Lebanese American University

School of Engineering

<u>Instrumentation & Measurements</u>

Dr. Ali El Ammouri

<u>Project Report:</u>

<u>Computer Aided Design</u>

Youssef Baby Lea – 201902735

Group number:26

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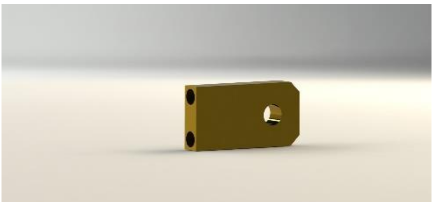
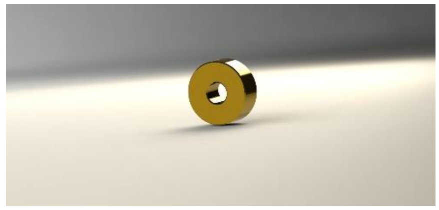
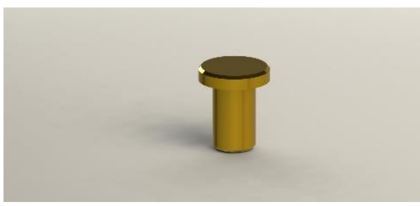
Introduction

This project is based on the reproduction of the vertical Stirling engine. It will be composed of several analysis including motion, where a motor will be placed on the shaft and showing the movement of the two pistons, as well as a simulation where the stress analysis will be studies, a flow simulation showing the air path between the pistons of the engines and an animation that would exhibit the motion of the engine at hand.

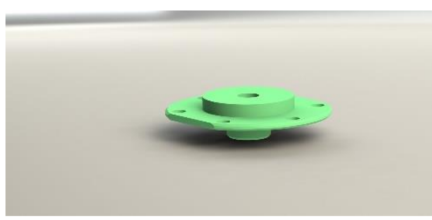
Rendering

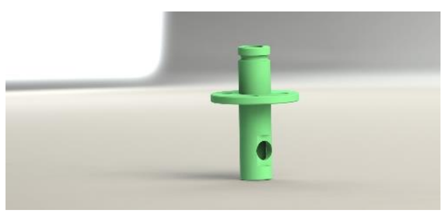
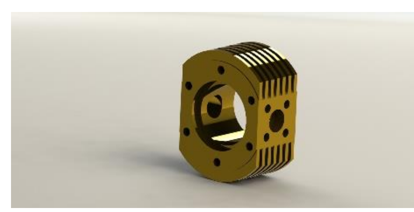
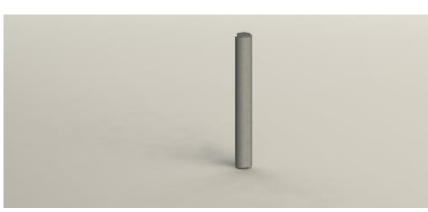
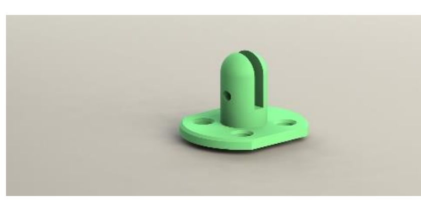





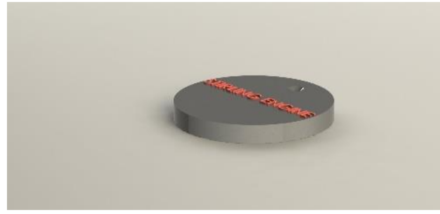
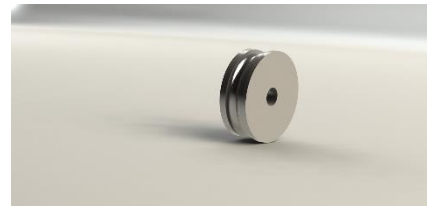
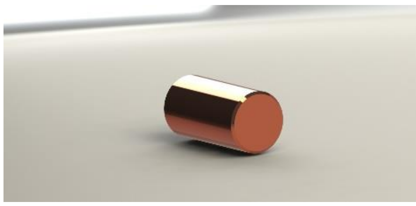





