CONTRA-PROPS

Recollections of Early Considerations by Advisory Committee for Aeronautics : A Pioneer's 1907 Patent : Suggestions for Further Research

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ONCE more it is our privilege to publish an article by Dr. Lanchester, "Grand Old Man of Aerodynamics." And once again one is amazed at the insight into the details of the mechanism of flight which he possessed in those very early days. As long ago as 1907 he not only visualised the advantages of contra-rotating airscrews, or as he termed them "co-axial propellers with reverse rotation," but he patented a form of drive, details of which are given in this article.

THIS subject came prominently before the Advisory Committee for Aeronautics as long ago as 1918, when it received close attention. In a communication by the writer, dated May, 1918 (R. & M. 1918-19, pp. 634 to 642), the problem was dealt with from a theoretical standpoint, following the lines of the writer's exposition in his specification of Patent 9413A, 1907, published some ten years previously. In this he divided the energy losses as due to three distinct causes: (1) skin-friction and eddy making, sometimes termed *form resistance*; (2) the sternward component of the slipstream essential to propulsion; (3) the rotational component of the slipstream, whose angular momentum is a measure of the driving torque.

It was shown that, under ideal conditions, the whole of the energy loss due to the rotational component of the slipstream might be avoided, leaving (1) and (2) above as the only sources of loss. Of these, (1) alone is to be regarded as a *propeller* loss; (2) is more correctly to be considered as a *propulsion* loss, for it is inevitable in the theory of propulsion and is not dependent on the *instrument*, whether it be a screw propeller or what not.

In order to avoid loss due to the rotational component, two conditions must be satisfied. The driving torques on the two members of the combination must be equal and opposite; that is, the algebraic sum of the two torques must be zero. The air acted upon must be the same for both propellers, and the action of the propellers must be homogeneous; without this provision it would be possible for energy to be lost in rotational currents and counter currents, in spite of the torques being balanced by being equal and opposite.

The first of these conditions is satisfied by a form of balance gear described and claimed in the 1907 specification, and illustrated in the figure. Following is a brief description:—

Two propellers, respectively of right-hand and left-hand pitch, are arranged to revolve about the same axis with equal and opposite torque. Their shafts are concentric, the outer one being hollow.

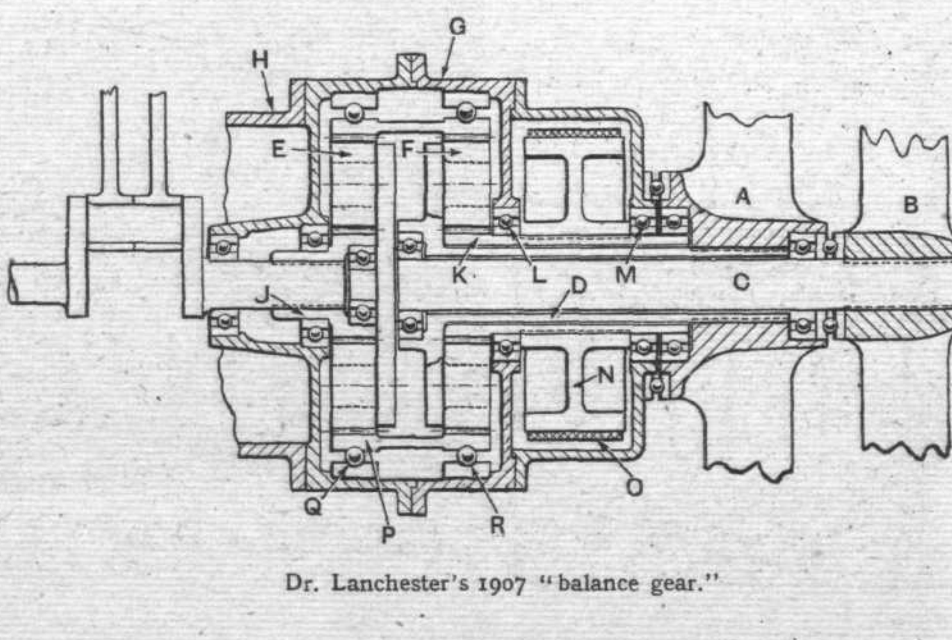
The drawing illustrates one form of the invention. Two propellers, A and B, of opposite hand, are mounted in driving connection with the shafts C and D, which are keyed to the planet elements E and F of the two trains of epicyclic gear contained within the casing G, bolted on to the extremity of the crank chamber H. One of the sun elements, J, is coupled direct to the motor shaft, and the other sun, K, is mounted to revolve in bearings L and M, and carries a brake drum, N, acted on by a brake shown as a band brake O. The ring element of the two trains of gear, P, is common to both, and is mounted in bearings in the casings Q,R, and is quite free to rotate, other than by its engagement with the planet pinions of the two trains.

When the sun element K is free to rotate, there is no driving effort exerted on either propeller; the planet elements can both stand still while both suns rotate in one direction, and the common ring element in the opposite direction.

When the sun K is brought to rest by means of the brake N,O, the planet elements are constrained to revolve (presuming the engine to be in action), but the extent to which they individually revolve is not determined except that, by the construction of the mechanism, the two propellers are acted on by equal and opposite torque. Thus the whole mechanism shown in the drawing is, in effect, a combined balance gear and clutch.

The second condition is by no means easy of fulfilment. It is just a question, as a practical problem, of how nearly the ideal can be approached; that can only be ascertained by experiment. As a "shot in the dark" the writer in his memorandum suggested that it might be hoped to save *half* of the rotational energy theoretically possible; his present view is that it should be possible to do better.

