MEE20002 - Computer Aided Engineering
Semester 1, 2017

ELECTRIC SCOOTER REPORT

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Chapter 1- Introduction

The demand of electric scooters is always a focus by means of economic, social & environmental factors. The challenge exists as there is always new and improved mechanical designs set by competitive markets. These new concepts set higher standards to adhere by. This project focuses on carrying out a commercially viable design for an electric scooter. The report will justify the specifications needed through simulation and Mechanical design while providing a cost analysis and environmental impact using the sustainability tool of Solidworks. The design for this scooter will be limited to certain features (set by the instructor) using the same software to model the prototype. The features in this design are to be in accordance with manufacturing suppliers.

1.1 Aims

Initial challenges are to research what are the required components incorporated in the design. The first decision was to abolish the use of excessive material that was not necessary. The primary objective with this project is to design a unit in terms of practicality while compensating on any additional features. The seat was therefore the first decision to abolish for the design. This feature carried an additional 7Kg of weight, reducing the stress on the chassis structure. Problems that are rectified through draft designs can be seen when drawing/modelling sketches. Initial design parameters provide a means that make up the connections of the scooter. This approach reduces editing features on the design tree that are either not necessary or feasible

In this project there were certain guidelines to adhere by. The chassis structure and handles must be designed from weldments. The chassis weldment supports enhanced the integrity of the structural properties. This is because the geometry of hollow shafts increases the moment of inertia of the weldments.

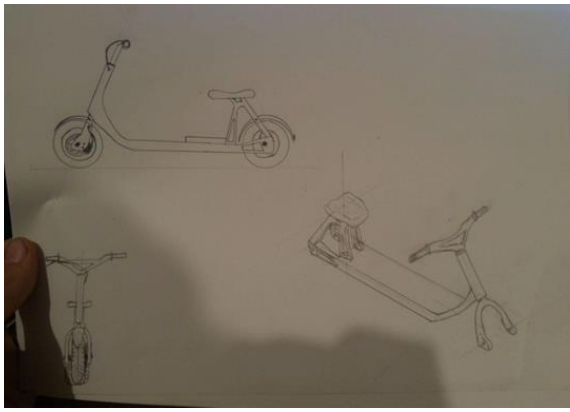
Sheet metal must be incorporated in the design. Sheet metal is and able to withstand any normal stress caused by the loading on the chassis structure. Loading on the chassis structure mostly comes from the weight of the user.

Shock absorbers were incorporated in the design to help absorb impact force and stress on the front wheel. The properties and size of the spring will indicate whether enough force can be absorbed

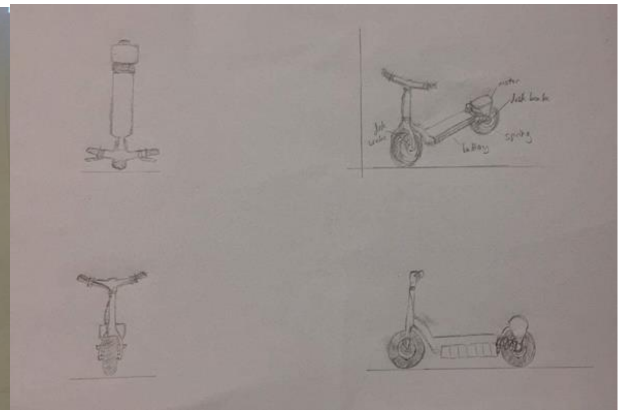
1.2 Concepts

The first step was to evaluate a concept matrix. This is to assess each criteria and is used to justify the selected design. It was the team’s first approach into the aesthetics and feasibility of each model.

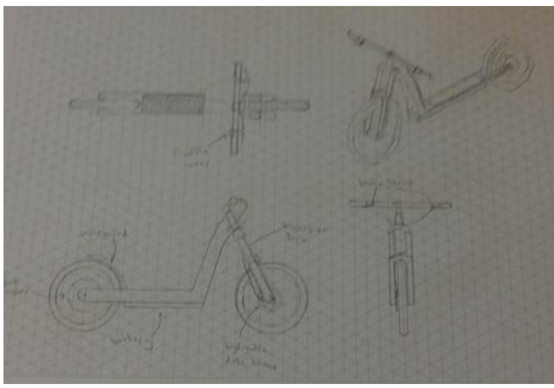
Leon's Design



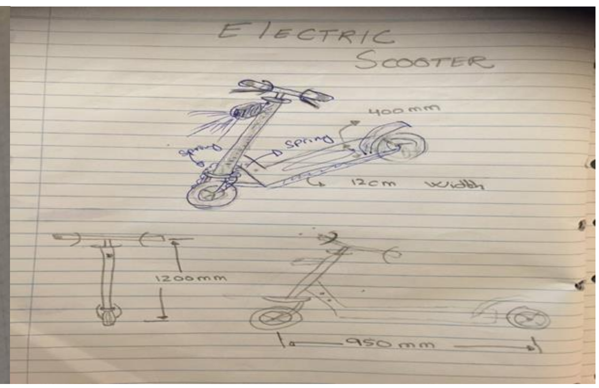
Kesara's Design



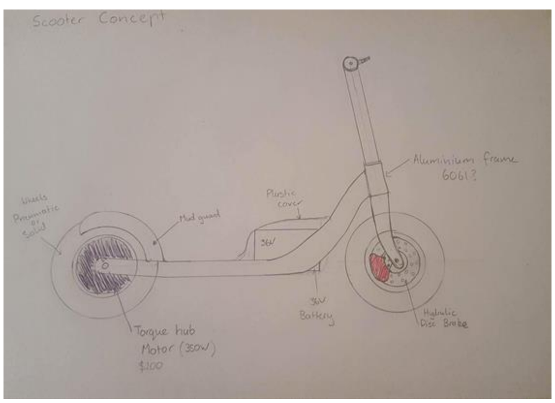
Thomas' Design



Hassan's Design



Jakes design



		Criteria					
		Cost	Durability	Drivetrain	Comfort	Efficiency	Total
Scooter Design	Leon	6	8	9	8	6	37
	Kesara	6	7	9	8	8	39
	Thomas	7	9	9	8	8	41
	Jake	8	6	9	7	8	40
	Hassan	9	7	9	7	7	39

1.3 Final concept

Thomas' concept of an off road scooter best met all the design requirements. This concept was then chosen to be further developed into a fully functional scooter. The different sub assemblies and components were then assigned to each group member.