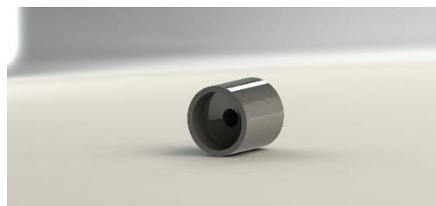


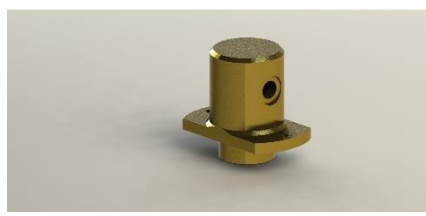













Motion analysis

a) Motor placement

As prescribed, the motor needs to be placed on the crack shaft which needs to then rotate at 650 RPM. Therefore, that task was indeed performed and now, we are able to study the displacement and the velocity of the motor at hand which later is beneficial for us to get certain measurements needed as the compression ratio.

The motor picked was a rotary motor that turns in a counterclockwise way as seen in the figure below.

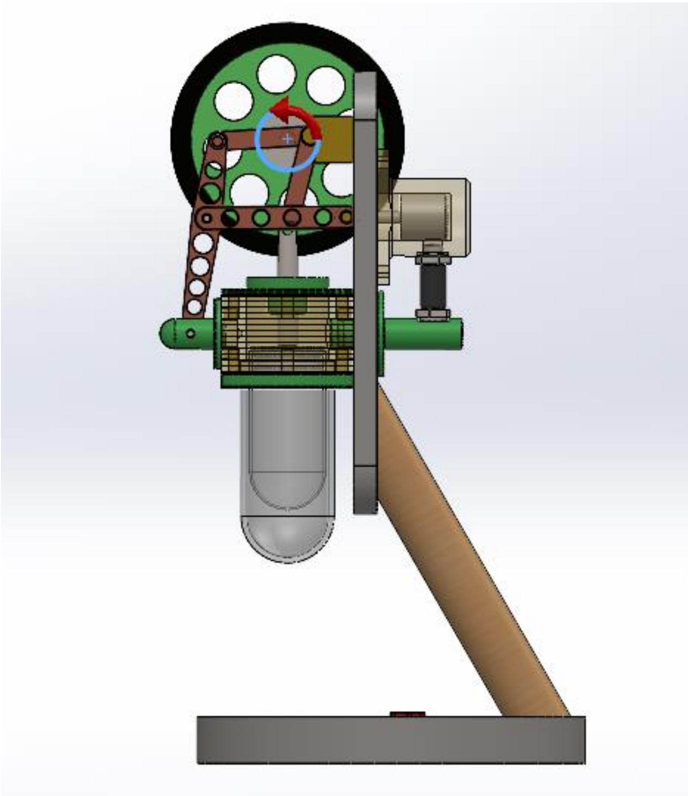


Figure 1:Motor placement on the crack shaft.

b) Displacement of the piston

First of all, in order to know what type of displacement needs to be applied to the piston, we first need to check the displacement of that piston which turns out to be following a line and not producing any angle. Therefore, the linear displacement was applied. Furthermore, from the origin axis given in Solidworks, a conclusion could be specified that the displacement is followed on the Z component.

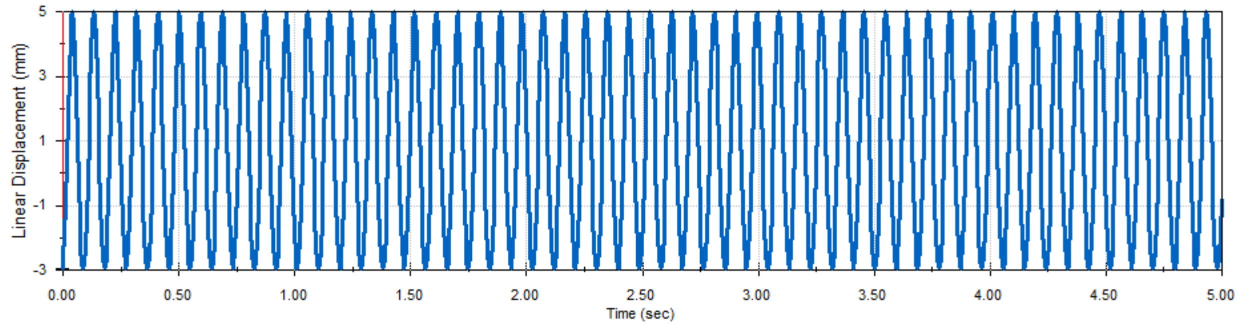


Figure 2: Plot corresponding to the linear displacement of the piston.

