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Integrating Project ACHA4008

Project second assignment

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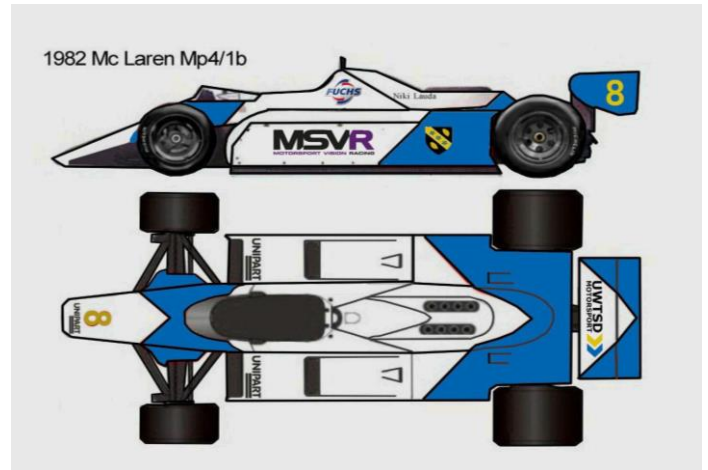
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1 Introduction

This report is an evaluation of our soapbox design and experimenting on Computer Aided Design (CAD) with the best way to model it before starting the manufacturing process. It includes images and calculations to back up the findings during the process.

2 Final design

We chose 3 main designs that were all inspired by old F1 cars. And our final design is closely based off the McLaren MP4/1b. This was our choice because it had the most aerodynamic front nose cone design. We did not need the downforce that the front wing produced so we removed that from our design, but we chose to keep the rear wing as it would help keep the car more stable at higher speeds.



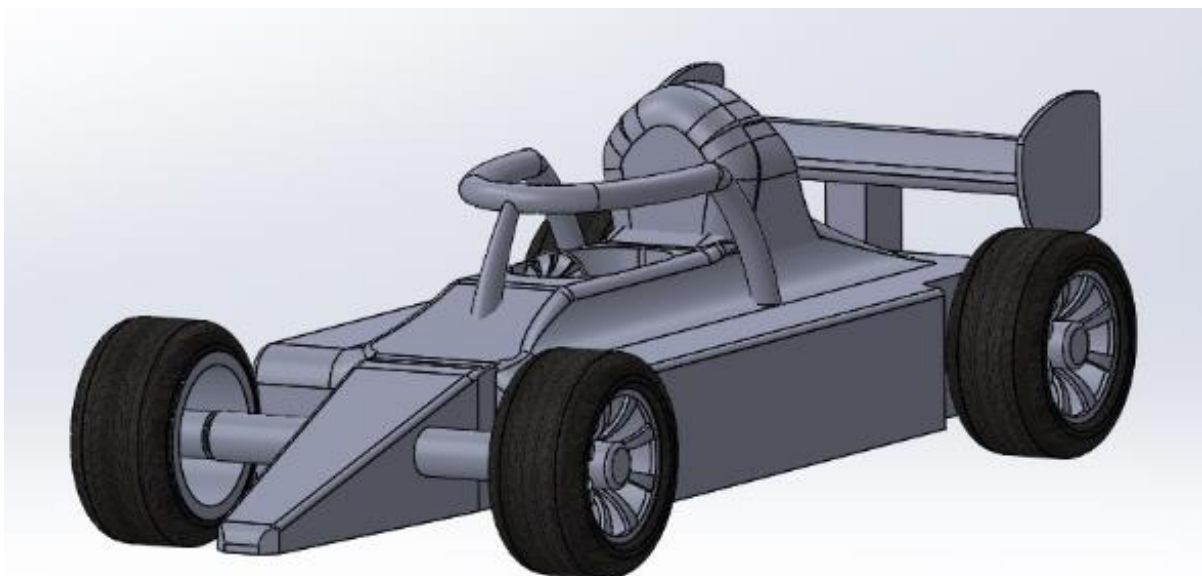
[Figure 2.1]

