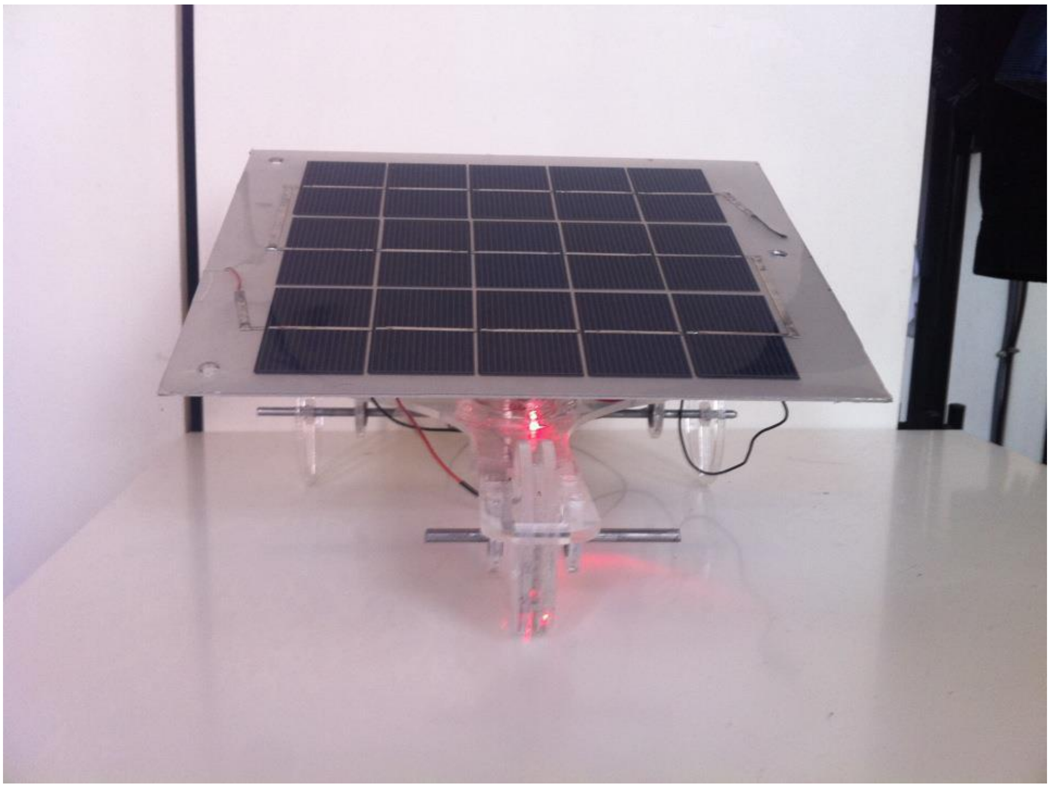
Group M10

Report

Case SSV part II



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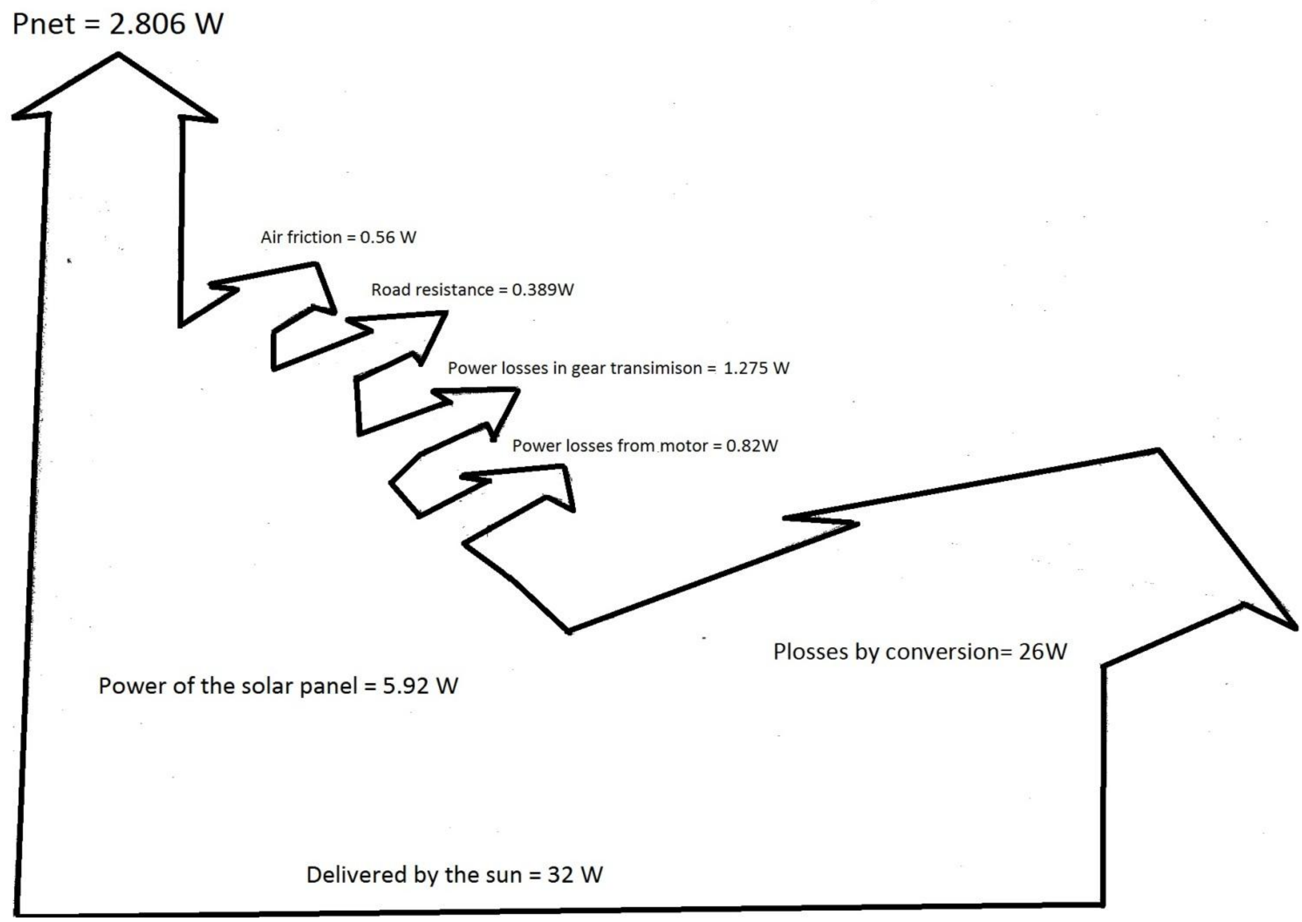
1.1 New Sankey diagram of our SSV

New Sankey Diagram



A simulation with Simulink showed that our car should be able to roll 11.5 m without any added power (from the solar panel or a battery). However, in reality, it only rolls 10.5 m.

There are several possible reasons for this 1m difference.
Perhaps, there is more friction between the road and our wheels than expected. We can adjust the coefficient of rolling resistance.
Another possible cause of power loss is the transmission. We use self-made Plexiglas gears which are manually positioned. Therefore, lots of power can be lost (which is confirmed by the noise created by the gears).
Also the air resistance might be higher than first assumed. This is due to the unknown air resistance coefficient.

When looking at the previous Sankey Diagram when the SSV reached 4m, there was 5.1W of energy available after subtracting power loss due to the efficiency of the motor.

Previously, we estimated that the loss in gear transmission was 20%. But as the simulation showed, we had too much power left. That's why we now assume a power loss of 25% in the transmission.

$$P_{GLoss} = 0.25 \times 5.1 = 1.275W$$

This leaves us with a remaining power of 3.725W. In addition there is the road resistance as follows:

$$F = 0.01 \times 1 \times 9.81 = 0.0981N$$

This leads to the counter torque on the axis:

$$T = 0.0981 \ \times 0.04 = 0.003924Nm$$

Leading to P_{loss}:

$$P_{RLoss} = 0.003924 \times 99.1 = 0.389W$$

There now is only 3.366 W left. The last power loss can be found in air friction. Previously, we assumed our drag coefficient to be only 0.4. We now realize that this value is on the low side. A different result is obtained when taking a more realistic drag coefficient of 0.6 in account.

$$F_{airFr} = 0.025 \ \times 0.6 \times 3.964^2 \times \frac{1}{2} \times 1.204 = 0.142N$$