1.4 Contributions

Name	Student Number	Parts designed	Chapter
Jake Minogue	100496175	Power Hub outer rim, Power hub side covers Power hub axle Headtube/Downtube Axle brackets	2-Propulsion
Thomas Jackson	101111990	Front and rear wheels (front hub, rims, tyres and spokes)	3-Wheels
Leon Ignatiadis	101156386	Final Assembly Handlebars Grips Bar ends Brake levers Fork	4-Cockpit
Kesara Kapugeekiyana	7707770	Chassis (weldment frame and sheetmetal body	5-Chassis

		plate)	
Syed Hassan Ali	2098571	Front and Rear Mudguard Battery Battery Housing(Sheet Metal) Front Light Brake Disk and Caliper	6- Auxiliary components

1.5 Summary

This report covers the design and testing of Electric Scooter capable of carrying an adult while maintain the balance.

The aim of the project was to design and build an Electric Scooter that is available in the market but also coming up with new idea. Our goal was to design a robust and easy to use whilst not compromising on strength. The design included special attention to the ergonomics of the rider/vehicle interface and safety.

Findings from this report depict that the cost of the unit would be low compared to other units that are sold in the electric scooter market. Parts would be easily sourced and there is minimum amount of features that would increase production time. All units are to the standard measurements and can be bought in bulk quantities. The weight of the scooter did not compare well to other units sold. This may affect the amount of units sold on a commercial scale. All criterion has been met for the operation of this unit and with better planning other necessary features such as a braking system could be manufactured. A lot can be taken away from this research project and the knowledge used to assess components in industry.
We carried out the Finite Element Analysis on all the main components such as chassis, wheel rim etc to make sure they are safe while driving.
Sustainability tool is used to evaluate the cost and environmental impact of each component contained in the assembly.

After some small changes to the initial design, the completion of a fully functioning prototype was achieved. Electric Scooter satisfies all the basic specifications and project goals and is enjoyable to ride.

Chapter 2- Propulsion

2.1 Literature review- Propulsion

2.1.1 Introduction

Electric motors have been the World's most important source or rotational motion since the observation of magnetic induction in electrical wires by Hans Christian Orsted in 1820. This chapter will explore development of the electric motor and how these developments have shaped our project today.

2.1.2 The Electric Motor

The basic principals of the electric motor were first observed by Danish physicist Hans Christian Orsted in 1820. He observed how current flowing in a wire caused the needle of a compass to change direction. This was the discovery of Electromagnetism. Michael Faraday, who in 1821, made a small apparatus that produced continuous mechanical rotation, although not strong enough to produce any useful work, further developed this concept on.

It wasn’t until 1834, that Thomas davenport produced the first electric motor that was capable of producing work, moving a small trolley around a track, and the full potential of this new technology was realized.

The electric motor reached commercial success in 1873, and soon after lead to the discovery that turning a motor in reverse could actually produce electricity as well; the first generator was born.

With over 150 years of development, electric motors today and cheap, efficient, quiet and reliable. There are three main types of electric motors used in consumer products like our scooter. They each have advantages and disadvantages.

AC induction

AC induction motors operate using AC power, sourced from the electrical grid, or directly from an AC generator. The feature a primary and secondary coil, which are coils of tightly wrapped wire. These coils generate an electromagnetic field, repelling each other and causing the armature and center shaft to rotate. A typical AC motor can be seen in *figure 1.* AC induction motors feature high starting torque and provide good power for their size. However the brushes used to transmit power to the rotating armature tend to wear out and need replacing. An AC motor is also unsuitable for our application, as it needs alternating current to operate, which cannot be stored for mobile use in devices.

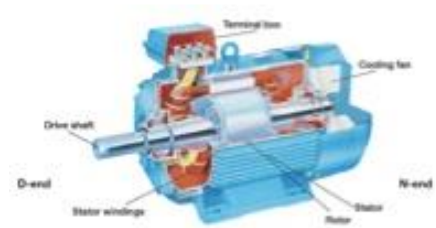


Figure 1

Brushed DC

Brushed DC motors *(figure 2)* operate in a similar way to AC induction motors, and also require brushes to transfer power to the armature. This means that these motors also suffer from wearing of brushes. Advantages of brushed DC motors are their high starting torque and ease of speed control (simply varying the voltage to the motor). Disadvantages include brush ware and also limitations with speed due to brushes overheating.

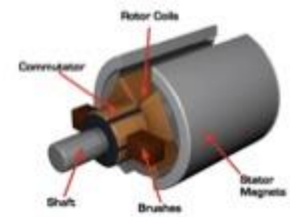


Figure 2

Brushless DC

Brushless DC motors *(figure 3)* utilize an electronic control circuit that reverses the polarity of the power supplied to the field windings, in order to keep the motor spinning in the same direction. This eliminates the need for brushes. Brushless DC motors tend to be more efficient than brushed motors. They also allow precise speed control and run significantly cooler, giving them a much longer service life. The major disadvantage of this type of motor is the initial purchase cost, due to the control circuit.

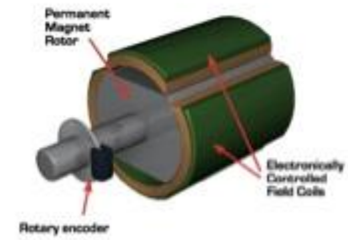


Figure 3

2.1.3 Conclusion

Given all the factors listed in the previous section, we have decided to use a brushless DC motor design. This will give us the most power utilizing batteries, and also the longest service life, with minimal maintenance. This will also reduce the size of the hub, as there is no brushes, thus saving weight and increasing scooter performance.

2.2 Propulsion Design and Development

2.2.1 Introduction

The power plant for the scooter is one of the most important decisions in the design of an electric scooter, many options were considered. This section will go into detail about what options were considered and how the final components were selected

2.2.2 Concept Evaluation

Electric motors are a very standard component in engineering, and only the correct size and power are key constraints in many applications. However in this scenario the weight and also how the power is transmitted to the wheel becomes a large consideration. The approach of mounting the electric motor to the frame was one of the first ideas to come forward. Similar to a motorcycle, the motor would be coupled to the rear wheel using a chain or belt. While this design is very established in the motorcycle industry, the constant maintenance that such a system requires makes it an unfavorable design for a product that is meant for the everyday consumer. This design also requires additional components such as motor mounts, chain or belt tensioners, as well as mover the motor itself into the rider’s foot zone.

