SSV CASE PART II

1 The Design Changes

While building the actual SSV we came across some problems and made some reconsiderations concerning the design. In the following paragraphs we will explain shortly what changed and why.

The Frame

When we had to change our Solar Panel attachement, as explained later on, we figured, that a suction cup would hold a lot better on plexiglas than on would. Also, with our shiny wheels, aluminium solar panel and plastic gears, wood would not fit in very well optically. Also, Fablab offers a range of plexiglas plates, so they would be easily available and affordable.

As we decided on a gear ratio that demanded a middle shaft for better transmission, we decided on making the shape broader in the back, also allowing the self made Pillow Block Bearings to be spread further apart, giving the back axle more stability.

The Wheels

The rear wheel are mini-CDs, as planned. To give them more strength we always glued two CDs together. The front wheel has eventually changed to a standard suitcase or chair wheel, that can losely rotate, due to reasons explained in the following part.

The Front

As found in the technical drawing, we realized that it was easier to attach the two front wheels to a frame, that was in turn attached with an elastic system to them main frame. In that way, both wheel would always remain parallel, which would reduce friction. We also added a copper wire as a guiding rail around the front wheels, to protect the CDs.

The idea behind this design was the following: if the SSV would collide with the wall, the copper wire would push along the wood, while at the same time gently pushing the wheels in the oppsite direction, this adjusting the path of the SSV parallel to the guideing walls.

After several attemptes and idea exchanges with our coaches, we had to admit that the walls did excert too much friction and the front of the SSV was not designed in a way to easily attach side wheels, rolling along the wall. We thus opted for the easy but safe solution of redesigning our SSV front. Instead of two wheels we inserted one freely rotating wheel in the drill hole formerly occupied by the pin attaching the two parts. The screw of the wheel went through the hole and gidely held an aluminium strap in place, parallel to the back axle. On this strap two side wheels were attached, now allowing the SSV to collide with the walls withoud crashing.

This solution vary quite a bit from the original design, but allowed us to keep the costs limited and even to reduce the weight.

The Back Axle

The Back Axle was construced as planned. With wider spread bearings, the wheels would keep the brass axle in place, making a spacer redundant. Again, we switched materials, as brass axles are available in every good DIY store, why alternatives would demand a higher price and more time invested.

The Solar Panel

As mentioned before, a sort of fixable cardan joint attachement was not realiable, due to the imagined part not being sold commonly, and also the solar panel just consisting of a flat aluminium back bone, not allwing easy attachement. We just opted for the common but effective solution of a double suction cup holder, also used for Ipads, thus definately supporting the weigth of our solar panel, even with wind interference.

The Motor

Getting very fond of the characteristics of our 3D printed gears, we also ordered a motor clip in FabLab, also giving us a more coherent design.

The Gears

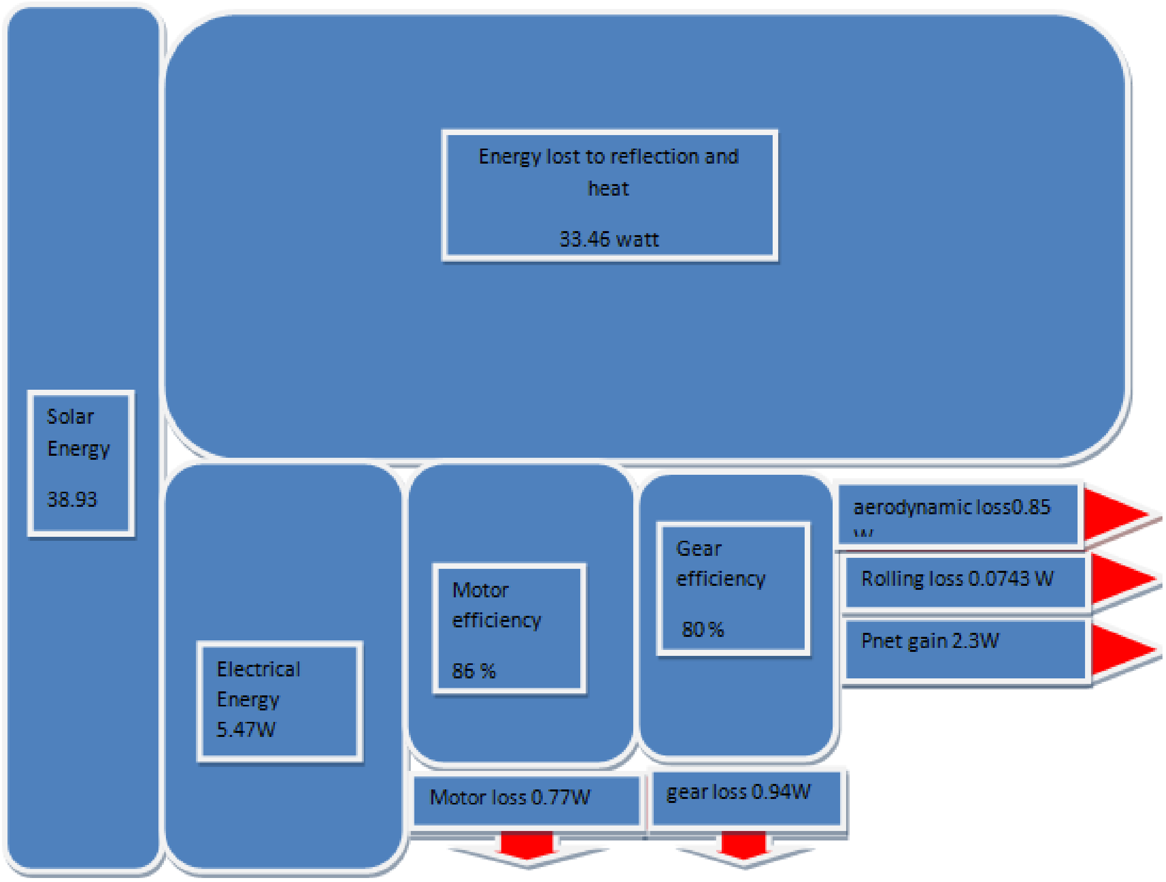
The gears were designed with Autodesk Inventor and printed in FavLab, as planned.

