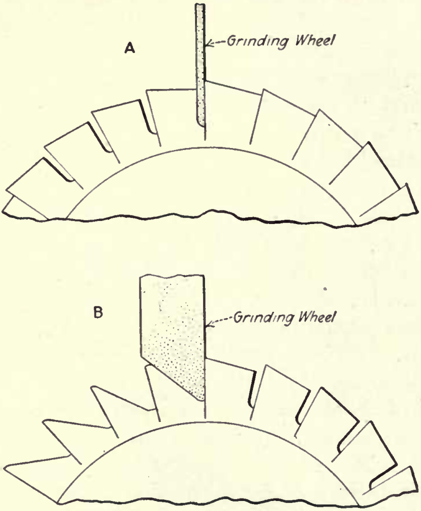

Fig. 164.—Method followed in re-cutting milling cutters without annealing them.

they are held on an arbor between centers. The method followed in re-cutting cutters without annealing them is illustrated in Fig. 164. After the cutter is placed on an arbor and the arbor located between centers, the first step is to grind grooves as shown at A. The illustration is self-explanatory. The wheel used for this work should be of medium grade in shellac bond about 40 to 50 grit. After the cutter has been gone around and all the teeth cut out, the next operation is to grind away the superfluous stock as shown at B. This work is done with a wheel in 46 grit on the writer's 6 grade. The face of the wheel is trued to produce the desired angle to the teeth.

The operation is simple and after a little practice, the average operator can secure excellent results through the exercise of a little care. In gashing out the teeth, one tooth should be operated on at a time and several cuts taken to bring the gash to the required depth. In the re-cutting operation with the beveled wheel, the depth of cut should not be deep enough to cause the wheel to burn the work. In the latter operation also, one tooth should be worked on at a time until it is ground to the required depth as this practice will give better results than can be obtained by taking a small cut from each tooth, one after another.

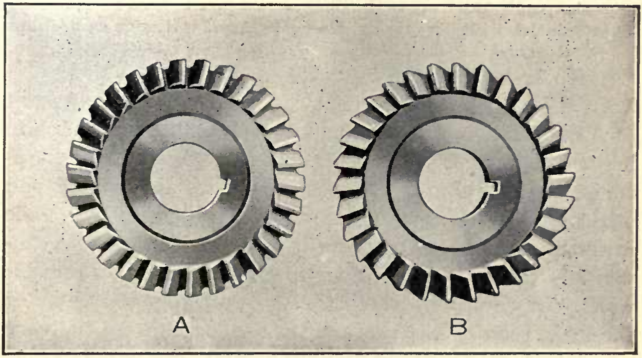

Fig. 165.—Steps taken in re-cutting a milling cutter without annealing.

Upon first trial, the operator will, no doubt, burn and ruin a few cutters, but a little practice will make him proficient. In Fig. 165, two cutters are shown. Cutter A has been gashed only while B shows the finished cutter ready to be put to use again. The side teeth can be cut if necessity demands, but since these teeth are seldom ground, they are rarely worn to the extent of needing re-cutting.

CHAPTER TWENTY-ONE

SAW SHARPENING

Band saws and circular saws—Operation of band-saw sharpening machine—Sharpening band saws—Grinding in new teeth—Care of machine—Selection of wheels for saw gumming—Machines for sharpening cold saws—Sharpening hack-saw blades.

WHEN we stop a moment to consider the vast amount of timber that is annually cut and converted into lumber for various purposes, it is easy to see why saw sharpening, or saw gumming as it is termed in lumber mills and other wood-working establishments, is an extensive trade in itself. A man who sharpens wood-working saws is invariably called a filer, although he seldom uses a file in his work, and the room where the saws are repaired is called the filing room. The name, of course, dates from the time when the file was the only tool to be had for saw sharpening and, in common with many other misplaced trade terms, it probably will endure for years to come.