The shortcomings of this idea were quickly realized and other alternatives were sourced. Power hubs have been used in small-motorized devices for years. They are a clever design that incorporates the electric motor into the hub of the rear wheel. Unlike a conventional electric motor where the rotor spins inside the motor housing, the hub motor has a stationary rotor, which forms the rear axle, and the motor housing rotates and makes up the center of the wheel. Hub motors are maintenance free and have very good power to weight ratios. This form of motor also does away with dangerous moving parts such as belt and chains, which could cause injury, should the rider crash.
Three design concepts were then evaluated against each other to select the one that best suits the application. Table 1 shows the ratings given to each concept in each evaluation category.

Design	Maintenance	Performance	Reliability	Cost	Weight	Safety	Total
Belt drive	7	8	6	7	5	6	39
Chain drive	5	8	7	7	4	6	37
Hub Motor	9	6	9	8	7	9	48

Table 1

The hub motor consistently outscored the other ideas and was the option that the team decided to pursue. This option is cheap, reliable and has more than adequate performance for this application. This also frees up room on the deck for the rider and reduces the overall length and weight.

2.2.3 Design

A suitable hub was then sourced to meet the size and power requirements of the project. See table 2.

500mm Powered wheel

Motor	Brushless DC non gear hub motor
Power	350W
Rpm	1000max
Voltage DC	36V
Wheel diameter (with tire)	500mm
Max Speed (theoretical)	71.6Km/h
Max speed (governed)	30Km/h

Table 2

This hub provides ample power to get the single person scooter up to speed and leaves power in reserve for uphill stretches. The speed of the motor will be governed to 30km/h for safety, as this is a non-road going vehicle.

This component was modeled in solidworks using solid modeling.

Table 3 shows some of the calculated performance characteristics of the scooter, given the selected batteries and the wattage of the motor. These calculations were done using simple electrical equations and are only a rough guide.

Current draw (P/V)	9.72amps
Battery Current capacity	21ah
Runtime at full current draw	2.16 hours
Distance covered at full speed	64.8 km

Table 3

These calculated values are likely to be conservative. They are done assuming the motor would use the full 350w of power at all times, however full power is only used when accelerating or ascending slopes. Whilst cursing on flat terrain the power usage will be a fraction of the full rated power of the motor, thus battery life could be as much as 3 hours.
The final solid works design for the hub motor is (*figure 4)*. The hub is made up of 4 key components. The outer rim, *(figure 5),* features the flange that mates with rest of the wheel, cooling fins to help sync heat away from the motor and threaded holes around the periphery that receives the side cover bolts. The outer rim would also feature the permanent field magnets that make the brushless DC motor function.

Figure 4

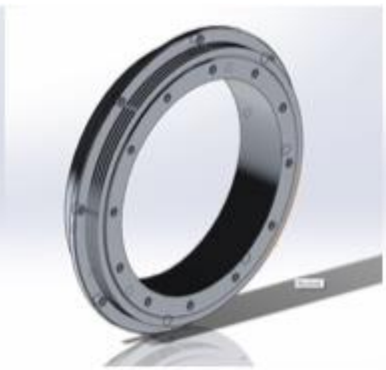


Figure 5

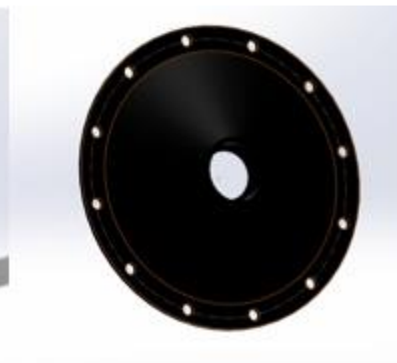


Figure 6

The two side covers (*figure 6*) make up the case of the motor and transfer the load of the scooter to wheel by means of bearings pressed into machined recesses. The axle goes through the inner races of the bearings and is held stationary with respect to the frame. The axle would also feature the windings that get energized by the batteries. The outer rim and side covers are both made from 6061 aluminum, while the axle and bearings are hardened steel. All components are held together by means of M8x1.5 socket head cap screws. The engineering drawings for the hub somponents can be found in Appendix 1.3

2.2.4 Conclusion

The design selection and then solid modeling of the drive hub was carried out without many issues, and was delivered on time. Some minor issues encountered were problems with fasteners upon reopening files on certain computers. A solution to this problem was found in week 11.

2.3 Sustainability and Finite Element Analysis

2.3.1 Introduction

Sustainability of a design is an important part of modern engineering. As engineers we have a duty of care to the planet and must ensure that everything we do is done in the most sustainable way possibly. Likewise safety, especially when human life is at stake, is of the utmost importance. To ensure that designs are strong enough for their assigned task, extensive testing is carried out using Finite element analysis.

2.3.2 Sustainability

The side cover of the power hub was subjected to a sustainability study. This was carried out using the sustainability add on within Solidworks. This module allows key parameters such as life expectancy, country of manufacture, country of use, material, manufacturing process and many more, to be input into the software, and output the key impacts this has on the environment. Impacts such as energy consumption, material usage, water usage and disposal are displayed so that different materials can be compared.

The side cover was initially assigned the material of 2024 aluminum alloy. This alloy has good strength to weight ratio and has good fatigue resistance. It was felt that a more sustainable material should be sourced, so a sustainability study was run. 2024 was set as the baseline, with parameters such as country of manufacture and use set as Australia, and the product life expectancy set. A search was then run to find a similar material with greater tensile and yield strengths. 6061 aluminium alloy was then selected from the search returns. 6061 is one of the most commonly available aluminium alloys. It has higher tensile and yield strengths than that of 2024 and is also slightly lighter. 6061 also returned far more favorable impacts on the environment as detailed in the sustainability report (*appendix 1.1).*

2.3.3 Free Element Analysis

Free element analysis (FEA for short) is a method of analyzing stress and deformation within a 3D solid model. Solidworks features a built in simulation module where this form of analysis can be run.