What could have been done better

While our SSV is now full functional, there are still possibilities for improvement.

- A smaller version of the double suction cup would also suffice, even though it could not be found on the market so far.
- Seeing that our assambly is not perfect, slot instead of drill holes for the screws might have been smarter, allowing slight adjustments of the placements, if a screw is not placed precisely.
- With a plexi glas plate of half a centimeter we went for security. Seeing the SSV in action now, 0,4 or even 0,3 mm should also have sufficed, thus reducing weight.
- For the same reason as above, we did not cut out much from the plexi glas plate. Cutting out some more material would still allow enough strength
- After letting the gears run for some time without much visible wear off, it would also be possible to design our gear train with smaller and thinner gears.
- Slots could have been lasered into the frame, allowing the permanent placement of a switch.

2 Improved Sankey diagram



Energy lost to reflection and heat
33.46 watt
Solar Energy
38.93
Electrical Energy
5.47W
Motor efficiency
86 %
Gear efficiency
80 %
aerodynamic loss0.85
Rolling loss 0.0743 W
Pnet gain 2.3W
Motor loss 0.77W
gear loss 0.94W

This report will show an improved version of sankey diagram. The first sankey diagram was based on virtual world parameters. After building the SSV we have seen their will some change to our sankey diagram.

Our simulation indicates with 1 seconds our SSV will cover almost 1 meter (0.868 m) i.e. around 10 meters in 10 seconds. When it came to practical rolling experiment we found this much lower. The rolling experiment was done through the downward slope (4 m) , we have observed it rolled around 3 meters before collision.

The difference for the reality and virtual test can be attributed to the following reason

- The difference in weight: the addition of solar panel, solar panel stand causes an increase in weight making the calculation of rolling resistance, potential and kinetic energy that much different.
- The efficiency of gears: we have produced the gears ourselves in fablab. During our test there were noises which indicate to us there mesh was not exact.
- During test of SSV we were having design problem. The guide to the collision we designed needed to be formatted. We have decided to go with one wheel plus adjust the guide as well.

Loss on Rolling Resistance

This new loss is caused by the change in mass. As mass is increases , it will increase the rolling resistance.

Fr= M×Crr×g

Where M=0.947 kg , Crr=0.008 , g=9.81m/s^2

Fr=0.0743W

Loss on the gear

These gears were designed and made by ourselves. The test has showed they don't mess as well as we would hope for so we have decreased the efficiency from 90 to 80 percent.

4.7 ×0.20= 0.94 W

All the other parameters remain the same. The aerodynamic looses, the efficiency of the motor and solar panel efficiency will remain the same. These are the parameters that did not change.

New power net

Pnet = Pmotor – (Pairloss + Proling+ Pgear)

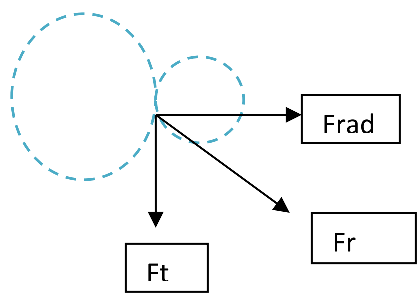
Pnet = 4.23 – (0.0743+0.94+0.85) = 2.36 W

Shaft material used

The material which was used for the shaft is brass. It is an alloy of copper and zinc. It has low density and has a character of low friction. Other uses include making gears and locks. We took our shaft to the strength of material lab in GroupT where it was confirmed to us it was indeed brass.

Analysis of forces transmitted from the motor to gear 1

We know the following parameters



Torque constant= 8.55 mNm/A

Max efficiency= 84% I=0.83 A

Gear ratio i=11 Let ø=20°

T= Ke × I × η × i = 8.55* 0.84*0.83*11 =0.067 Nm

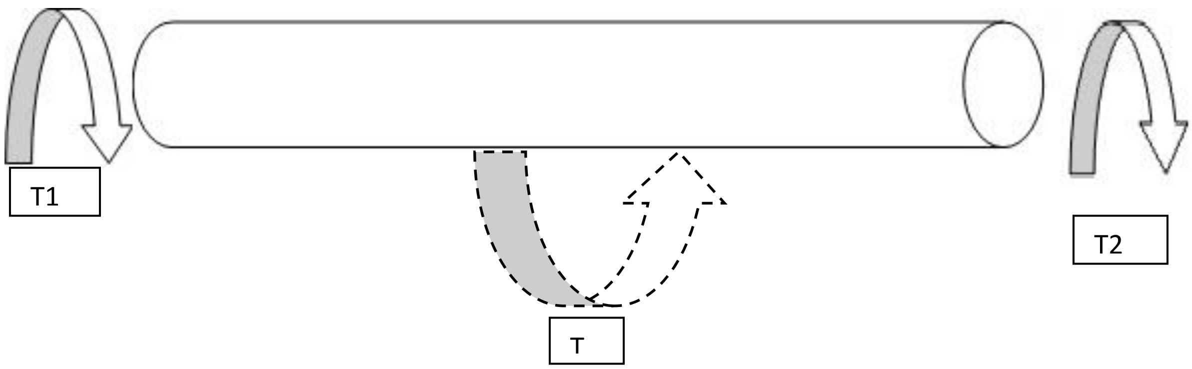
T = F× r = $\frac{0.067}{0.025}$ = 2.68 N

F_{rad} = F=2.68

$F_{tangital}$ = F × tan20 = 2.68 tan200.975

Fr= 2.85 N

Analysis for torque distrbution



Assumption for torsion

- The shaft is homogenous
- Torque is constant and transmitted through out each section by shear
- Analysis only valid for hollow or solid circular section

Our shaft full fills these criteria so we can use the formula directly to find the torque. Our shaft is restrained at both ends by the holders. This will make the total angle of twist (ø) balanced.