$$T = 0.142 \times 0.04 = 0.00568Nm$$

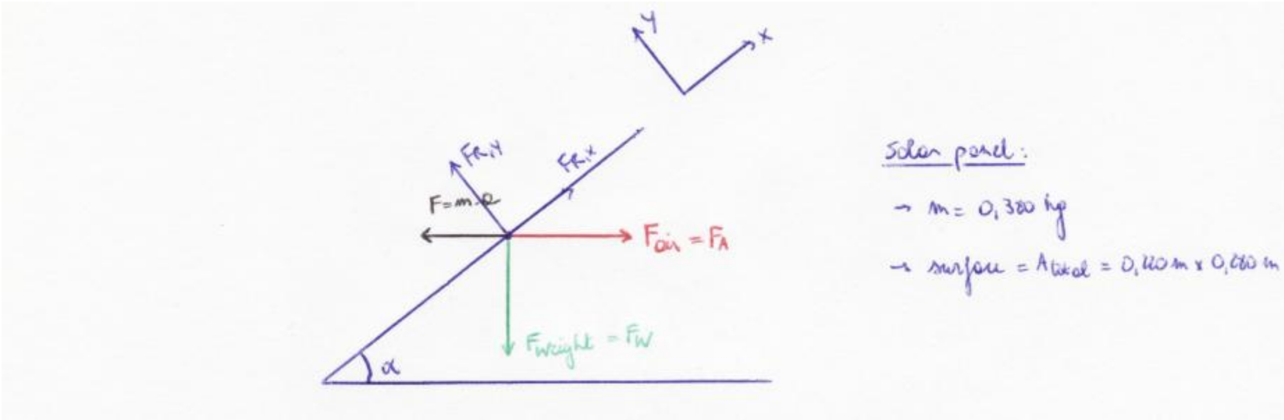
$$P_{airLoss} = 0.00568 \ \times 99.1 = 0.56W$$

This leaves us with a net power of 2.806 W, instead of the previously obtained 3.41W.

1.2 Calculations solar panel

Structural analysis of the solar panel

We first determine the worst case angle α.



Therefore we search for the maximal force in the y-direction.

$$F_{max}(\alpha) = F_W \cdot \cos\alpha + F_A \cdot \sin\alpha + m \cdot a \cdot \sin\alpha$$

→ deriving $F_{max}(\alpha)$ to α and setting this equation equal to zero gives the angle α for the worst case:

$$\frac{\partial F_{max}(\alpha)}{\partial\alpha} = -F_W \cdot \sin\alpha \cdot \dot{\alpha} + F_A \cdot \cos\alpha \cdot \dot{\alpha} + m \cdot a \cdot \cos\alpha \cdot \dot{\alpha} = 0$$

$$\dot{\alpha}\left(-F_W \sin\alpha + F_A \cdot \cos\alpha + m \cdot a \cdot \cos\alpha\right) = 0$$

so $-F_W \sin\alpha + F_A \cdot \cos\alpha + m a \cos\alpha = 0$

$$\frac{F_A + m \cdot a}{F_W} = \frac{\sin\alpha}{\cos\alpha}$$

Before we continue, we first calculate the forces acting on the panel.

$$\rightarrow F_A = \frac{1}{2} \cdot C_w \cdot \rho \cdot v^2 \cdot A_f \quad \text{with} \quad v_{max} = 4{,}121\ m/s$$

$$A_f = \text{frontal surface} = A_{total} \cdot \sin\alpha$$

$$C_w = 0{,}8$$

$$\rho = 1{,}2041\ kg/m^3$$

$$F_A = \frac{1}{2} \cdot 0{,}8 \cdot 1{,}2041 \frac{kg}{m^3} \cdot (4{,}121)^2 \frac{m^2}{s^2} \cdot (0{,}220m \times 0{,}280m) \cdot \sin\alpha$$

$$= 0{,}5039 \sin\alpha \ (N)$$

$$\rightarrow F_w = m \cdot g$$

$$= 0{,}380\ kg \cdot 9{,}81\ N/kg = 3{,}7278\ (N)$$

$$\rightarrow F = m \cdot a \quad \text{with} \quad a = \frac{v_{max}}{t} = \frac{4{,}121\ m/s}{3{,}347\ s} = 1{,}2313\ m/s^2$$

$$= 0{,}380\ kg \cdot 1{,}2313\ m/s^2$$

$$= 0{,}4679\ (N)$$

Since we now know every force, we can continue calculating the angle α.