The axle of the power hub was a prime candidate to be analyzed for the torque load that it is subject to. As the outer rim of the hub is repelled during operation of the motor, this applies a reaction torque to the axle shaft itself. Through some simple calculations using the motors power and the rpm range, a generous maximum torque was

Figure 7

calculated to be 50N.m (the actual torque is likely to be far less)
A new study was then created in Solidworks and fixtures were set to mimic how the axle is fixed in practice. The torque load of 50N.m was then applied to the central portion of the shaft *(figure 7)*. A standard mesh was then created and the analysis was run. The results were very pleasing, with developed stress and displacement all very small, and a factor of safety of around 6 was reached. The full details of the FEA can be found in the report (*Appendix 1.2)*

2.3.4 Conclusion

A more sustainable and stronger material was found for the side cover of the power hub. This allows us to manufacture the scooter more sustainably and also cheaper, as the savings in materials and energy lower our production bottom line. The FEA of the hub Axle was also very successful, showing a high factor of safety and requiring no further modification. All the part files for the hub can be found in the Appendix 1.4 file.

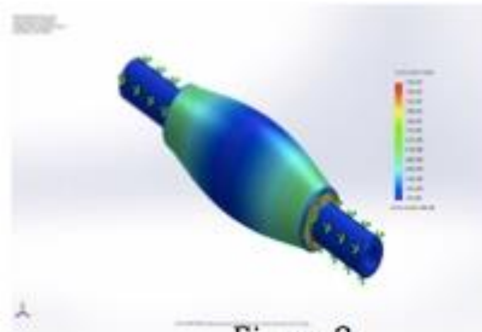


Figure 8

Chapter 3- Wheels

3.1 Literature review- Wheels

3.1.1 Introduction

As they are the most efficient method for moving large objects, wheels are extremely commonly used in many different types of vehicles. The design of the wheels was inspired by bicycle wheels with solid spokes, as are common on some BMX bikes. The three main parts of the wheel that will be described in this chapter include the tyres, spokes, and the hub.

3.1.2 Tyre

Being the only part of the wheel that comes in contact with the ground, the tyres are a highly important part of the successful operation of the wheel. For the tyres to function effectively, they must have a suitable tread pattern, be made of a suitable material, and have a way of holding in air.

Tread Pattern

For a tyre to work effectively, it must have as much surface area of rubber in contact with the surface of the terrain as possible. On dry, sealed surfaces, slick tyres provide the maximum amount of grip possible. When a tyre is used on rough, wet or muddy terrain, however, having a tread pattern on its surface provides more grip, as more surface area can contact the ground. The spacing, size and shape of the tread all affect the grip characteristics of a tyre. Large, sharp edged knobs with wider spacing are generally very effective in wet, muddy conditions. The sharper edges dig into soft terrain, and prevent the tyre from sliding across it. In on-road use, however, these knobs make the use of such a tyre less efficient. This is due to the increased rolling resistance, which can be caused by the deformation of the tyre. This is why tyres for use on road are generally much stiffer than those intended for dirt and mud.

Material

As with any engineered product, the material of a tyre is an extremely important part of the way in which it will function. The main effects on the performance of a tyre determined by the material are grip and wear resistance. These are achieved by selecting a material that is softer or harder respectively. Different compounds of rubber and other materials are used in modern tyres, the specifics of which are kept secret by manufacturers. Common materials used include natural rubber, synthetic rubber, sulfur, and a nylon fabric for puncture resistance. (GMBN, 2017)

Holding Air

To provide the wheels with grip on the terrain over which they are rolling, most tyres are pneumatic, meaning that there is a thin layer of rubber containing pressurised air. This gives some compliance to the tyre, allowing it to absorb impacts from running over small objects, resulting in a more comfortable ride for the user.

Since John Boyd Dunlop developed pneumatic tyres for his son's bicycle, such an approach has been common in many applications. (*Our 124-Year Journey,* c. 2012)

A recent study tested different types of bicycle wheels as part of a low cost agricultural system, to determine if a pneumatic tyre or a rigid wheel (no tyre) would provide more or less resistance. The study found that, when comparing the rolling resistances of the two wheels, the pneumatic tyre's resistances were lower under all tested circumstances. (Ahmad, D et al. 2013)

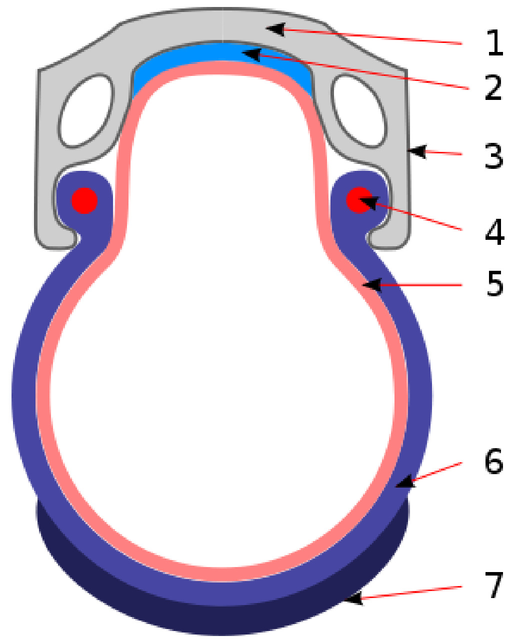


Figure 3.1

Most bicycle wheels hold air by using a system of two parts; the tyre (Figure 3.1, part 6 and 7), and the inner tube (Figure 3.1, part 5), which is placed inside the tyre. The tube is filled with air through a one-way valve, until the pressure is high enough to deform the tube, stretching it to the point at which it contacts the main tyre. To keep the tyre and tube attached to the wheel, a small lip is shaped into the tyre, called the bead (Figure 3.1, part 4). This part registers into a shoulder in the rim (Figure 3.1, part 1), and holds the two parts together.

3.1.3 Rim, Spokes and Hub body

For a tyre to function as it should, it must be mounted to a suitable wheel. Wheels are generally made up of three parts, the rim, the hub, and the spokes.

The rim is the part of the wheel (Figure 3.1, part 3) that the tyre attaches to. It must be designed in such a way that the bead of the tyre can fit into its flanges, locking the tyre in place. On bicycle wheels, they are often made either of aluminium alloys or carbon fibre.

Connecting to the axle, the hub is the central part of a wheel. Depending on the type, the hub may be integral to the wheel, as in the case of bicycle wheels, or a separate part to which the wheel is bolted (such as car wheels). A bicycle hub is made up of the hub body, the bearings and the axle. The axle spins on bearings in the hub body, and is attached to the frame of the bicycle. Depending on the design of the wheel, either sealed or ‘cup and cone’ style bearings may be used. Sealed bearings are more common on more expensive, high performance wheels and cup and cone bearings are used where keeping costs down is a priority.