i.e. φ1 + φ2 =0 and T= T1+ T2

$$\varphi 1=\frac{T1 \times L1}{G\times J} \quad \varphi 2=\frac{T2 \times L2}{G\times J} \quad = \frac{T1 \times L1}{G\times J} =- \frac{T2 \times L2}{G\times J}$$

$$= \frac{T1 \times 0.074}{G\times J} =- \frac{T2 \times 0.031}{G\times J}$$ J and G are the same for it is same material

= T1 0.074= T2 0.031 $\quad T1=\frac{T2\times 0.031}{0.074}$ = T2 * 0.42

From the calculation of torque delivered by the motor to the gear1 we can have the total torque delivered to the shaft

i.e. T = T1 + T2 (shown in figure above)

= 2.68 Nm = T2 * 0.42 + T2

T2 =1.88 Nm T1= 0.79 Nm

For Maximum torsion

$$\tau_{max} = \frac{Tmax \times R}{I} \quad \text{where } I=\frac{1}{4}\Pi R^4 \text{ and } R=0.025$$

$$= \frac{1.88 \times 0.025}{6.13 * 10^{-7}} = 76.67 \text{ Kpa}$$

For Maximum shear stress

The maximum shear stress is found looking at the shear force diagram and taking the maximum point for computation.

$$\tau_{max} = \frac{Vmax \times Q1}{I \times t} \quad \text{where } I=\frac{1}{4}\Pi R^4 \quad \text{and } Q= \frac{2}{3}\Pi R^3 \quad t=d = 0.05$$

$$= \frac{4.77 \times 3.27 \times 10^{-5}}{3.06 \times 10^{-7} \times 0.05} = 10.19 \text{ Kpa}$$

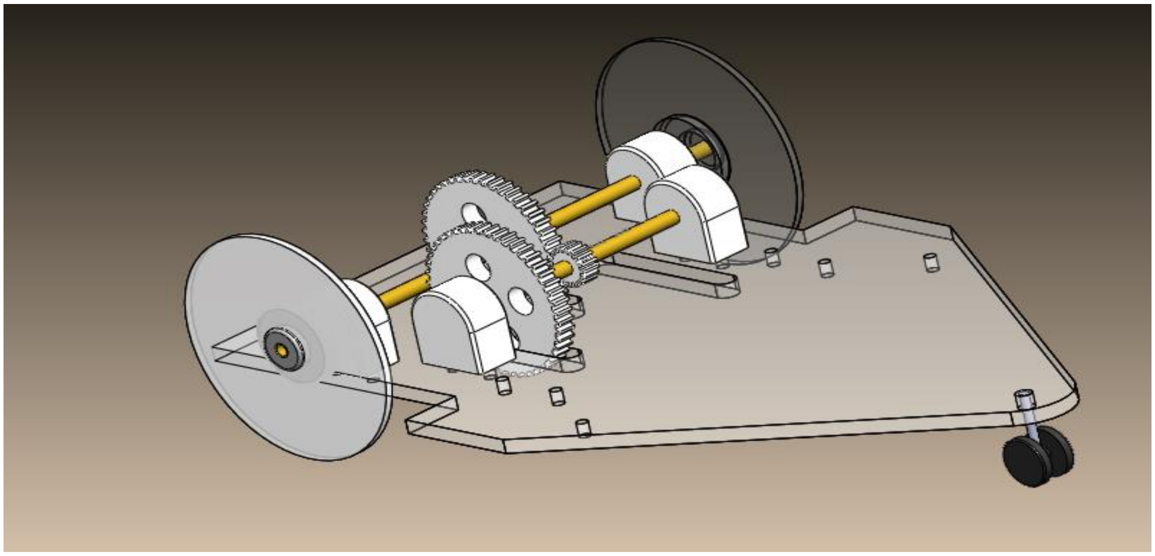
For Maximum Bending stress

From the information provided from the moment diagram we can also compute the maximum bending stress.

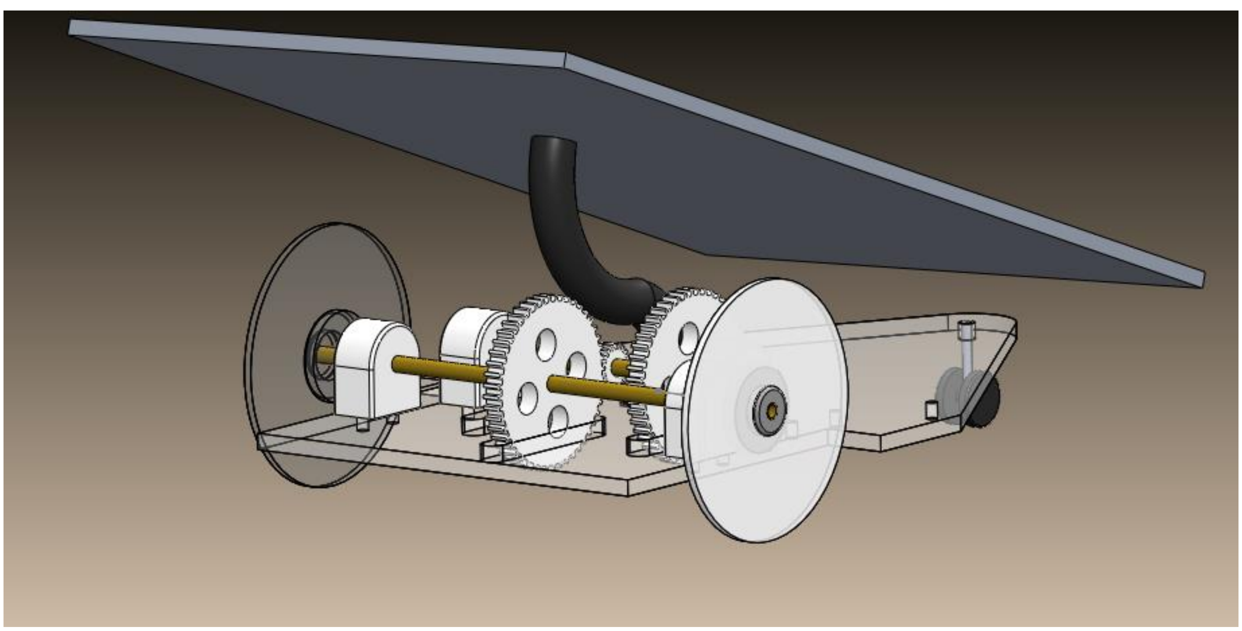
$$\sigma max = \frac{Mmax \times R}{I} \quad \text{where } I=\frac{1}{4}\Pi R^4 \quad R=0.025$$