From the figure above representing the displacement of the piston, we are now able to get the maximum as well as the minimum values.

Now, for the maximum value of the Linear Displacement, it corresponds to the position of the piston when it is fully advanced, a value equal to 5mm. While, on the other hand the minimum value of the displacement is nothing but the position of the piston when it is retracted, corresponding to a value of -3mm.

c) Velocity of the piston

Now moving on to the velocity of the piston, the magnitude of the velocity was taken in order to get a velocity that is purely positive and not ranging between one negative and another positive value.

Now, the maximum velocity that was achieved by the piston can be identified from the plot in the figure below which is equal to 254mm/sec.

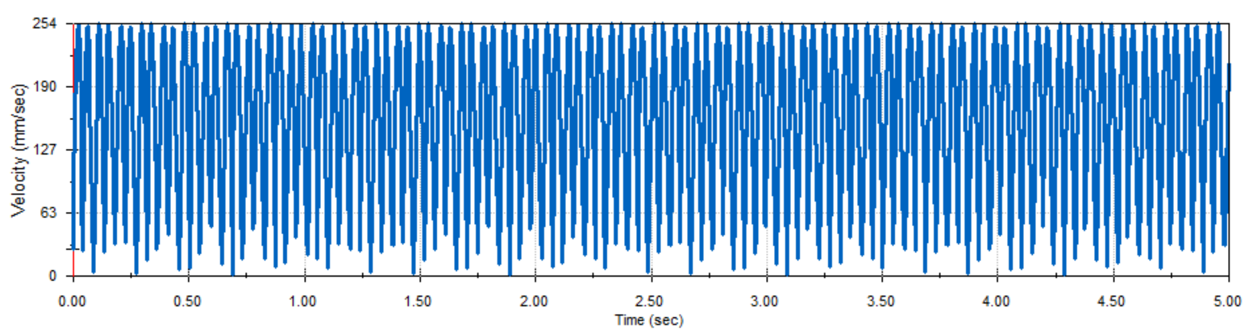


Figure 3: Plot corresponding to the linear velocity of the piston.

d) Compression ratio

The compression ratio of the motor is given by:

$$CR = \frac{V_U}{V_C}$$

CR: compression ratio.

Vu: uncompressed volume of the cylinder.

Vc: compressed volume of the cylinder.

Now, we know that the volume of the cylinder is given by:

$$V = \pi \times r^2 \times h$$

With:

r: radius of the cylinder.

s: height of the cylinder.

Therefore, we have to get the value of "h" being the height of the cylinder when the piston is retracted and when it is advanced. This would be possible by using the built-in tool provided by SolidWorks that permit us to evaluate certain measurements. This takes us to have:

- h=0.82 when the piston is compressed.

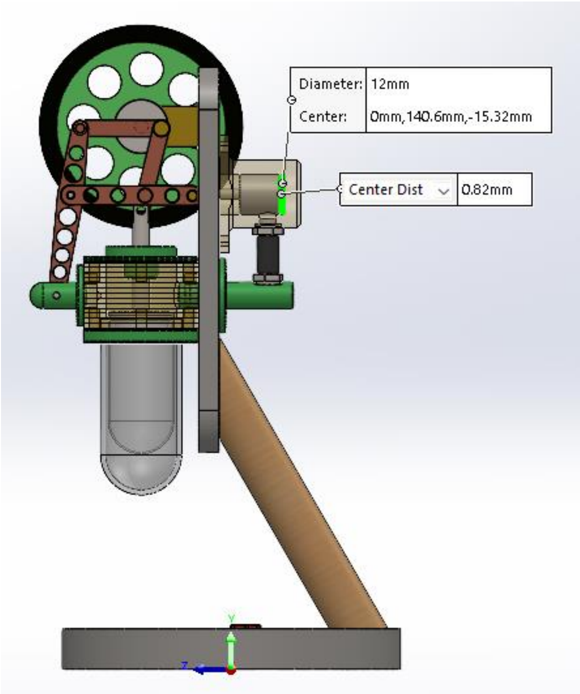


Figure 4:h when the piston is retracted.