Spokes are the parts connecting the rim to the hub. On most bicycle wheels, they are made up of thin pieces of wire, threaded at one end into a spoke nipple mounted in the rim. They are mounted alternately on flanges on either side of the hub. This is so that, should the rim become bent out of shape, it can be repaired by tensioning particular spokes to pull it straight again. (BikeRadar, 2014)

Some spokes are not adjustable in this way, such as those on a car wheel. These often have the rim and spokes as a single piece. Because of this, although they are generally very durable and do not deform under normal use, they are not as easy to repair.

3.1.4 Conclusion

Having researched different options for wheels and investigated the performance of each option, it was decided that a hybrid design between a standard bicycle wheel and a solid-spoked car wheel would be employed. The bicycle rim and tyre would reduce rotational weight, the solid spokes would reduce maintenance requirements, and the bicycle hub would be ideal because of its efficiency.

3.2 Wheel Design and Development

3.2.1 Introduction

As decided from the research detailed in the literature review in part 3.1 of the report, a design that was a hybrid of a bicycle wheel and a car wheel was to be employed. A number of different configurations of this concept were trialled in the CAD modelling until the following final design was chosen.

3.2.2 Concept Evaluation

The front and rear wheels presented different challenges in their designs which each ultimately led to the car-bicycle hybrid design being chosen. This was partially dictated by the rear wheel, as a standard wire-spoked design would not have been compatible with the hub motor used.

Another reason for solid spokes being used was their simplicity in maintenance. As they cannot loose tension or break as easily as thin wire spokes, nothing needs to be done to maintain them in working order. If the wheels were to be subjected to an extreme impact and break, they would have to be replaced. This is a reasonable trade-off, as assuming the wheels are designed strongly enough, the impact required to damage the wheels would be higher than is likely to occur during normal off-road use of the scooter.
The size of the wheels was decided to be 20 inches, based on what is already used in BMX bicycles. These relatively large wheels for a scooter would provide a smoother ride over rough terrain, as well as allowing for a standard, off the shelf tyre to be used.

3.2.3 Design

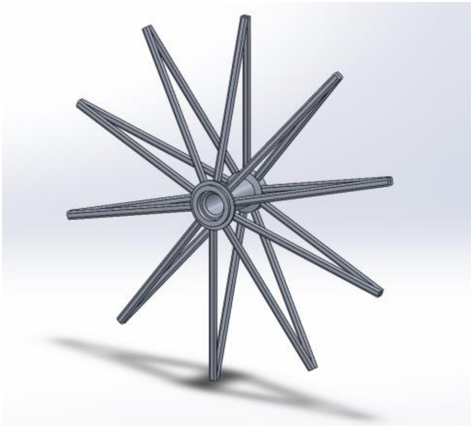
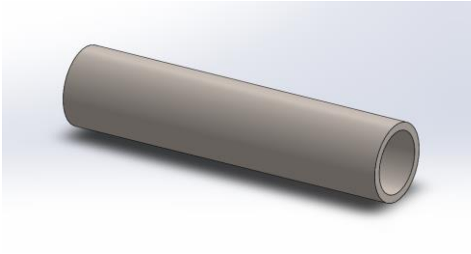
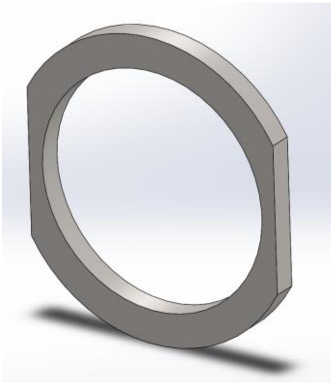
Dimensions of the wheel were set out at the beginning of the design process according to what is generally used in 20” BMX wheels, and these are as follows:

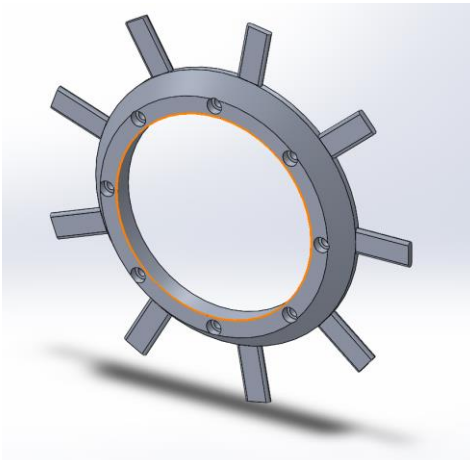
Rim outer diameter	508mm (20”)
Rim width	30mm
Spoke Length (front wheel only)	251mm
Wheel bearings	25x37x7mm sealed cartridge bearing

Parts

The individual parts made for the two wheels are detailed in the following table. As some of the parts were identical between the two wheels, these were reused in multiple places.

Common to Both Wheels:		
Part Name	**Description**	**Image**
Rim	The rim of the wheel. Spokes connect this to the hub, and the tyre attaches to the outside.	
Tyre	The tyre, attaches to the rim. This model has a deep tread pattern, ideal for off-road, but a smoother example could be used also.	
Front Wheel Only:		
Part Name	**Description**	**Image**

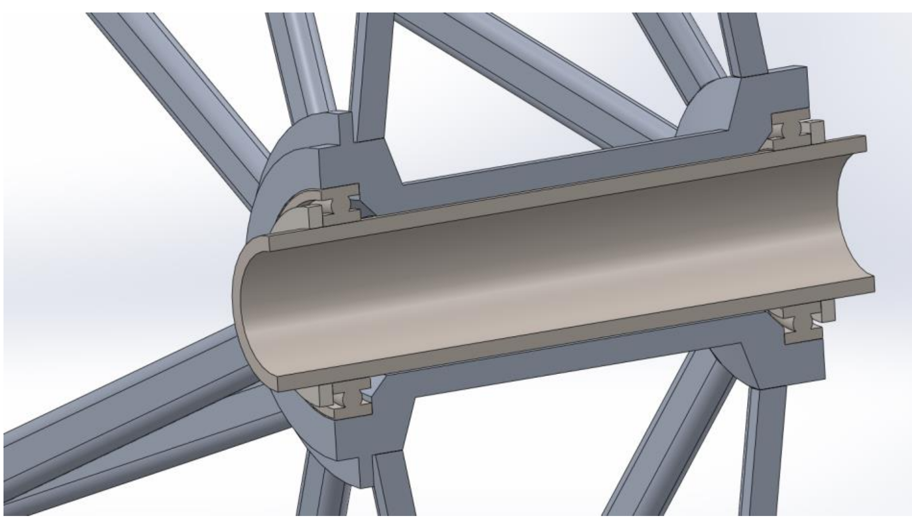
Spoked Hub	Front hub, with spokes attached. Rim attaches to outside of spokes, and hub internals fit inside the hub body. Flange for mounting of brake disk.	
Hub Sleeve	Part of hub internals, sleeve has front axle (part of fork) attach through it, and is fitted to bearings on OD. Each end threaded to fit Hub Sleeve Nut	
Hub Sleeve Nut	Part of hub internals, holds hub sleeve in place, centralised with wheel. Threaded internally to fit to Hub Sleeve.	