$$= \frac{30.14 \times 0.025}{3.06 \times 10^{-7}} = 2.6 \text{Mpa}$$

3.1 3D SSV TeamT



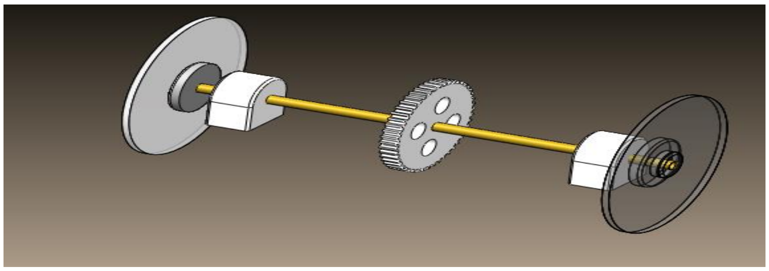
Picture 1 SSV without Solar Panel and Holder



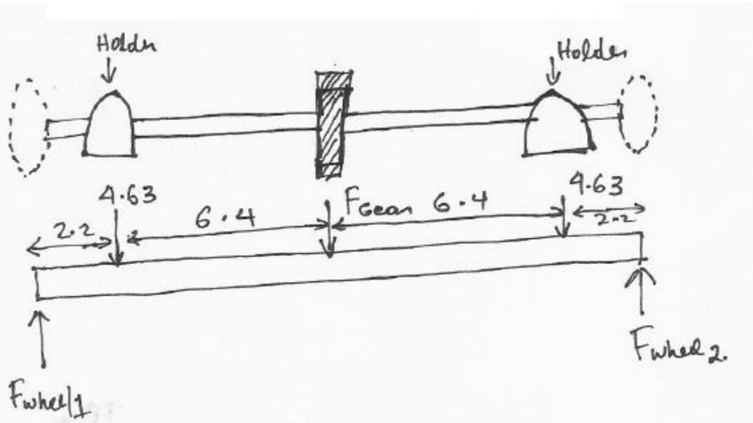
Picture 2 SSV TeamT 3D Assembly

3.2 Make a simplified model of the drive

3.2.1 Driven Shaft



Picture 3 Driven Shaft



Total mass = 0.943

0.943 kg × 9.81 = 9.25 N

Mass Gear = 0.03

0.03 × 9.81 = 0.294 N

Assumptions

- The wieght of the car is distrubted evenly on the holders.
- The mass of big gear is 0.03 kg
-

$\Sigma F_y = 0$: $F_{wheel_1} + F_{wheel_2} = F_1 + F_{Gear} + F_3$

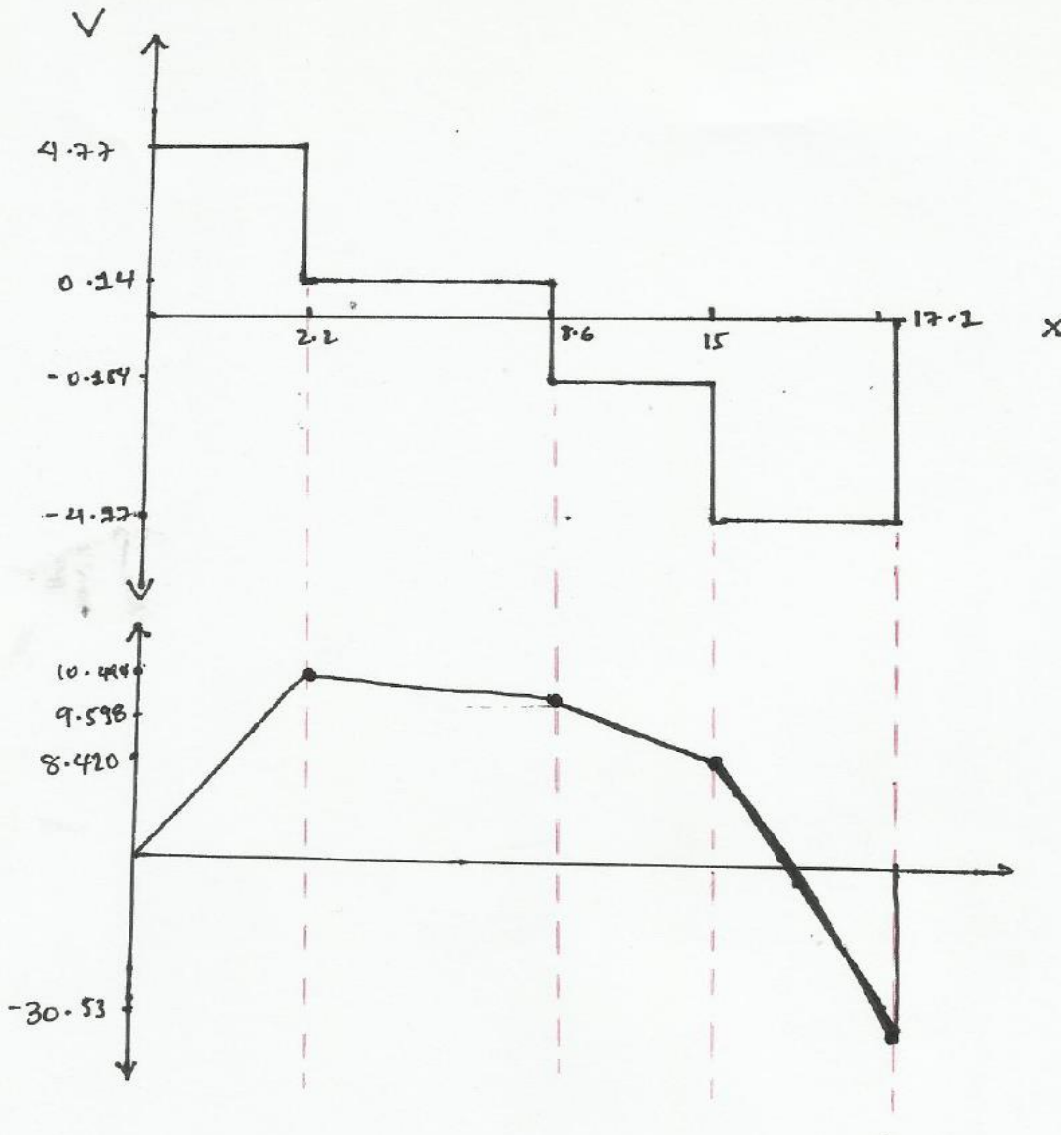
: $F_{wheel_1} + F_{wheel_2} = 4.63 + 0.294 + 4.63$