- h=8+0.82=8.82mm when the piston is uncompressed.

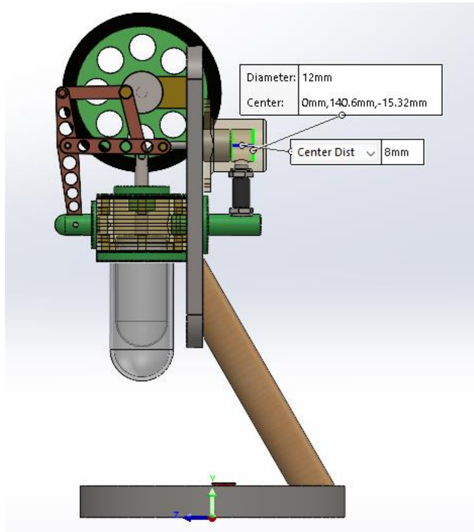


Figure 5:h when the piston is advanced.

However, the since we have the plot of the displacement, there is an easier way to find the distance when the piston is fully advanced (uncompressed) which corresponds to the maximum value of the displacement equivalent to 5mm minus the minimum value of the displacement which is -3mm. We need to also add 0.82mm.

Therefore, h is given by: 5- (- 3)+0.82=8.82 mm.

Now, we have the values of "h" needed, we can then get the volumes Vu and Vc.

$$V_u = \pi \times r^2 \times h = \pi \times 6^2 \times 8.82 = 997.518$$

$$V_c = \pi \times r^2 \times h = \pi \times 6^2 \times 0.82 = 92.74$$

Therefore,

$$CR = \frac{V_U}{V_C} = \frac{904.778}{92.74} = 10.756$$

Simulation

Simulation is performed in order to know if the piston can sustain the force that will be applied to its surface when the motor is running at 650RPM. Now, we are supposed to get the force that needs to be applied. In order to do so, we got a graph representing the torque in function of the speed as seen in the figure below.

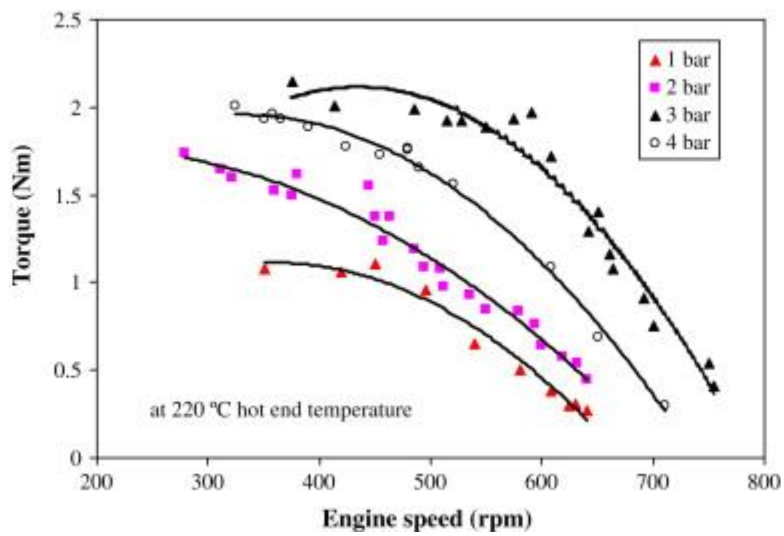


Figure 6:Torque vs. speed curve.

Therefore, we are able to extract the torque at a speed of 650 RPM following the 1 bar legend which give us a torque of approximately 0.25Nm which will be applied on our piston.

However, we need the force that needs to be applied at the face of the piston which leads to getting the force from the torque using the formula below:

$$\tau = rFsin\theta$$

τ: Torque in Nmm.

r: Radius.

F: Force.