Front Wheel Bearing	Standard industrial bearing. Sealed to avoid water ingress.	
Rear Wheel Only:		
Part Name	**Description**	**Image**
Spoked Adaptor Ring	Ring bolts onto hub motor, with spokes connecting this to the rim	

Assembly

Front Wheel Rear Wheel

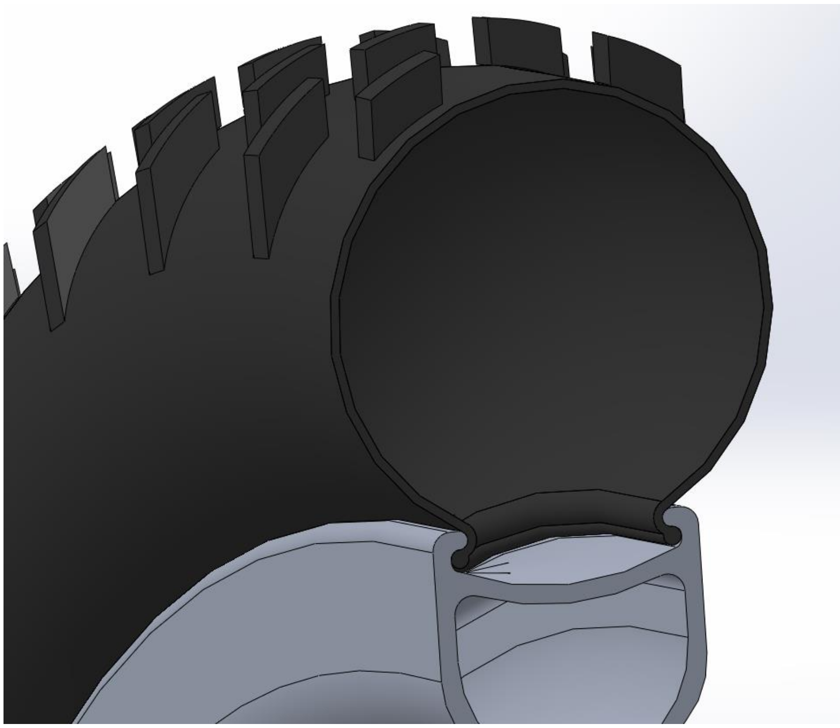
The above pictures show the final assembled wheels. The tyre and rim are identical on both wheels, while the spokes and hubs differ between them. The reason the rear wheel could not have the triangular spoke cross section was because of the design of the hub motor. The design used relies instead on thicker, stronger spokes to achieve a similar result as the front hub.
To see more closely the function of the front hub, a section view is shown below.Each end of the hub has a recess to fit a bearing, where the two sealed bearings are placed. The hub sleeve is fitted inside the bearings, with a small gap between it and the hub body itself for clearance. This way the only parts it comes into contact with are the bearings themselves.



Front Hub Cross Seciton

The two Hub Sleeve Nuts are shown on either side of the bearings, fulfilling two purposes. They are there to hold the sleeve in place, so that it does not slide out of the bearings when the wheel is not installed into the scooter, as well as to hold the bearings in their recesses.

A section view of the tyre and rim is also shown.



Rim and Tyre Cross

The rim is of a similar design to many commercial bicycle wheels, in that it is comprised of a hollow tube with a flange to accept the tyre’s bead. This can be seen in the image above, where the tyre and rim meet. The way in which the two interlock prevents the tyre from coming off of the rim, provided sufficient air pressure is inside the tyre.

3.2.4 Conclusion

The two wheels were successfully designed, and both have relatively simple designs. This means that they should be cheaper to manufacture than a more complicated design may have been, as well as easier to maintain for the end user.

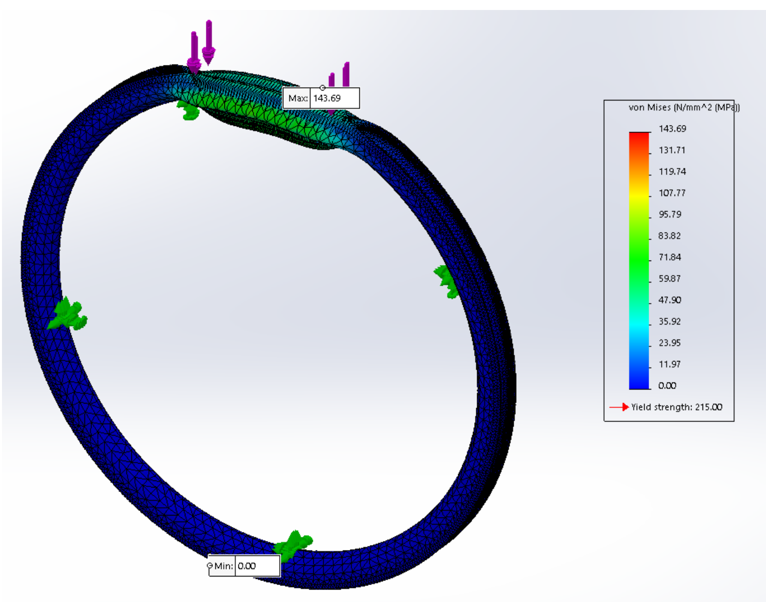
3.3 Finite Element Analysis

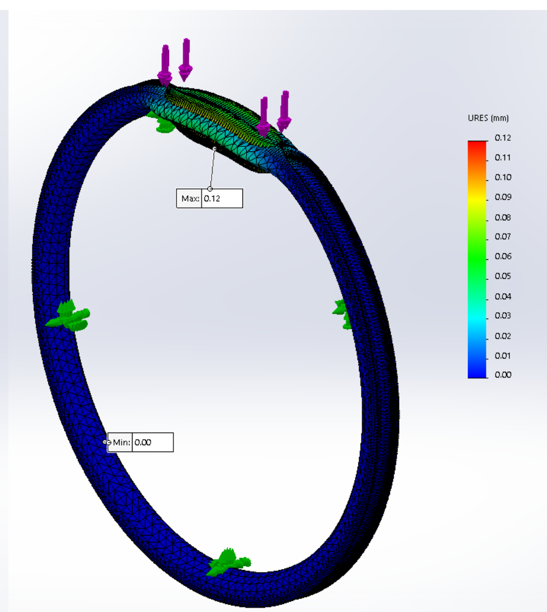
3.3.1 Introduction

The material chosen for the rims was 6063 T6 aluminium. With this selected, the rim part was tested using the Sustainability and FEA tools in Solidworks. Because of complications with the way in which the spokes and rim meet in the assembly, as well as the difficulty of modelling a tyre, it was decided that a simpler FEA should be carried out.