$F_{wheel_1} + F_{wheel_2} = 9.544\,N$

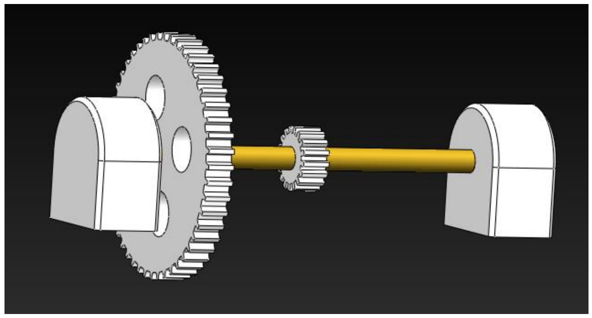
$\Sigma M_1 = 0$ $F_{wheel_2} \cdot 17.1 = 4.63 * 2.2 + 0.294 * 8.6 + 4.63 * 13$

$F_{wheel_2} = 4.77\,N$

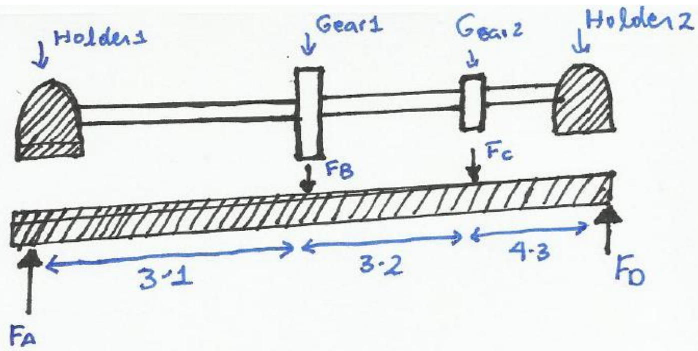
$F_{wheel_1} = 4.77\,N$


V
4.77
0.14
-0.184
-4.77
2.2
8.6
15
17.2
x
9.598
8.420
-30.53

3.2.2 Driving Shaft



Picture 4 Driving Shaft



Assumption.

- The shaft is evaluted without considiring the force transmited by the motor
- $g = 9.81\ m/s^2$
- Mass Gear1 = 0.03 kg
- Mass Gear2 = 0.01

F_{Gear1} :

$F_{Gear1} = 0.03\ kg \times 9.81\ m/s^2 = 0.294\ N$

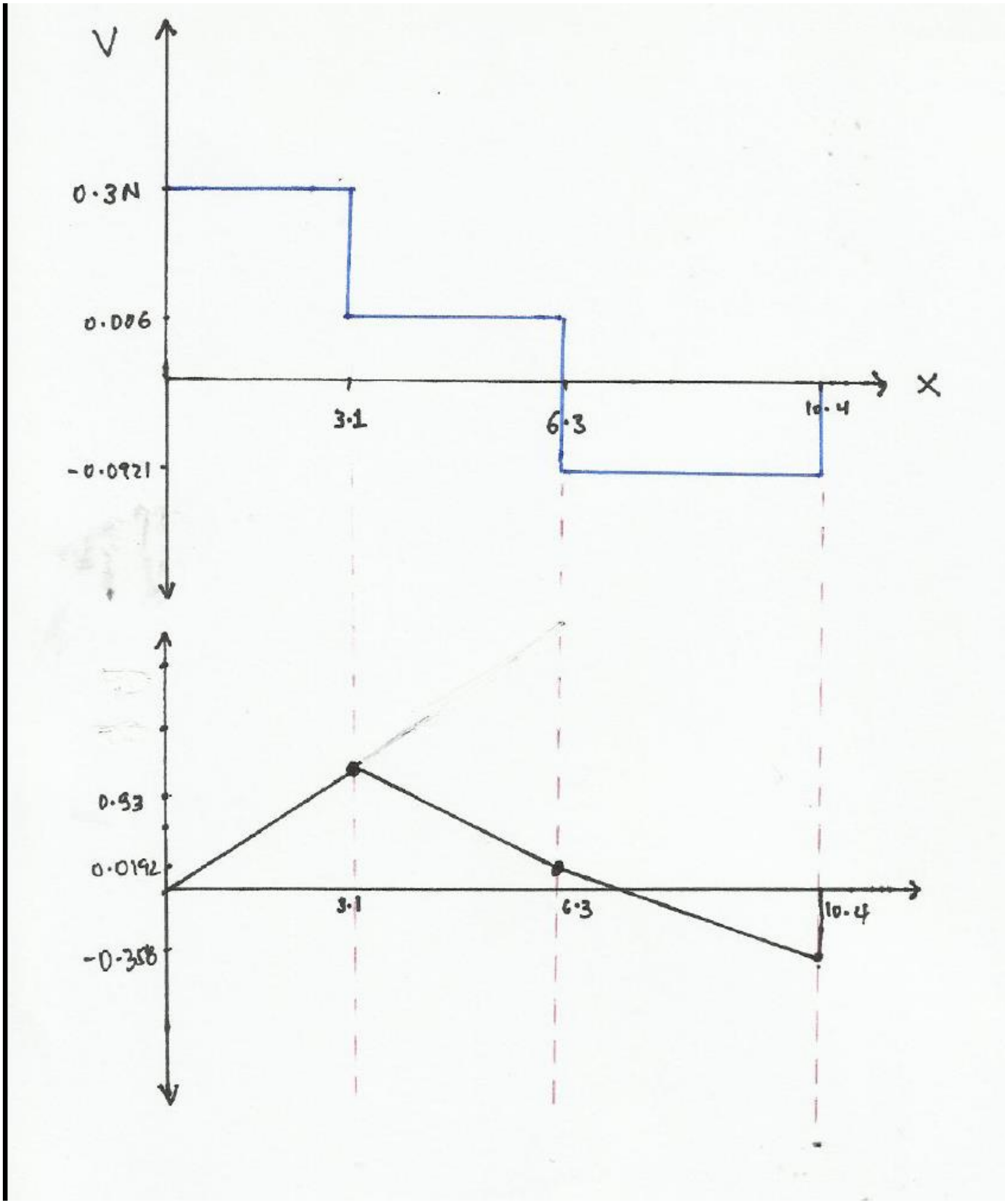
$F_{Gear2} = 0.01\ kg \times 9.81\ m/s^2 = 0.0981\ N$