Saws are of two kinds, that is to say, band saws and circular saws, and there are various types of each kind. For cutting up logs, circular saws are not as economical as band saws owing to the fact that the former have to be of a comparatively thicker gauge to insure the necessary stiffness and strength. The added thickness, of course, makes extra sawdust which is an economic waste. Nowadays, circular saws are used in comparatively few mills. Still, there are a few circular mills left which carry saws as large as 6 feet in diameter. Many circular saws are used as cut-off saws for various purposes such as cutting long logs into the desired lengths before they are sawed into boards and for edging and trimming lumber, etc.

The majority of mills today are band mills and the saws used are often 50 feet long, being driven by two large pulleys. in width, they run from 10 to 14 inches. A smaller type of band saw, called a re-saw, is generally about 25 feet long and from 6 to 10 inches wide. Many filers make their re-saws from old hand saws.

Two machines used for saw gumming are shown in Figs. 166 and 167. The machine shown in Fig. 166 is for sharpening band saws, while the one shown in Fig. 167 is for circular saws, the saw shown being a cut-off saw which is readily seen from the shape of the teeth.

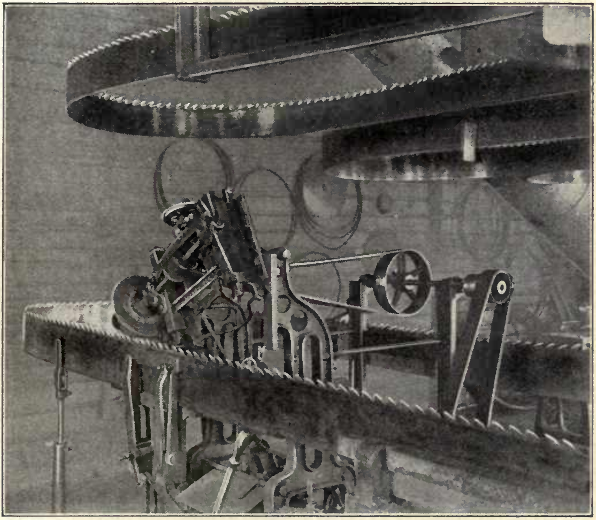

Fig. 166.—Type of machine used for gumming band saws.

Both types of machines operate on practically the same principle, that is to say, means are provided for feeding the saw under the wheel, tooth by tooth, and for lowering and raising the wheel to form the desired shape of the teeth. In the machine illustrated in Fig. 166, the head is set over at an angle and is fed up and down by an adjustable cam arrangement which can be set to form different kinds of teeth. The saw is fed forward by means of an adjustable dog that pulls the saw along tooth by tooth the desired distance, the feeding taking place while the saw is out of the gullet of the tooth.

The machine shown in Fig. 167 has practically the same arrangement for feeding the saw along, but the head travels straight up and down. It also swivels alternately to form the desired angle on the teeth. Both machines shown are fully automatic.

The grinding of band saws is divided into two distinct operations called by the filer, "roughing out" and "pointing up." The latter operation is comparatively simple and requires only a few cuts around the saw. This operation takes place after the dull saw is taken from the mill. After a saw has been in use a few days, it has to be re-swaged and after this operation it has to be ground again before it is fit for use.

The operation of roughing out is where the real work of the filer comes, for logs, as they come to the mill, are not composed wholly of wood by any means. Sometimes, in felling, a small stone becomes imbedded in the wood. Again perhaps, the log grew on a farm, and some thrifty farmer might have hung a horseshoe, a piece of broken chain or other bit of discarded metal in the crotch of one of the limbs, which in time grew over and covered up the metal. Logs are often bound together in rafts for floating down the river by wooden cross-pieces, held together by treenails. The holes for the treenails are bored with ship augers and sometimes an auger is broken off and left in the log. The rafts are often chained together and the chains are spiked to the logs. From this it is seen that many factors are present to keep the filer continually on the job for when a saw, traveling at a high speed, strikes one of these obstructions it sometimes happens that every tooth is literally stripped off nearly down to the bottom of the gullets.