3.3.2 Finite Element Analysis Results

As no spokes were in the model of the rim, the fixed geometry was set to be the inside surface of the rim, which is not realistic. Even so, using a 3000N load on a section of the rim showed the type of deformation that would occur should the rim hit the ground harder than the tyre could hold. The figure below shows the von Mises stress in the rim. As the maximum stress, 143.69MPa, is below the yield strength, 215.00MPa, the rim would only bend and not break





catastrophically.

When looking at the displacement results of the FEA, it is clear that under this amount of stress, the rim does deform slightly, but not enough to prevent the rim from being rideable. The below image shows the results for displacement:

FEA Results - Stress

FEA Results - Displacement

Despite the appearance of the simulation, where the displacement is greatly exaggerated to demonstrate in what way it moved under the stress, the maximum displacement is 0.12mm. This is a relatively small amount, and would likely allow the scooter to continue being ridden without incident.

3.3.3 Conclusion

The results of the FEA testing carried out on the rim demonstrated that 6063 T6 aluminium was a good choice of material. The maximum stress reached was below the yield strength, therefore the wheel would not fail catastrophically. The factor of safety was 0.668, which is lower than would be ideal. Because of this, it may be necessary to set a weight limit for riders, to ensure that there is no chance of a dangerous failure of the wheel during use.

Chapter 4- Cockpit

4.1- Literature Review- Cockpit

4.1.1 Introduction

The cockpit of any form of rideable/ driveable form of transport plays a significant role in how a user experiences the device which they are using. A well-designed cockpit allows for comfort, a feeling of security and heightened experience for the user.

4.1.2 Parts

Handlebars

Handlebars keep the rider attached to the scooter, which is extremely important. If the handlebars were to fail in a case where the user went off a drop, it would result in horrific injuries. Because of this, handlebars must all be made to a high standard and undergo massive tests before being put into production.

Brakes

Brakes come in many different forms, because of this it can be easy to choose ones which do not perform well for the task at hand. Disc brakes have proven themselves to be one of the best designs in both reliability and function. The first successful use of the disc brake was in 1939, on the Daimler Armoured Car. Since then, disc brakes have been developed to work with cars, motorbikes, pushbikes, and almost any form of transport which requires reliable brakes.

4.2 Design and development

4.2.1 Introduction

The design of the cockpit for this scooter was influenced significantly by that of a downhill bicycle. As they would be performing similar tasks, the various layouts used in downhill riding were considered.

4.2.2 Concept evaluation

There are many different options when it comes to creating a cockpit for an electric off-road cable scooter. Handlebar rise, width, weight and strength must all be considered, as well as finding a suitable material for the grips and a well-designed brake lever for the rider’s safety.

Choosing a brake style for the scooter was quite simple. All members agreed a disc style of brake would work best, and there were only 2 options when picking a type of disc brake. Cable and hydraulic brakes are used in mountain biking, one of these had to be chosen to be used on our scooter. Cable disc brakes are extremely cheap and require little to no maintenance, unlike hydraulic brakes which require bleeding and adjustment to keep performing safely and are worth significantly more. Having tested both cable and hydraulic brakes on mountain bikes extensively, it was obvious that the cable style would not have the braking power to stop our scooter. Unlike a mountain bike, our scooter carries more weight and has a motor, which would require more stopping power. The cable brakes were unable to consistently brake hard enough due to brake fade (rotors and pads getting hot and loosing efficiency) which deemed them unsafe for this use.

The handlebars for the scooter were required to have some rise to them and use a common diameter base for use with existing stem clamps. The rise of the bars would ensure the rider was not bending down too much, while keeping most the scooter as low as possible for a lower centre of gravity. Using an off the shelf style of stem clamp would allow users to further customise the feeling of the cockpit by extending or reducing the reach of the stem. 31.8mm and 24.9mm are the 2 most common sizes of stem clamps in mountain biking, the 31.8mm has less flex and higher strength so it was the obvious choice.

4.2.3 Final design

The final design of the brakes (figure 2) were modelled after Shimano SLX hydraulic brakes (figure 1). The levers used are a straightforward design and offer a solid grip when applying the brakes. Spare parts for these are readily available which keeps service costs down.

Figure 1

Figure 2

The handlebars stem clamp was determined to be best at 31.8mm, while the rise of the bars was set at 70mm for a comfortable riding position. Initially the bars had a backwards sweep to them but that was removed in the later staged of development as it was proven to give the rider better control of the scooter without it. 7050-T7651 aluminium was chosen as the material for the bars. It's the most commonly used material for handlebars, and further testing proved why in the FEA section.

4.2.4 Conclusion

Once a design had been chosen, designing the pieces were underway. The parts were completed without many issues and were ready to undergo material selection and testing around mid semester.

4.3 Finite Element Analysis

4.3.1 Introduction

Fixture: lower section of handlebars, where stem connects.
Load: Testing for worst case. A 150kg person going off a 1.5 meter drop has both their feet slip of in the air leaving all their weight to be supported by the bars. Forks have 280mm of travel.

Favg=(0.5mv^2)/d= 7875N, divided by 2 for each hand = 3937.5N on either side of the handlebar, rounded to 4000N. Angle perpendicular to ground.