$$\frac{F_A + F}{F_w} = \frac{\sin\alpha}{\cos\alpha}$$

$$\frac{0{,}5039 \cdot \sin\alpha + 0{,}4679}{3{,}7278} = \tan\alpha$$

$$0{,}1352 \sin\alpha - \tan\alpha + 0{,}1245 = 0$$

$\Rightarrow$ We determine α by iteration, which leads to $\alpha = 8{,}244°$

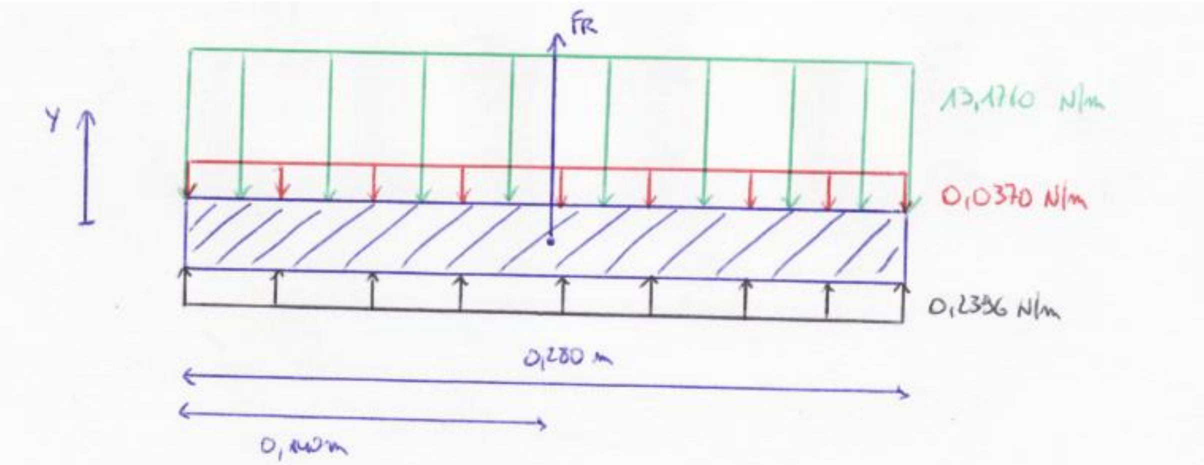
Now that the angle is know, we can calculate the forces again (taking into account that the surface of the solar panel is 0,0616 m²).

$\rightarrow F_A = 0{,}0723 \text{ N}$ and $q_{F_A} = 1{,}1737 \text{ N/m}^2$

$\rightarrow F_\omega = 3{,}7278 \text{ N}$ and $q_{F_\omega} = 60{,}5162 \text{ N/m}^2$

$\rightarrow F = 0{,}4679 \text{ N}$ and $q_F = 7{,}5958 \text{ N/m}^2$

When we indicate all distributed forces and also the reaction force of the supporting point onto the solar panel, we get the following drawing. The solar panel is reduced to the shape of a beam (so al distributed forces are already multiplied by 0,220 m and of course we also multiplied them with sine or cosine α corresponding to their projection onto the y-axis.)



The reaction force (already projected onto the y-axis) is then…

and so $F_R = \left(13{,}1760 \frac{\text{N}}{\text{m}} \cdot 0{,}280\text{ m}\right) + \left(0{,}0370 \frac{\text{N}}{\text{m}} \cdot 0{,}280\text{ m}\right) - \left(0{,}2396 \frac{\text{N}}{\text{m}} \cdot 0{,}280\text{ m}\right)$

$F_R = 3{,}6326 \text{ N}$

To determine the sheer force diagram and the bending diagram, we make two sections.

① $0 < x < 0,140$

$$\rightarrow D - 13,1760 \cdot x + 0,2336 \cdot x - 0,0370 \cdot x = 0 \rightarrow D = 12,9734 \cdot x$$

$$\rightarrow -M + (13,1760 \cdot x) \cdot \frac{x}{2} + (0,0370 \cdot x) \cdot \frac{x}{2} - (0,2336 \cdot x) \cdot \frac{x}{2} = 0 \rightarrow M = 6,4867 \cdot x^2$$