When accidents of this kind happen, the operation of roughing out the saw is in order. This requires much grinding as every tooth has to be ground in again, to the desired depth, which takes many hours of heavy grinding. When the filer makes a new saw from a blank, which is common practice in some parts of the country, the roughing out

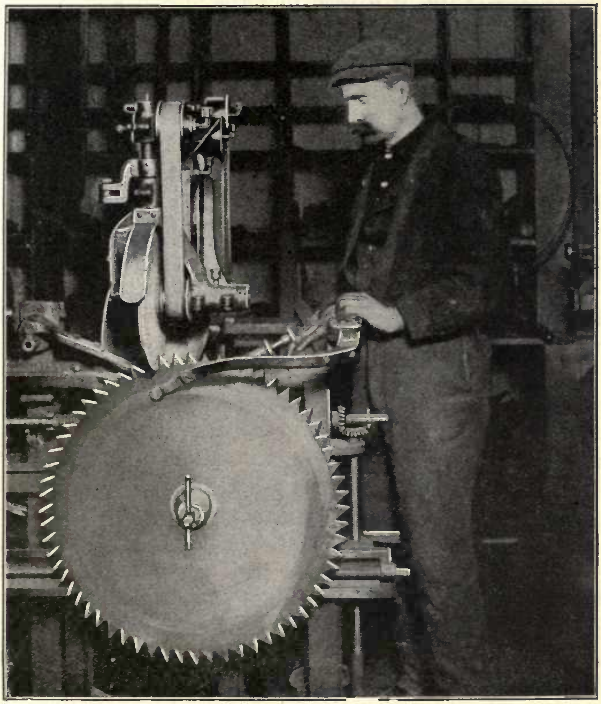

Fig. 167.—Type of machine used for gumming circular saws.

operation also takes place. It is first necessary to stamp the teeth in the saw and then grind them to the correct shape. The stamping operation is essential, otherwise the feed dog would have no depressions to grip to carry the saw along.

From the above, it is seen that the filer in a large band mill works under difficulties and aside from the above hindrances he has other troubles to contend with. It is, of course, necessary that the filing room be in close proximity to the mills on which the saws are used. The ideal location for the filing room is in a detached room on the level with the mill floor. The object of the detached building is to eliminate, as much as possible, the vibration which is always a detriment to good grinding of any kind whatsoever.

Another factor that is the cause of much trouble in the filing room is that the engine that runs the mill also runs the line shaft in the filing room. Thus, when the saw goes through a large log the speed of the engine is lowered a few revolutions per minute before the governor can feed more steam to compensate for the extra load. While the engine lowers its speed a few revolutions a minute, it is readily seen that the grinding wheel on the saw-gumming machine is lowered in speed in a greater ratio as it runs correspondingly faster than the engine. This factor of uneven wheel speed interferes with good results and for this reason the mills, where careful planning is in evidence, are equipped with small independent engines for supplying power to the filing room.

Saw-grinding machines are very seldom equipped with means for carrying away the dust caused by grinding, and for this reason they should receive careful attention. The wheel spindle boxes should be examined frequently and the wear taken up when necessary, for a loose wheel spindle cannot be depended upon for the best results. The cams and their rolls should be examined and oiled frequently. The cams wear out of shape in time: thus they fail to produce the proper kind of tooth. A worn cam lets the wheel down into the gullet of the tooth too abruptly, which not only spoils the shape of the tooth, but wears away the wheel too rapidly.

Great care should be used in the selection of wheels for saw gumming because inferior abrasives often burn and case harden the saws, causing them to crack. If a crack shows up at the bottom of a tooth, the only thing to do is to cut the tooth out and braze in a new one which is an expensive operation. These wheels should be of an alumina abrasive and soft enough to cut freely, but not soft enough to wear out too fast. The grade depends principally on the condition the machine is in and other local factors such as undue vibration. Too much vibration wears out the wheels readily and a harder wheel must be used than could be employed under more favorable conditions. The wheels used for this work run from 30 to 46 grit and 7 to 10 grade according to the writer's grade scale. Combination grit wheels with a base of 30 or 36 are excellent for this purpose.