θ: Angle.

- $\tau = 0.25\,Nm = 250\,Nmm$

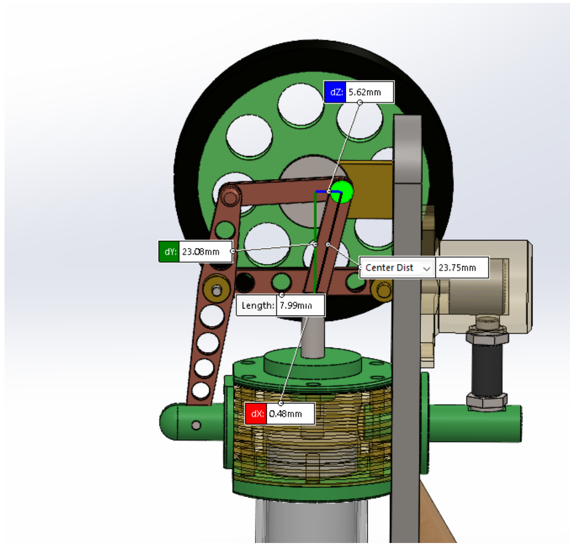
- 

Figure 7: Radius used to get the force.

From the figure above, we are able to determine the radius that will be used,

r= 5.62mm

- $\theta = 90°$

- $F = \frac{\tau}{r sin\theta} = \frac{250}{5.62 \times \sin{(90)}} = 44.48N$

You can find the report in the “Documents used in final report” folder under the name: Simulation report.

Sustainability analysis

The sustainability analysis is a built-in tool in Solidworks that is very helpful in terms of knowing what the impact of the production of the part at hand is environmentally and financially. The analysis varies with the type of process picked, the type of material picked, the region of production, and many more. Therefore, picking the appropriate conditions is essential in terms of producing the part. Solidworks also provides a built-in feature where it is possible to generate a report containing all the important information from our analysis.

You can find the report in the “Documents used in final report” folder under the name: Sustainability report.

Flow simulation

Flow simulation was performed between the two pistons in the vertical Stirling engine. This analysis will show the flow of air between those two pistons.

A report was generated showing the different aspects in order to perform this analysis.

Moreover, a lid needed to be created to close the path of the air and to be able to calculate the flow rate as seen in the figure below.

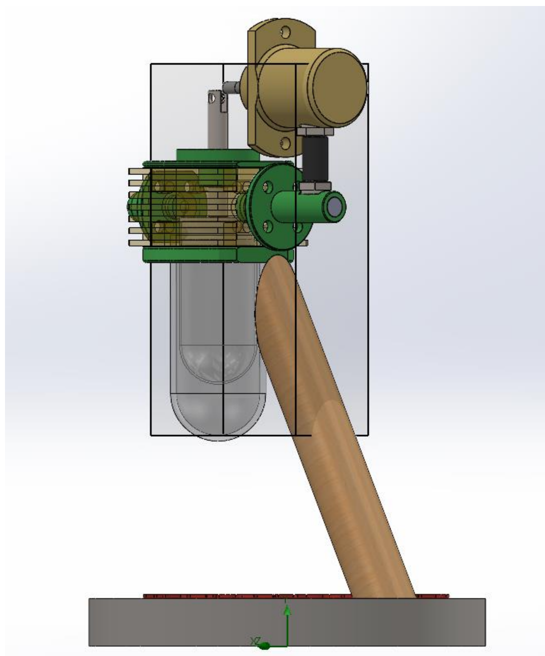


Figure 8: Flow analysis between the pistons.

You can find the report in the “Documents used in final report” folder under the name: Flow report.

Conclusion

To conclude, this project highlighted all the main advantages of Solidworks which is used widely in many companies. The reason behind its importance is the many tools it presents which were used in the projects such as the many simulation tools which it presents. The simulations include, motion analysis, simulation, flow simulation and many more. Moreover, reports generated automatically help the designer's job in terms of summarizing all the important results that need to be taken into account.

References

https://www.youtube.com/playlist?list=PLRhna5_X7uWs0Eye3ZmpM9YVIfjdfRUNq

https://sciencing.com/convert-torque-force-7495906.html