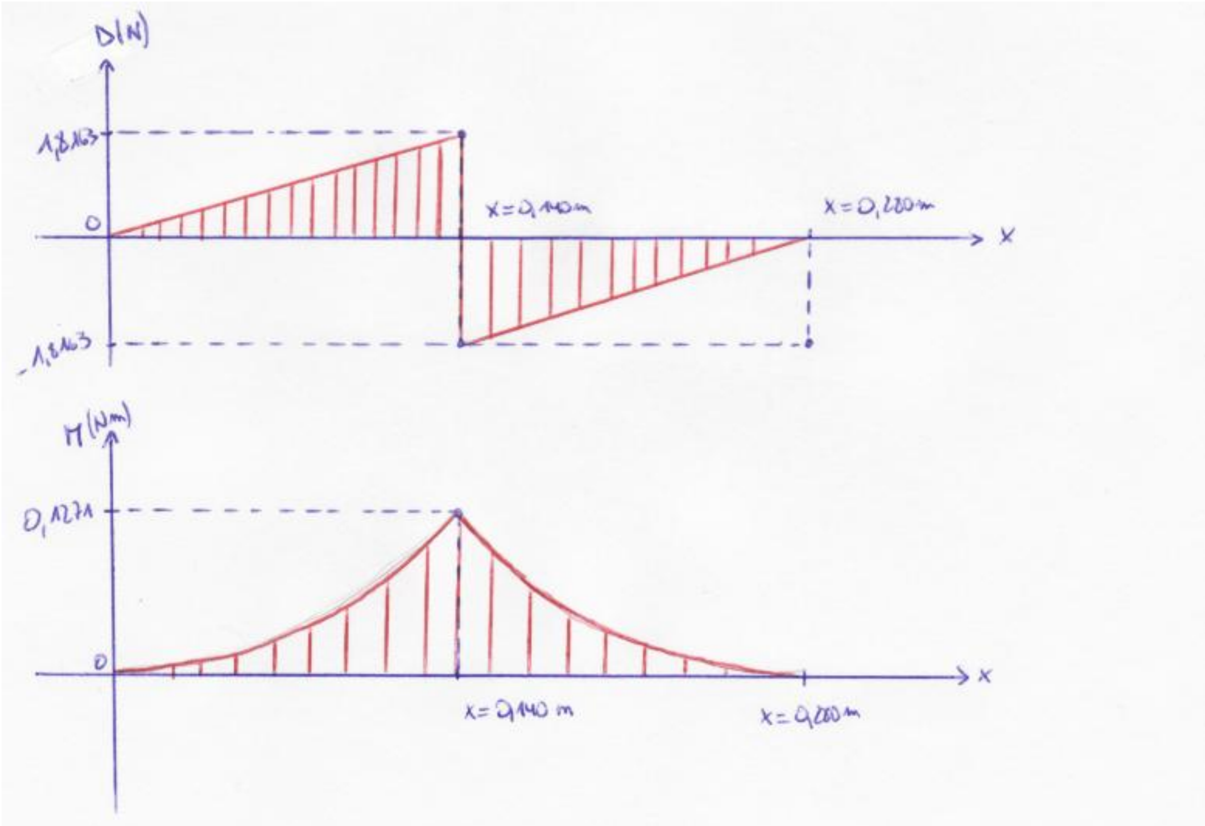
② $0,140 < x < 0,280$

$$\rightarrow D - 13,1760\, x + 0,2336\, x - 0,0370 \cdot x + 3,6326 = 0 \rightarrow D = 12,9734\, x - 3,6326$$

$$\rightarrow -M + (13,1760 \cdot x) \cdot \frac{x}{2} + (0,0370 \cdot x) \cdot \frac{x}{2} - (0,2336 \cdot x) \cdot \frac{x}{2} - 3,6326\,(x - 0,140) = 0$$

$$M = 6,4867\, x^2 - 3,6326\, x + 0,5086$$

The previous equations lead to the following diagrams.



Now that we have found these diagrams, we can easily calculate the maximal bending stress, maximal sheer stress and the strain of the solar cell.

1. Maximal bending stress

$$\sigma_{max} = \frac{M_{max} \cdot y}{I} = \frac{M_{max} \cdot h/2}{\frac{b \cdot h^3}{12}}$$

- $M_{max} = 0{,}1271\ \mathrm{Nm}$
- $h = 0{,}002\ \mathrm{m}$
- $y = 0{,}001\ \mathrm{m}$
- $b = 0{,}220\ \mathrm{m}$
- $I = 1{,}4666 \cdot 10^{-10}\mathrm{m}^4$

$$\sigma_{max} = 0{,}8667\ \mathrm{MPa}$$

2. Maximal sheer stress

$$\tau_{max} = \frac{D_{max} \cdot S_y}{I \cdot b}$$

- $D_{max} = 1{,}8163\ \mathrm{N}$
- $S_y = y' \cdot A = 0{,}0005\ \mathrm{m} \cdot (0{,}220\ \mathrm{m} \cdot 0{,}001\ \mathrm{m}) = 0{,}11 \cdot 10^{-6}\mathrm{m}^3$
- $b = 0{,}220\ \mathrm{m}$
- $I = 1{,}4666 \cdot 10^{-10}\mathrm{m}^4$

$$\tau_{max} = 0{,}006192\ \mathrm{MPa}$$

3. Strain

$$\sigma = E \cdot \varepsilon \rightarrow \varepsilon = \frac{\sigma}{E} = \frac{0{,}8667\ \mathrm{MPa}}{68{,}7\ \mathrm{GPa}} = 12{,}6157 \cdot 10^{-6}\mathrm{m}$$

1.3 Sankey diagram Umicar

Two cases will be calculated for the Umicar Sankey diagram. The first being the Sankey diagram of the Umicar at full speed and the second at half the speed.