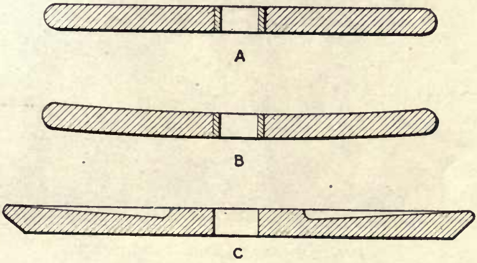

Fig. 168.—Three types of wheels used for saw gumming.

There are three shapes of wheels used for saw gumming, as illustrated in Fig. 168. A is a plain straight wheel, B is tapered on both sides while C is a shape called a Covel saw gummer. There is a difference of opinion among filers as to which shape is the best to use. Some filers get excellent results with plain straight wheels, while others insist that the tapered cutting side gives a better wheel clearance and there is, no doubt, some truth in the claim.

Re-saws are ground in exactly the same manner as are large band saws with the exception that the machine used is comparatively smaller. A re-saw grinding operation in a planing mill is shown in Fig. 169. The filer in the planing mill has comparatively few troubles compared to his brother in the big band mill, for the saws in planing mills, aside from cutting through an occasional nail, are seldom put to severe use.

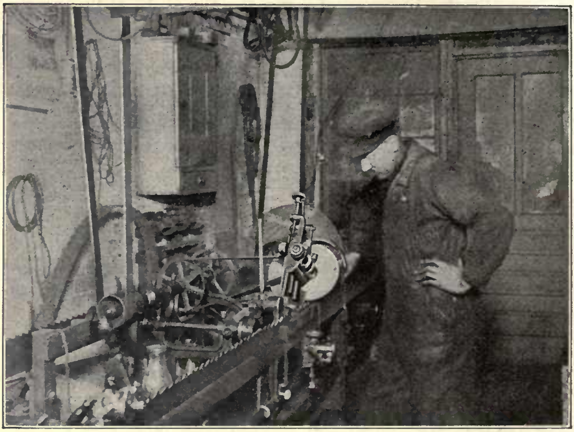

Fig. 169.—Grinding a small band re-saw.

A different type of machine than the one heretofore shown for sharpening circular saws is shown in Fig. 170. This machine is used for sharpening small circular saws as used in planing mills and furniture factories. The saw is located in a horizontal position. This machine is not automatic as far as the feed is concerned as the operator has to space the teeth around by means of the lever operated by his left hand. For small saws, these semi-automatic machines give excellent results. The same wheels are used for re-saws and small circular saws as are used for larger saws, the only exception being that the grits are somewhat finer.

Another important branch of saw sharpening consists of grinding metal cutting saws as shown in Fig. 171. These are often termed "cold saws" and are used for cutting bar stock, structural-steel sections, rails, etc. They are also frequently used in steel foundries for cutting away the sprues from large castings. As may be imagined, they are often put to severe usage and for this reason they require frequent grinding.

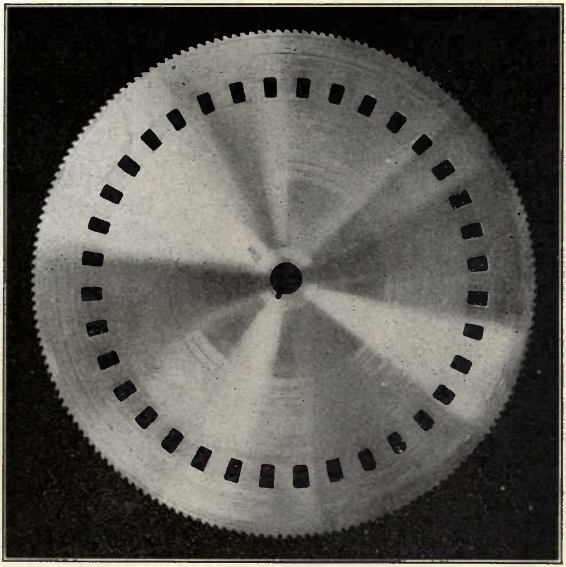

Fig. 170.—Metal cutting or cold saw used for cutting large steel sections.