Whether the problem is to determine the data for the best possible design, or to find an expression for optimum efficiency, even on the supposition that the whole of the rotational wake energy is conserved, it is anything but



Dr. Lanchester's 1907 "balance gear."

easy. In fact, the writer believes that, up to the present, no theoretical solution has been discovered. The case for the combination put forward in his own memorandum (cited above) is far from convincing and in no sense final.

Beyond this a further unknown factor is introduced when account is taken of the loss of rotational wake energy due to the residuary turbulence in the rotational wake. As a problem to be settled by experiment, one method of approach is to take the individual propellers, as designed for ordinary duty, and mount them co-axially a sufficient distance apart to avoid direct interference. Then the leader will be running under normal conditions and show normal efficiency. The follower will be subject to two opposite influences, one tending towards a higher revolution speed due to the sternward wake being already established; the other tending towards a lower revolution speed due to the air on which it operates having opposed rotational momentum. It being assumed that the combination is driven through a balance gear, equality of torque takes care of itself. The combination is then tested in the wind tunnel and the results recorded and plotted.

The whole process is then repeated, using propellers designed on the same system but with a higher value of P/D (coarser pitch), and then again with a higher P/D ratio still. If the main contention in the memorandum is correct, there will be an increase in efficiency with increased P/D ratio till an optimum value is reached, which may be regarded as the practical solution. A falling efficiency associated with an increase in the P/D ratio would betoken that the optimum condition has been passed.

The gain to be anticipated from the use of a higher P/D ratio would be due to the lower blade-velocity for a given flight speed and incidentally, a reduction in the propeller noise. Such higher ratio is permissible because a portion at least of the rotational wake energy is conserved. The procedure suggested above does not tell us how much, or what proportion of the rotational wake energy is conserved (that will depend upon the extent to which the action of the propellers on the air coming within their grasp is homogeneous), but it means that we reach a practical solution for optimum condition without such knowledge.

The experimental campaign would not be quite so simple as it might appear from the above description. Not only would the tests on each combination require to be repeated for many variations of velocity and thrust, the results being analysed in the form of plotted graphs, but side issues arise which would require independent examination. For example, owing to the contraction of the slipstream as and after passing through the leading screw, it is necessary that the follower should be of somewhat smaller diameter than the leader, in order that both should act on the *same column of air*. Then again the whole programme might need to be repeated with different numbers of blades, or with propellers based on different formulæ of design. Also there would be a preliminary enquiry to establish the minimum distance of separation consistent with non-interference.* Such work is worthy of the renewed attention of the staff of the N.P.L. with the equipment they have at their command.

* The following references may be given as relating to early investigations of the present problem: Technical Reports of the Advisory Committee for Aeronautics, 1918-19, pp. 642 *et seq.*, and p. 655, paragraph (4). Also (quoted on p. 643) R. & M., 421, 385 and 429. But as these latter do not appear in any index they are difficult to locate. These are additional to the writer's contribution, ref. pp. 634 *et seq.*

AUXILIARY SQUADRONS in the WAR

More than 200 Enemy Aircraft Accounted for : First to Fly Several New Types

PILOTS of R.A.F. Auxiliary fighter squadrons have already accounted for more than 200 enemy aircraft in offensive operations this year. This is over a quarter of the total number of German aircraft destroyed by Fighter Command in raids over the Continent and the enemy's seaboard since January.

In addition, members of Auxiliary squadrons have been pioneer pilots of new types of aircraft now being used against the enemy. It was an Auxiliary Hurricane squadron which opened the fighter campaign against enemy shipping in the Channel. An Auxiliary squadron was the first to be equipped with American Airacobra fighters, and pilots of another Auxiliary squadron made the first raids over France with bomb-carrying Hurricanes.

War of the Roses

The West Riding of Yorkshire Squadron and the West Lancashire Squadron have each destroyed more than 50 enemy fighters on offensive operations this year. In one week in June the West Lancashire Squadron shot down 17 Me 109s for the loss of only one of their own pilots. In one sweep they accounted for seven of the enemy. In July they shot another 17 German machines out of the French skies, including five in one day. Their brilliant fighting won them the congratulations of the Secretary of State for Air.

Like its colleagues from Lancashire, the West Riding Squadron was in at the start of the offensive. Until August the pilots were led across the Channel by a pilot who now commands a Spitfire Wing and has 17 German machines to his credit. Airmen from many nations have contributed to the success of this squadron. The personnel includes Belgians, Canadians, New Zealanders, Frenchmen and Poles.

Among other Auxiliary squadrons which have gained distinction in fighting over enemy territory are the South Yorkshire, County of Chester and City of Edinburgh Squadrons.

Attacks on Shipping

Early in September Fighter Command took a hand in the war against enemy shipping in the Channel. In new-type Hurricanes, pilots of one county squadron opened the campaign with low-level attacks on *flak* ships, patrol boats, minesweepers and tankers. This new form of attack was an immediate success, and within a few weeks the squadron had definitely sunk eleven vessels and damaged many others.

Pilots of the county squadrons fly at mast-head height to gun enemy ships and sweep in over tree-tops to release bombs on airfields, factories and gun posts. Once the bombs, which are fitted with delayed-action fuses, are dropped, the Hurricanes become fighters again, and the pilots seldom return until they have used up their machine-gun ammunition against enemy fighters or ground targets.

While the daylight offensive has been going on, other Auxiliary squadrons have been engaged in the night defence of this country. Although "customers" have been fewer lately, one squadron has now bagged more than 60 night raiders.