$\Sigma F_y = 0 \qquad F_A + F_D = F_B + F_C$

$\Sigma M_A = 0 \qquad 0.294 * 3.1 + 0.0981 * 6.3 = F_D * 10.6$

$F_D = 0.092\ N$

$F_A = 0.300\ N$



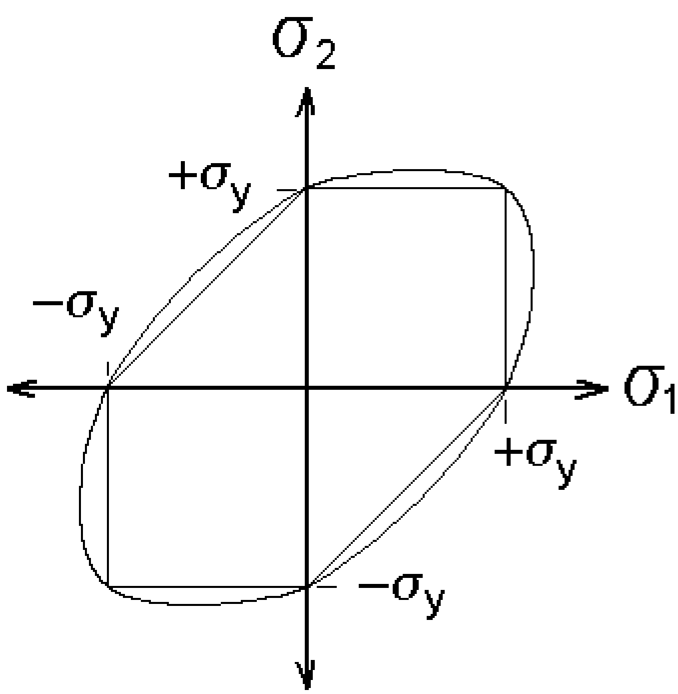
V
0.3N
0.006
X
3.1
6.3
10.4
-0.0921
0.93
0.0192
3.1
6.3
10.4
-0.358

3.3 Von mises analysis

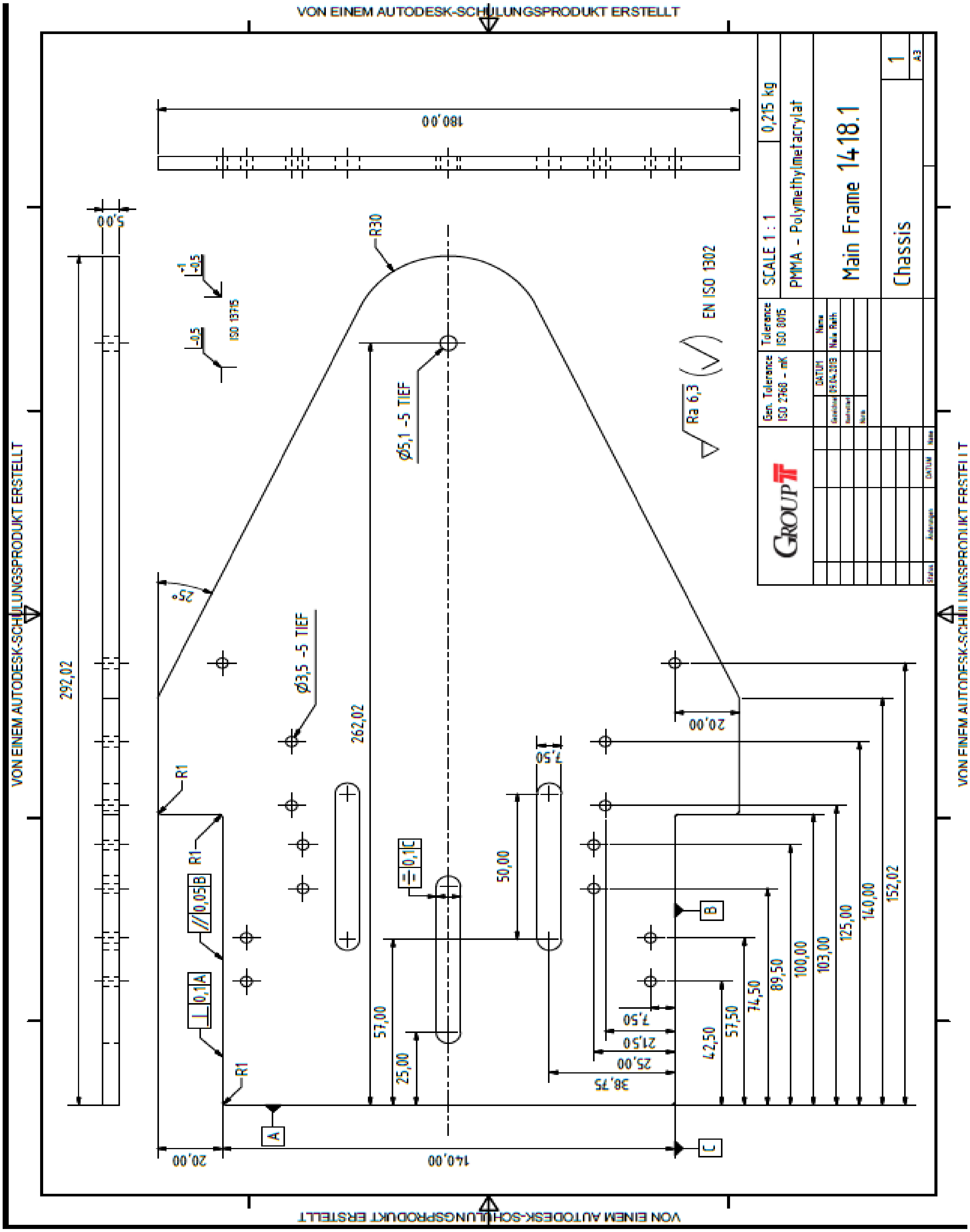
The von mises analysis is used to determine the yield stress that will point to us the stress before failure. Von Mises postulated "that a material will yield when the distortional energy at the point in question reaches a critical value". To determine the von mises stress we have to first know the principle stresses. Then we can apply the formula of von mises to find the yielding stress.