The operation of sharpening the saw shown in Fig. 171 is illustrated in Fig. 172. This machine is a product of the Matteson Mfg. Co., Chicago, and is designed on the principle involved in the saw-sharpening machines previously described in this chapter. That is to say, it has means for feeding the wheel with an up-and-down motion while the saw is fed onward, tooth by tooth, by a feed dog. These motions are automatic.

The operation of sharpening cold saws is somewhat similar to re-cutting milling cutters as previously described, because two cuts are generally taken; one to grind out the gullets and a following cut to sharpen the teeth, giving them the proper relief at the same time. For grinding out the gullets, the wheel is beveled to the correct angle, the wheel being dropped directly into the tooth. For sharpening the periphery of the saw, the wheel is beveled slightly; only just enough to insure the proper cutting clearance.

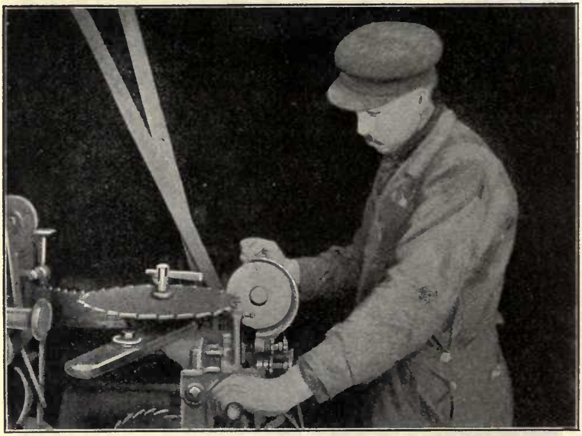

Fig. 171.—Type of semi-automatic machine used for sharpening small circular saws.

Another machine extensively used for sharpening cold saws is shown in Fig. 173. This is made by the Newton Machine Tool Works, Philadelphia. The machine is self-contained and electrically driven by means of a motor placed on a supplementary base while the rest of the mechanism is supported by a cast-iron column.

This machine is fully automatic in operation beyond locating the saw and setting the hand adjustment for depth of cut. To insure each tooth being of the correct contour, the feeding pawl is set so that the wheel grinds both the back and the front of the tooth in the roughing-out operation. In grinding saws in which a tooth or two has been broken out (which is not infrequent) an auxiliary feed pawl is provided. This pawl engages the next tooth back of the break.

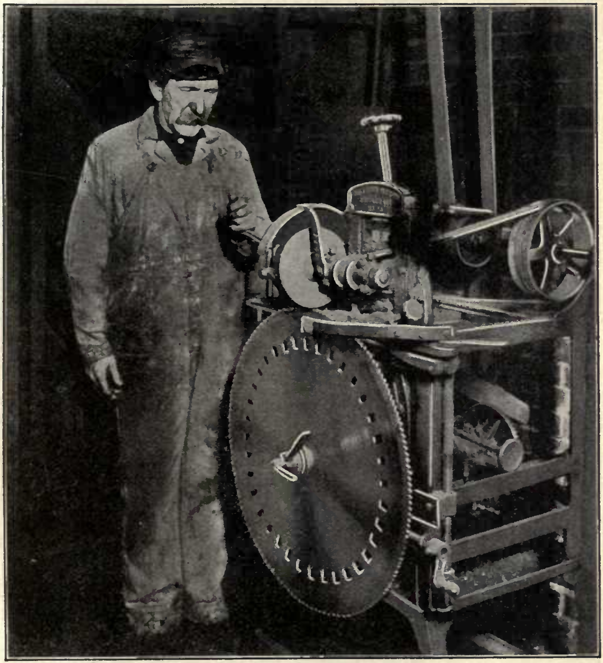

Fig. 172.—Sharpening a cold saw on a Matteson saw-sharpening machine.