3 CAD model

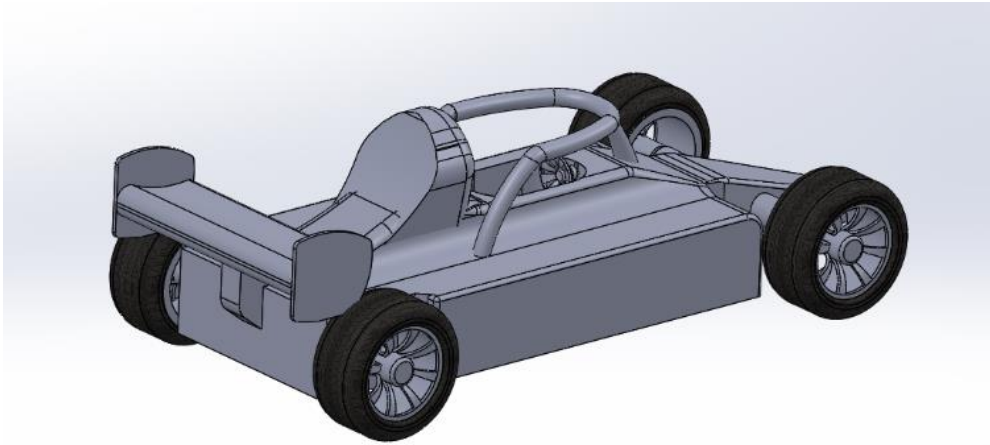
The CAD model below (Figure 3.1-3.7) is based off our final design drawing (Figure 2.1).

This model was designed in 4 different parts: the spoiler, the “halo” roll bar, the wheels, and the body of the car itself. It was then assembled and aligned to produce the final design. The car we have chosen to design is quite complex and when thinking about manufacturing, we may consider making the bodywork with less edges and more of a smooth shape.

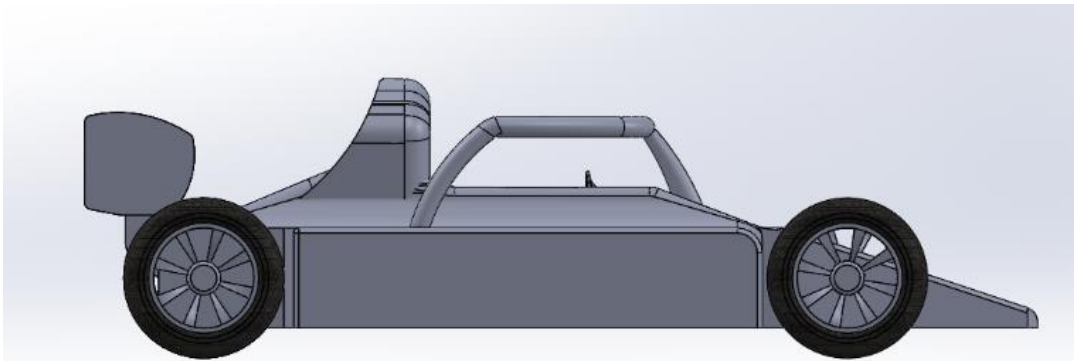
Below are 6 different views of the CAD model:



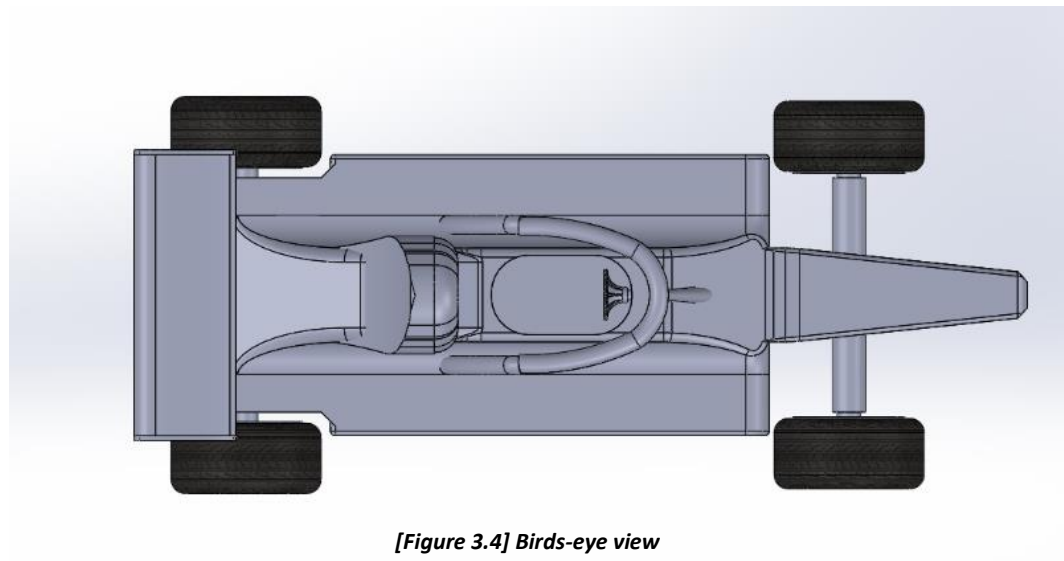
[Figure 3.1] Angled view from front.