We can plot the ellipse using this yielding strength.

$$(\sigma_1 - \sigma_2)^2 + \sigma_1^2 + \sigma_2^2 = 2\sigma_y^2$$



4 2D technical drawing of the frame of your SSV



5 SSV collides Calculations

Your SSV collides with the side of the track on the flat part at maximum speed under an angle of 10°. What is the impulse, if you assume an elastic collision? How long does the collision need to last for the force to remain below 10 N?

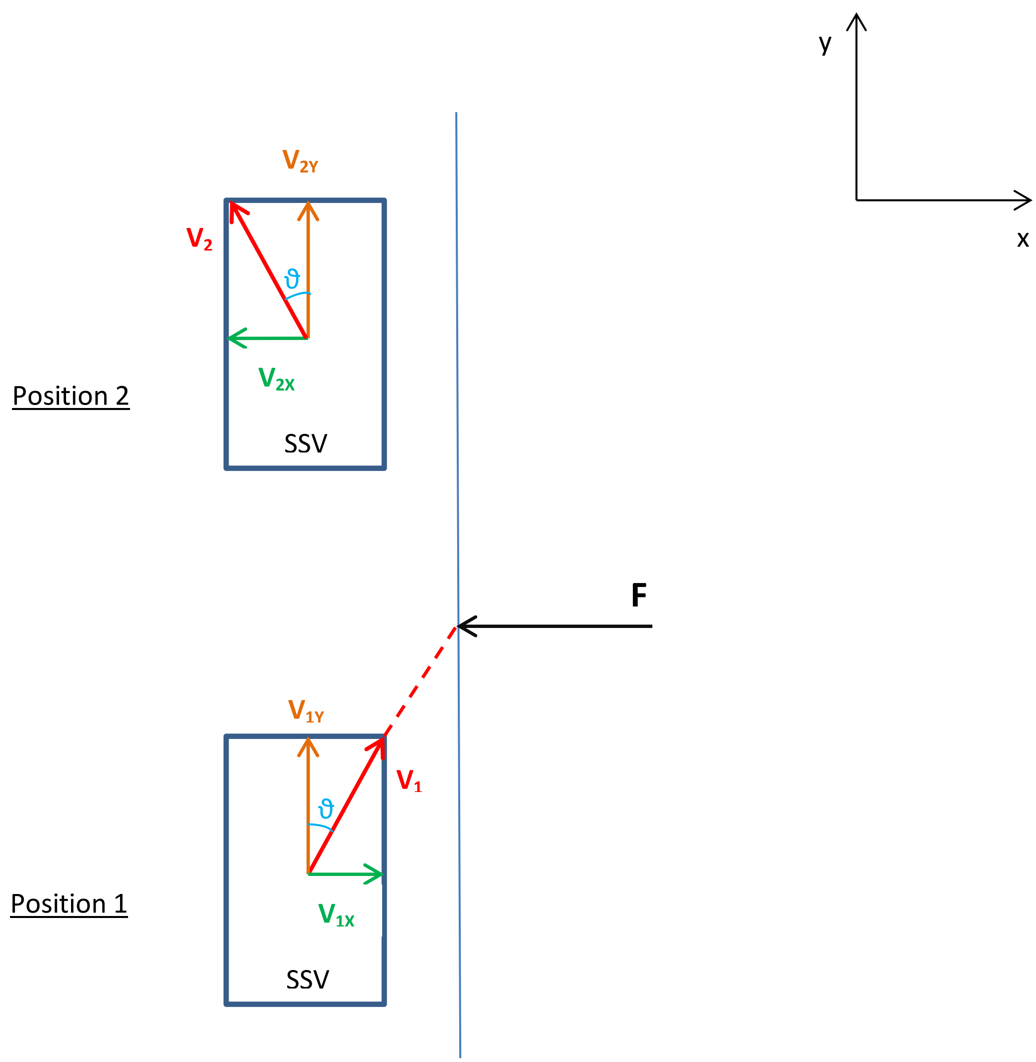
Given

F=10(-1i) N

V_{max} = 2.8m/s

1kg = m

ϴ = 10°



Solution

Since we are assuming to have an elastic collision, the magnitudes of $V_1 = V_2 = V_{max}$