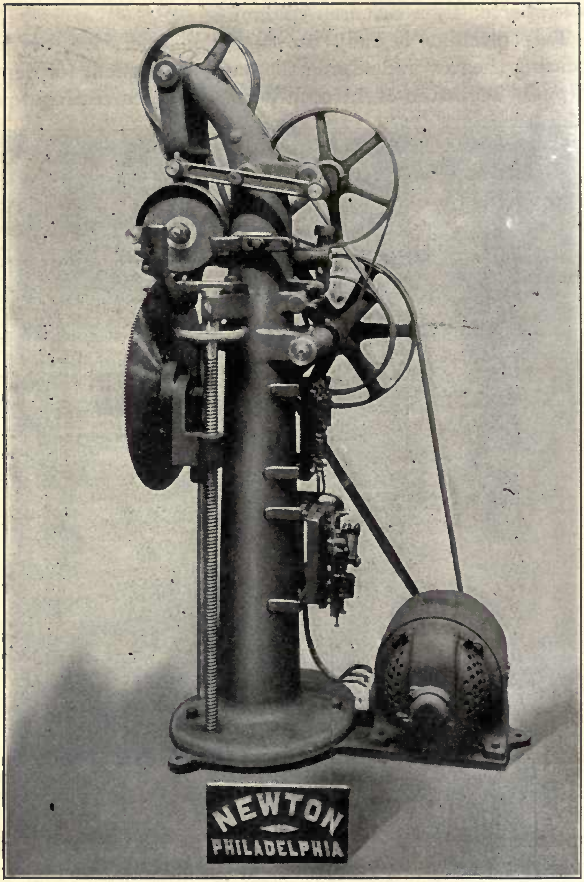

Fig. 173.—Newton self-contained automatic cold-saw sharpening machine.

Broadly speaking, the operation of sharpening cold saws is simple and it is easily carried out if a few simple precautions are taken. In the first place, these saws should be sharpened frequently. It should be borne in mind that they are really no more or less than huge milling cutters and as such they should be given careful attention. When slightly dull, they cannot work to maximum efficiency, but if they are kept sharp they will yield excellent results. Several saws for each machine should be kept on hand and dull saws should be replaced with sharp ones at frequent intervals.

The wheels used for sharpening cold saws should be of a free-cutting nature and at the same time they should hold their shape well. This applies to the wheels used for grinding the periphery of the teeth as well as those used for forming out the gullets. As the grinding in question is steel, the wheels should be made of an alumina abrasive. Grits from 40 to 60 in the writer's grades ranging from 10 to 12 generally give good results.

The machine shown in Fig. 174 was designed especially for sharpening hack-saw blades and the slow-running band saws as used at the present day for cutting metals of various kinds. Some years ago, when hack-saw blades were made of carbon steel they were thrown away as soon as the teeth became too dull for practical use. At the present time, however, when the majority of hack-saw blades are made of high-speed steel, it is evident that the average manufacturing plant's expenditure for blades under such conditions is comparatively high and attention has been directed to reclaiming the worn blades.

The machine in question is designed and made by the Wardwell Mfg. Co., Cleveland, Ohio, and its operation is comparatively simple. As the illustration shows, it is not unlike the machines previously described for sharpening wood-working saws. The machine is provided with a main drive which extends across the back of the frame and power is transmitted by means of a belt to the shaft seen in the foreground, upon which the grinding wheel is mounted.

This wheel is comparatively thin, is made in elastic bond, and is of medium grit and grade.