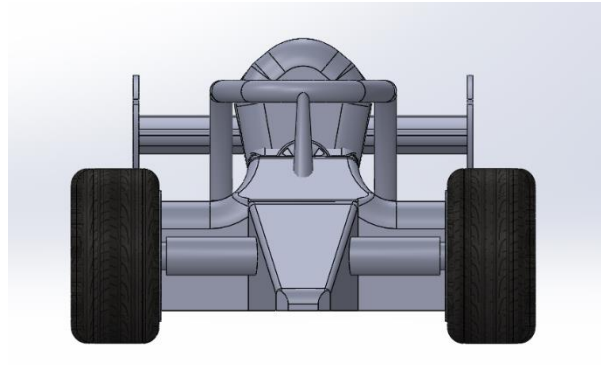
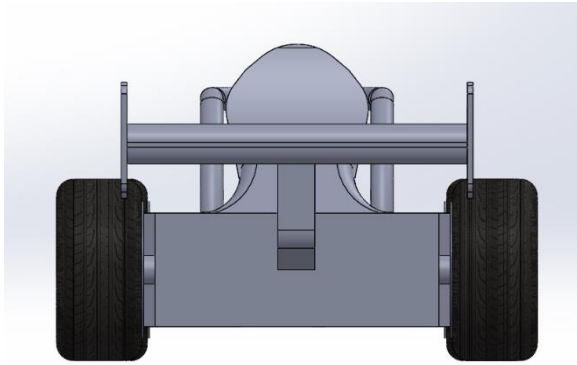
[Figure 3.2] Angled view from back.



[Figure 3.3] Side view



[Figure 3.4] Birds-eye view



[Figures 3.5 & 3.6] Front and back view

While our design is good in some aspects, there are other parts that could be changed to make the car more suitable. Looking at the front and back view, the roll hoop is quite bulky. An improvement we could make would be adjusting the shape of the bodywork to more of a boat shape. This would be a simpler design and could actually be better from aerodynamic perspectives, as there would be less 'bulk' to create drag. The big "air intake" behind the seat is unnecessary and will also cause quite a lot of drag. In further design processes we should remove it and make the roll hoop a bit smaller, this would increase the cars maximum velocity.

4 Calculations

4.1 Weight

For our bodywork we are using fibreglass because it creates a strong, solid shell that will protect the driver if the car hits anything, furthermore it will allow the soapbox to not have too much weight loaded at the front, which would make steering harder, heavier, and you would be in less control of the vehicle, which is why we went for a lightweight, but strong material that would be stable over obstacles and in small jumps that it would be exposed to on a soapbox course. It will also make the car a bit more 'slipstream' by producing a smooth surface for the air to slide over which in turn generates more speed overall. It isn't super light like cardboard, but it has much more strength and durability to it, and we want to have some weight to make sure the car travels as far and fast as possible. Ideally it would weigh around 800-900kg, this would be stable enough to complete the course, while ultimately staying in one piece and still being light enough to travel at some pace. (J. Elisson) (2021)

4.2 Forces

Thinking about forces included in this, we looked at how the angle of the slope that the car is released from would affect the acceleration. The larger the angle, the larger acceleration you would experience.

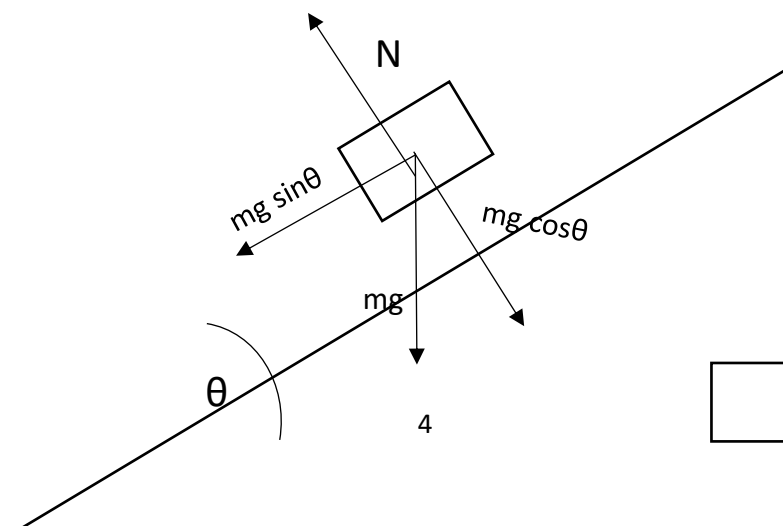
$$F = mg \times \sin \theta \quad F = ma$$

$$mg \times \sin \theta = ma$$

This can be proven by:

$$g \times \sin \theta = a$$

In addition, another calculation in forces to consider is the centre of the mass, which is where the soapboxes weight is centred, due to it being very aerodynamic and low down to the ground, having the lowest possible centre of gravity is best as it reduces drag, and air resistance, this is also an advantage as it keeps very stable when manoeuvring under speed, it is very important as if it not done correctly and is too far forward, it would cause understeer, whereas too far back, it would cause oversteer, which is why you need it to be well balanced to calculate the centre of gravity of a soapbox racer, you need to take moments about the rear axle, and will need to use scales on all four wheels, to see how balanced out the weight distribution is, you will also need to measure and calculate the weight of the frame, engine, all mounting brackets, the chassis, and wheels, Aswell as the steering system, it can be complicated but ultimately is best to understand as it will show where is best to place the driver on the chassis to keep distribution as equal as possible throughout the soapbox,



[Figure 4.2] Diagram to show the forces on the soapbox car

with θ being the soapbox on an inclined angle, If $\theta=30$, then $\sin \theta= 0.5$. And if $\theta=40$, then $\sin \theta= 0.64$. Therefore, as g is constant, the larger θ , the larger a will be, it also means that the heavier the soapbox, the faster acceleration down the hill it will have, this can be proven by the formula $F_g = d(mv)/dt = mg \sin(\theta)$

F_g represents forces acted upon gravity where is it equal to $9.81m/s^2$, with M representing as the total of mass, so driver and all parts of the vehicle, this can be used to figure out the acceleration force down a hill slope.

We can also use a formula to calculate the moment of inertia of the soapbox which is

$$F_w = -(1/2)mwg \sin(\theta)$$

The moment of inertia is very significantly involved with the aerodynamics of a soapbox car, Intertia represents the resistance of changes during a rotating motion, which in a soapbox car, is how fast it can turn direction and rotate down the hill, however the moment of inertia entirely depends on how evenly distributed their mass is, depending how far forward the moment of inertia is on the wheel, it can differ in ways that if it is near to the wheel rim, then the inertia will be overall larger, which in turn rotates slower, on the other hand, if it is more centre balanced, then it will rotate faster, which is why inertia is very important to understand and get right when building a soapbox racer, and can have a significant impact on the handling, braking, turning and straight line performance on the track, which is why driving seating position is so important as if it is placed near centre of mass then it will be producing minimal drag and lower inertia.

To work out rolling resistance of the tyres on the soapbox, we can use the formula³

$$F_R = -CRmg \cos(\theta)$$

With F_R being the friction force, and CR representing the resistance coefficient of the tyres, which in a soapbox, would be very low due to the rubber quality and tyre depth we used, the rolling resistance is a big factor and an important calculation to take on board when determining the overall efficiency and speed that the soapbox will generate, the CR is the resistance that the wheels produce as they roll on the track, some factors that can fluctuate the amount of resistance are the type of wheel used, appearance of the rim, and OfCourse how evenly distributed the weight of the soapbox is, so if you were to use new tyres with plenty of grip with light weight strong wheels, then it would help improve lowering the resistance Aswell as ensuring the wheels are balanced with proper tire pressure which you should refer to the guidelines to see. And finally, by minimising the contact patch between wheel and road, you can help reduce the rolling resistance of the vehicle, such as using slimmer tyres.

4.3 Energy

When thinking about energy, Potential energy and kinetic energy are important, especially when an object released from rest is involved. At rest, the car will have maximum potential energy and no kinetic energy. But at maximum velocity, the car will have maximum kinetic energy but no potential energy.

Potential energy: $PE=mgh$ (h being vertical height from centre of mass).

Multiply mass by acceleration of gravity by the vertical height from the centre of mass (of the car at start point). This will give us the potential energy and therefore the

Kinetic energy: $KE=1/2 mv^2$

Using this equation and the equation for potential energy, we can work out the maximum velocity the car will travel.

If: $PE=KE$

$$mgh= 1/2 mv^2$$

The masses cancel out of this equation so either the already calculated value of potential energy can be used, or the formula: $gh=v^2$ can be used instead.

(As we are assuming all potential energy is converted to kinetic energy, this calculation will only be an estimation as it won't account for any air resistance or drag that might occur.

5 Summary

When designing this soapbox car, we focused on keeping the weight as low as possible. After looking at the calculations (forces involved), for future reference we may want to add more weight to the car. This would increase the acceleration of the soapbox (because $F=ma$). Also, it is most likely that we will do another redesign before manufacturing that is a little simpler and will have less drag.

Some other calculations we included were Friction, centre of mass: to figure out where best to place the driver, and moment of inertia (reducing this will reduce energy loss and vastly improve the performance of the soapbox racer. (P. Gale, 2008).

6 References

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