Total Power:

The only source of energy the Umicar will receive will be from the sun radiation we take this to be a 800 W/m^2

Solar panel loss:

There are two types of solar panels present on the Umicar. These are the following:

Emcore:

These have an area of 27,56cm^3 for each cell and 2578 Emcore cells in total with an efficiency of 24.5%. This gives an area of:

$$27{,}56cm^2 \times 2578 = 71049.68\,cm^2 = 7{,}105m^2$$

Generating the following power:

$$P_{Emc} = 800\frac{W}{m^2} \times 7.105m^2 \times 0.245 = 1332.6W$$

RWE:

These have an area of 30.18cm^3 for each cell and 280 RWE cells in total with an efficiency of 30%. This gives an area of:

$$30.18cm^2 \times 280 = 8450.4\,cm^2 = 0.84504m^2$$

Generating the following power:

$$P_{RWE} = 800\frac{W}{m^2} \times 0.84504m^2 \times 0.245 = 202.8W$$

Giving us a total power of:

$$P_{Emc} + P_{RWE} = 1535.4W$$

Motor loss:

The transmission is located inside the motor. This means there will be no separate transmission loss. The motor itself has a high efficiency of 95%.

$$P = 1535.4W \times 0.95 = 1458.63W$$

Controller loss:

This has en efficiency of 99%:

$$P = 1458.63W \ \times 0.99 = 1444W$$

Loss from physical resistance:

This is where the calculations of the two cases differ. Both the rolling resistance and air resistance are speed dependent. Firstly we need to find the full speed. This can be found by finding the roll resistance and air resistance in function of v and then solving for v. This is done below:

$$F_{rol} = m \ \times g \times Crr$$
$$F_{air} = \frac{1}{2} \times Cd \times A \times \rho \ \times \ v^2$$
$$F_{tot} = F_{rol} + F_{air}$$

From here we can calculate the maximum speed in a Power balance. The acceleration will be 0 because no acceleration will take place at maximum speed otherwise it wouldn't be at the maximum speed. To do this however we will need some additional information. As the Cd value we will take that of an angled cube as advised by our tutor being 0.8. For the frontal area ($0.81m^2$), mass (305 kg) and rolling resistance (0.005) can all be found in the Umicore documentation. The calculations are as follows:

$$F_{rol} = 305kg \times 9.81 \frac{m}{s^2} \times 0.005 = 14.96$$
$$F_{air} = \frac{1}{2} \times 0.8 \times 0.81m^2 \times 1.2 \ \times \ v^2 = 0.39v^2$$
$$F_{tot} = 14.96N + 0.39v^2 N$$

Note that there is no acceleration in the above equation as it is 0 at top speed.

Power balance:

$$F_{tot} \times v = (14.96 + 0.39v^2)v = 1444W$$

This can then be solved and so gain the top speed. The solved value for v is then 14.64 ms^{-1}. Now the friction losses can be calculated.

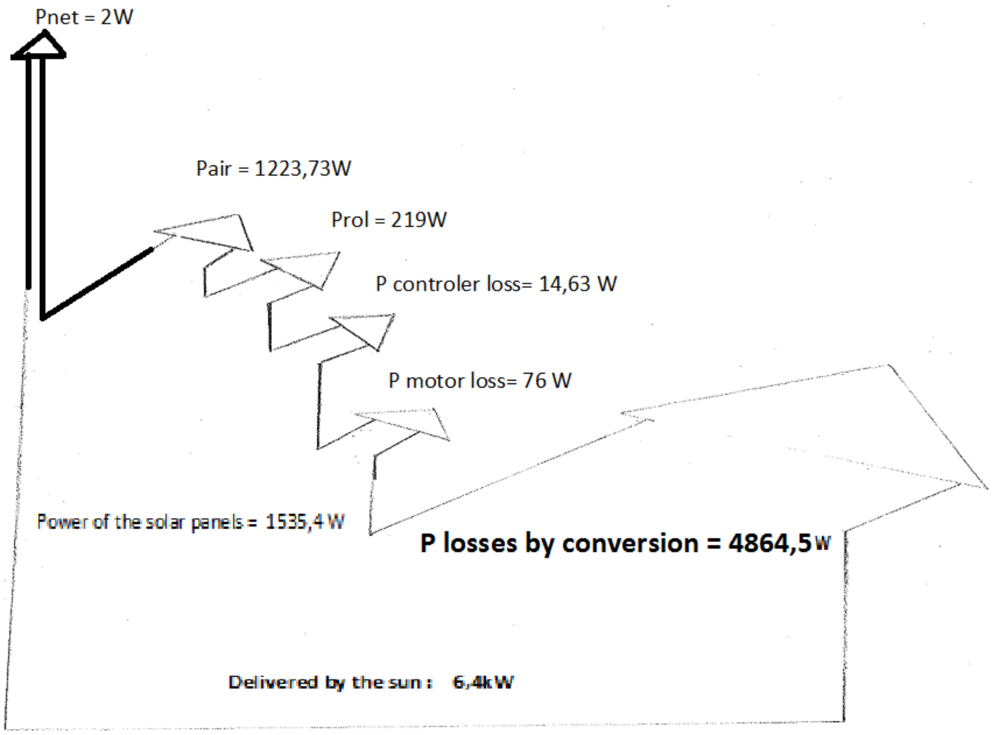
For maximum speed:

$$P_{rol} = 14.96N \times 14.64ms^{-1} \ = 219W$$
$$P_{air} = (0.39(14.64ms^{-1})^2 N) \times 14.64ms^{-1} = 1223.73W$$