The grinding-wheel shaft, or spindle, is suspended at the end of an arm, the opposite end of which swings in pivoted bearings, placed well part to reduce side motion to a minimum. This feature is necessary to insure correct spacing of the saw teeth. The arm is supported in a segment which allows the wheel to be set at an angle. This permits one edge, or corner, only of the wheel to come in contact with the face of the tooth being ground while the opposite edge, or corner, bears on the back of the tooth. This action serves to keep the wheel dressed constantly so that it always presents the proper shape for forming the gullets of the teeth.

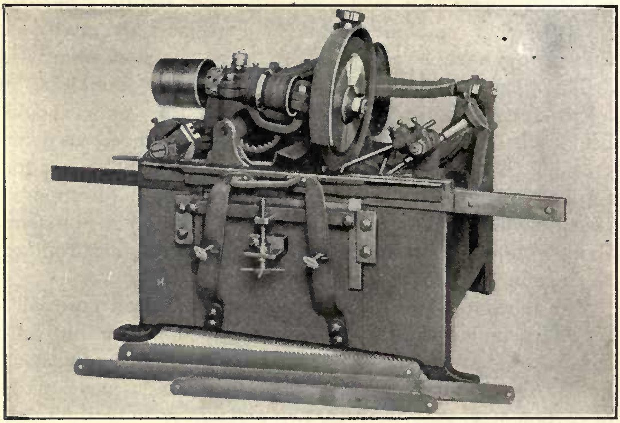

Fig. 174.—Wardwell automatic saw-sharpening machine.

Two adjustments control the movements of the grinding-wheel head. One governs the depth the grinding wheel is allowed to sink into the tooth gullet, while the other regulates the amount of cut to be taken from the back of the tooth. The last adjustment is made by an adjusting screw which comes in contact at the proper time with a roll which bears on the face of the cam. This cam is adjustable for forming all the different shaped backs of teeth.

Power from the feed mechanism is derived from the main drive shaft through a worm gear to a shaft at the left-hand side of the machine. On the end of this shaft is a slotted eccentric equipped with a screw feed. This eccentric governs the feed of the blade to the machine.

The operation of the machine is simple and exact and it is said that as little as one-half thousandth of an inch can be removed from either the face or the back of the tooth. The machine is automatic in operation, and, after being started, it requires no more attention until the saw has been sharpened, that is, when grinding a band saw. With hack saws, a group is placed in position and the feed pawls take these one at a time and feed them through the machine. A group of hack-saw blades are placed in the machine, being held by spring tension. The feed pawl bears on the inner blade only, thus as soon as this is fed out of the way, the spring action forces another in a position to be fed forward.

The blades are fed along by a double-pawl arrangement. Two pawls work at the same time, one on each side of the grinding wheel. The one on the right draws the blade in and starts the grinding of the first tooth, while the other on the left draws the blade clear of the grinding wheel and discharges it.

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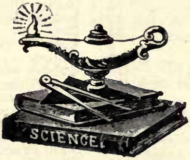

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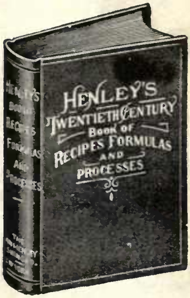

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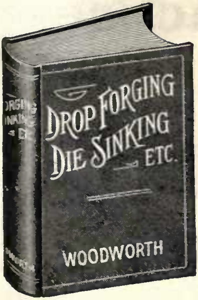

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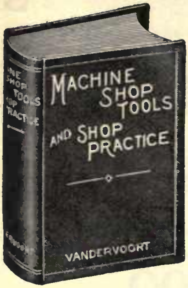

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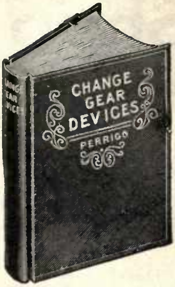

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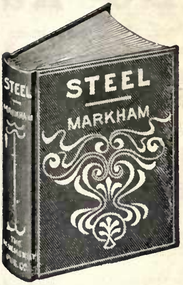

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