$(V_1)_y = (V_2)_y$

$(V_1)_x = -(V_2)_x = V_{max} * \sin\Theta$

The Principe of Impulse and Momentum :

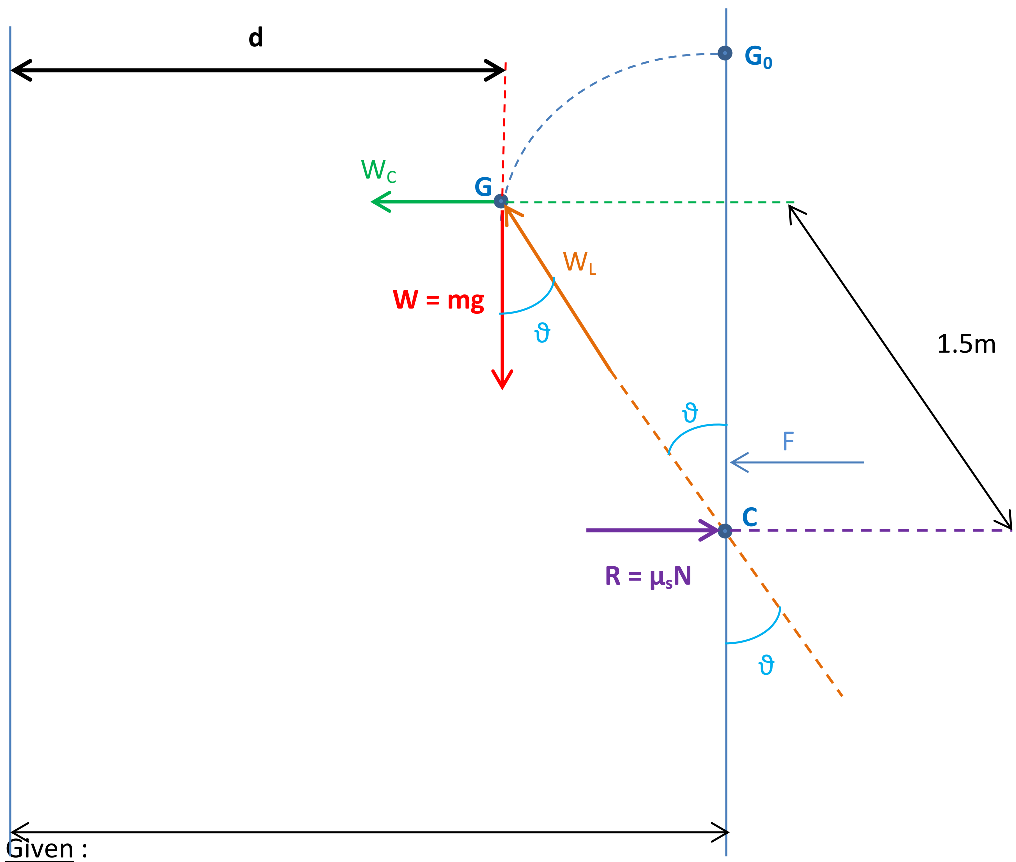
$$\begin{cases} L = m * V_{max} \\ (V_1)_x * m + F * t = -m * (V_1)_x \end{cases}$$

$\leftrightarrow F * t = -2m * V_{max} * \sin 10° = -0.97$ N s

$\leftrightarrow t = \frac{-2m * Vmax * \sin 10°}{F} = 0.097$ s

6 SSV approximation to a bike calculations

A cyclist is riding at a speed of 50 km/h. He arrives at a crossroad and needs to turn left. The radius of the turn is 10 m. What is the necessary inclination angle? Does he have to reduce his speed to make a safe turn? What is the maximum possible speed?
Mass of the cyclist: 60 kg; mass of the bicycle: 12 kg; distance between ground and centre of gravity: 1,5 m (when he is riding vertically); Static coefficient of friction between wheels and ground: 0,3.



Given :

12kg + 60kg = 72kg ; V = 50km/h = 13.89 m/s ; μ_{Static} = 0.3, r = 10 m

Unknowns :

ϴ = ?

V_{max} = ?

Solution :

1. Consider point G (mass Center)

Let use normal component formula,

$W_c = m * \frac{V^2}{d}$ eq.1

Where $d = 10 – 1.5\sin\Theta$

Let use kinetic equation by considering only mass center point,

$W_c = - W_L \sin\Theta$ eq.2

$W_L = \frac{W}{\cos\Theta}$ eq.3

Eq.1 = eq.2

$m*\frac{V^2}{10-1.5\sin\Theta} = -m*g\frac{\sin\Theta}{\cos\Theta}$

$\leftrightarrow 1.5*9.81\sin^2\Theta – 10*9.81\sin\Theta – V^2\cos\Theta = 0$

Suppose $\sin\Theta = a$

$\leftrightarrow f(a) \equiv 1.5*9.81a^2 – 10*9.81a – V^2\sqrt{(1 – a^2)} = 0$

From here on, we use Bisection Method to find a.

$\leftrightarrow$ a = -0.867056238, therefore Θ = Arcsin(-0.867056238) = 60.12°

2. Consider point C,

$\rightarrow R = F_{static} = \mu_{Static}*N$

$\rightarrow W_L = \frac{W}{\cos\Theta}$ Thus, $R = \mu_{Static}*m*g$

$\rightarrow N = W_L \cos\Theta = W$

$\rightarrow$ If $F \leq R$, the bicycle won't fall.

Therefore we consider the case : $F_{max} = R$;

$tg\Theta = \frac{Fmax}{W} \leftrightarrow \frac{\mu Static*m*g}{m*g} = tg\Theta \rightarrow \Theta_{max} = Arctg(\mu_{Static}) = 16.7°$

Since $F = m*V^2*\frac{1}{r} \leftrightarrow V_{max} = \sqrt{(\frac{r*F}{m})} = 5.425$ m/s

Since the cyclist speed (13.89 m/s) is higher than V_{max} , he should reduce his speed in order not to fall while he is turning.