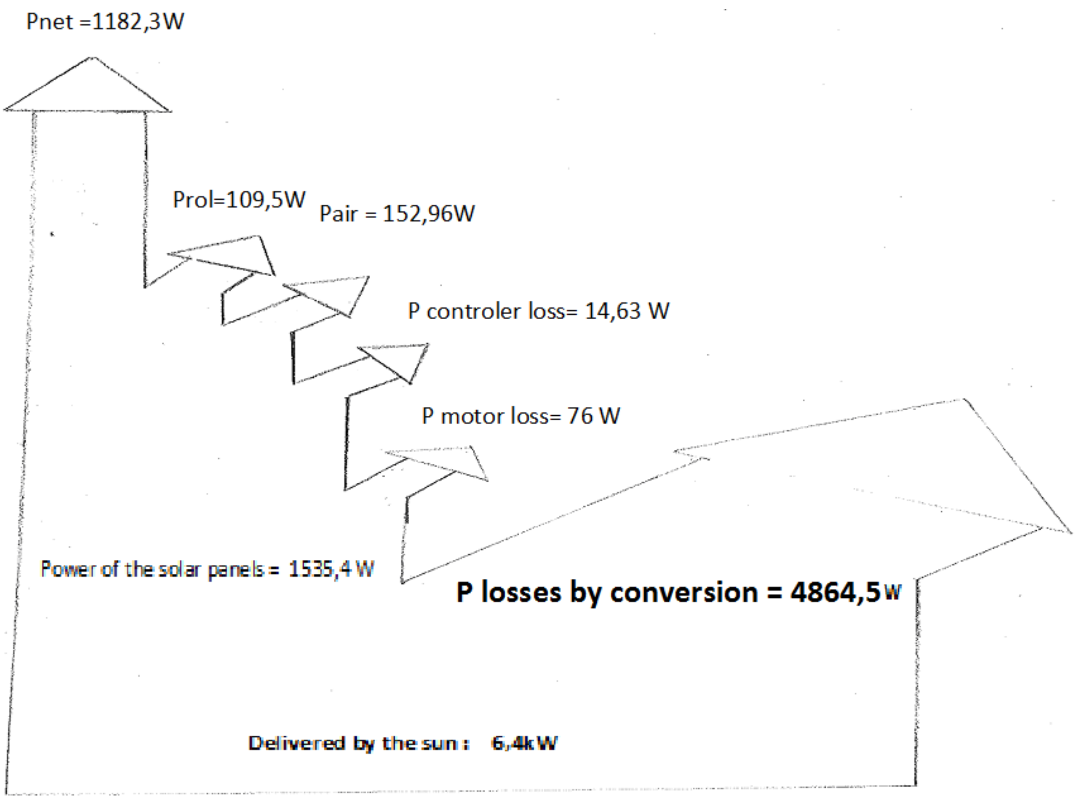
Half speed:

$$P_{rol} = 14.96N \times 7.32ms^{-1} \ = 109.5W$$
$$P_{air} = (0.39(7.32ms^{-1})^2 N) \times 7.32ms^{-1} = 152.96W$$

Sankey diagram for maximum speed:

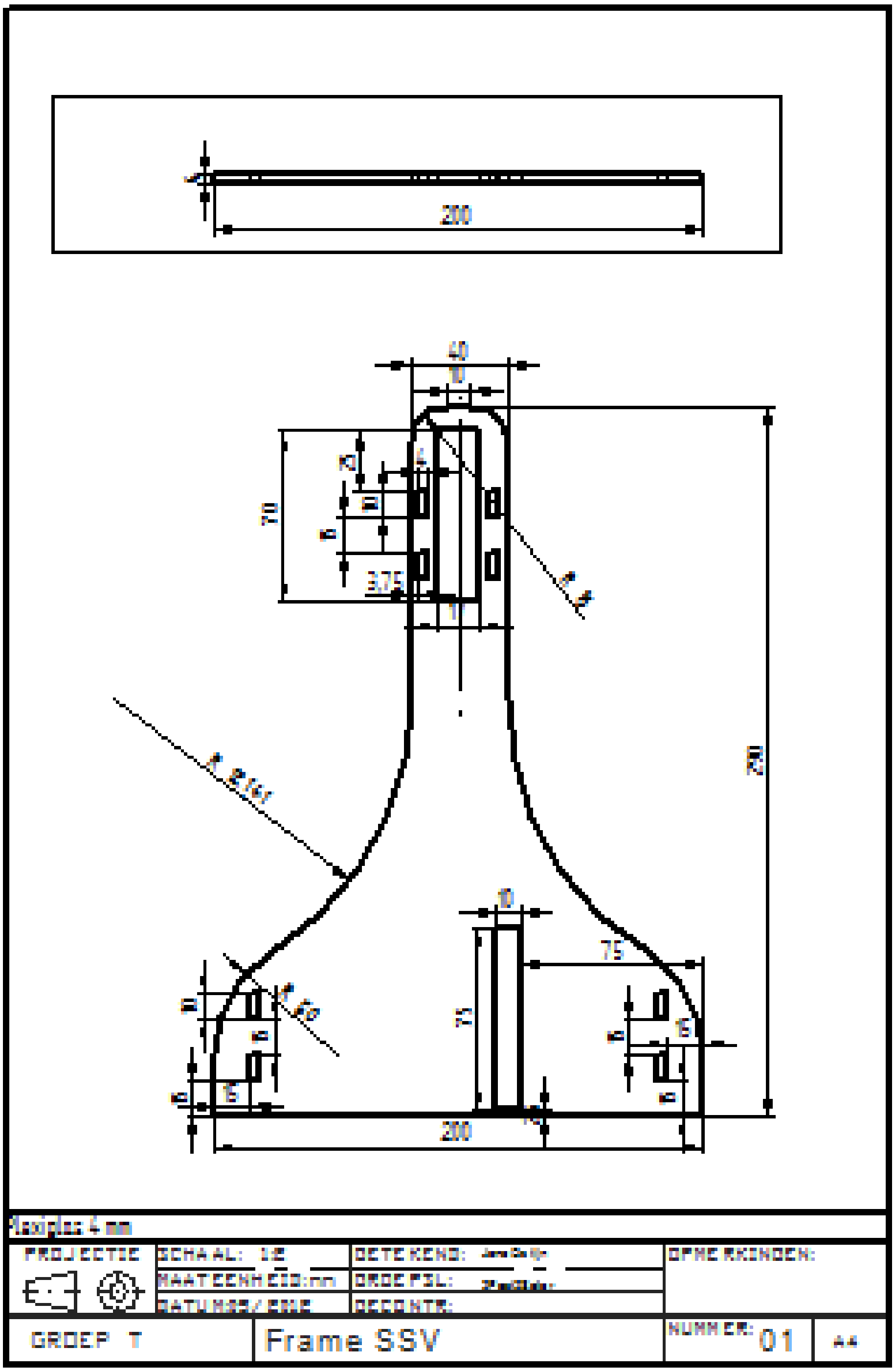


Sankey Diagram for half speed:



1.4 2D technical draw of the frame

For a better version of the frame, you can look at the pdf file.



2. Enterprising

2.1 Webpage

Our SSV is promoted on the next site:

http://struyfweb.hopto.org:24413/~christof/2F2S_site/index.html

We also have our Wiki page.

http://en.wikiversity.org/wiki/Topic:Engineering_Education/Engineering_Experience_4:_Design_a_Small_Solar_Vehicle/2012:_Team_PM10

2.2 Create team logo

Our logo can be found on the frame of our SSV.
Remark: you can also find our names in the rear wheels of our SSV.

2.3 Table costs SSV

In the next table you can find all the costs we made for building the car. We have a total price of 62,58 euro. But the final car costs less, because we have made different versions of cars during the project.

Parts	Store	Date purchase	Name team member	Price (€)	Shipping costs
Iron bar 3m	Metaleuven	27/03/2012	Jana	1,35	0
2 bars 50cm, 25cm	Gamma	27/03/2012	Jana	0,53	0
Plexiglas 6 mm	Fablab	27/03/2012	Jana	11,00	0
4 x bearings	Ateliers Bonte	27/03/2012	Jana	25,17	0
Wooden beam	Gamma	17/04/2012	Jana	2,28	0
Plexiglas 4mm	Fablab	23/04/2012	Jana	18,00	0
1 x battery 9V	Acco Leuven	26/04/2012	Jana	4,25	0
			Total	**62,58**	

Remark: We have no proof of payment from Fablab, because they give no tickets there. We paid it cash so we also have no proof on our bankcard.