Material: Test 1 – Plain Carbon Steel, Test 2 - 7050-T7651 aluminium, Test 3- Alloy Steel

Material Properties

Plain Carbon Steel

Elastic Modulus 210000 N/mm^2
Poisson's Ratio 0.28 N/A
Shear Modulus 79000 N/mm^2
Mass Density 7800 kg/m^3
Tensile Strength 399.826 N/mm^2
Compressive Strength N/mm^2
Yield Strength 220.594 N/mm^2
Thermal Expansion Coefficient 1.3e-005 /K
Thermal Conductivity 43 W/(m·K)
Specific Heat 440 J/(kg·K)

7050-T7651 aluminium

Elastic Modulus 72000 N/mm^2
Poisson's Ratio 0.33 N/A
Shear Modulus 26900 N/mm^2
Mass Density 2830 kg/m^3
Tensile Strength 550 N/mm^2
Compressive Strength N/mm^2
Yield Strength 490 N/mm^2
Thermal Expansion Coefficient 2.36e-005 /K
Thermal Conductivity 153 W/(m·K)
Specific Heat 860 J/(kg·K)

Alloy Steel

Elastic Modulus 210000 N/mm^2
Poisson's Ratio 0.28 N/A
Shear Modulus 79000 N/mm^2
Mass Density 7700 kg/m^3
Tensile Strength 723.8256 N/mm^2
Compressive Strength N/mm^2
Yield Strength 620.422 N/mm^2
Thermal Expansion Coefficient 1.3e-005 /K
Thermal Conductivity 50 W/(m·K)

Specific Heat 460 J/(kg·K)

4.3.2 Validation

Test 1 (plain carbon steel)

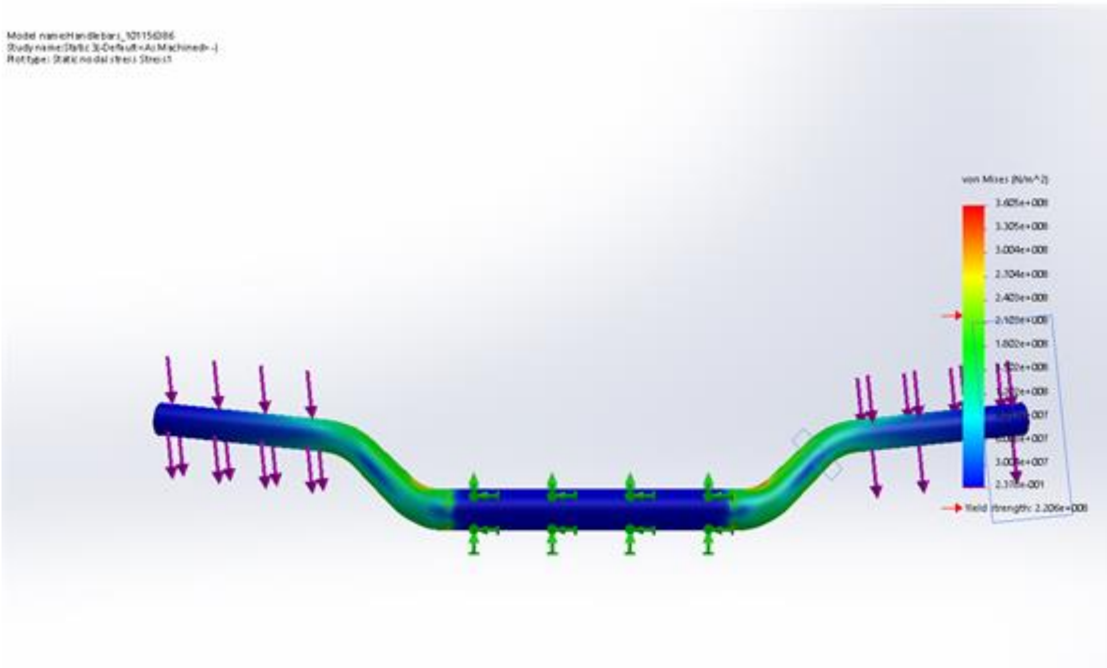


Figure 3

Yield strength- 2.206x10^8N/m^2, von Mises max 3.605x10^8N/m^2

Test 2 (7050-T7651 aluminium)

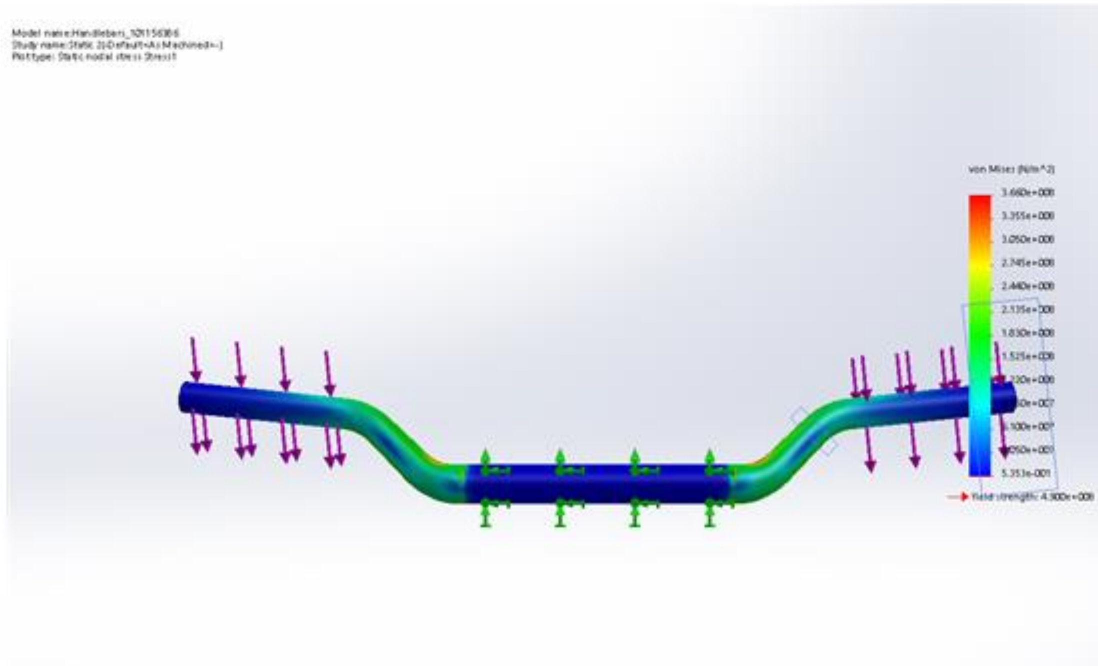


Figure 4
Yield strength- 4.9x10^8 N/m^2, von Mises max- 3.693x10^008 N/m^2

Test 3 (Alloy Steel)

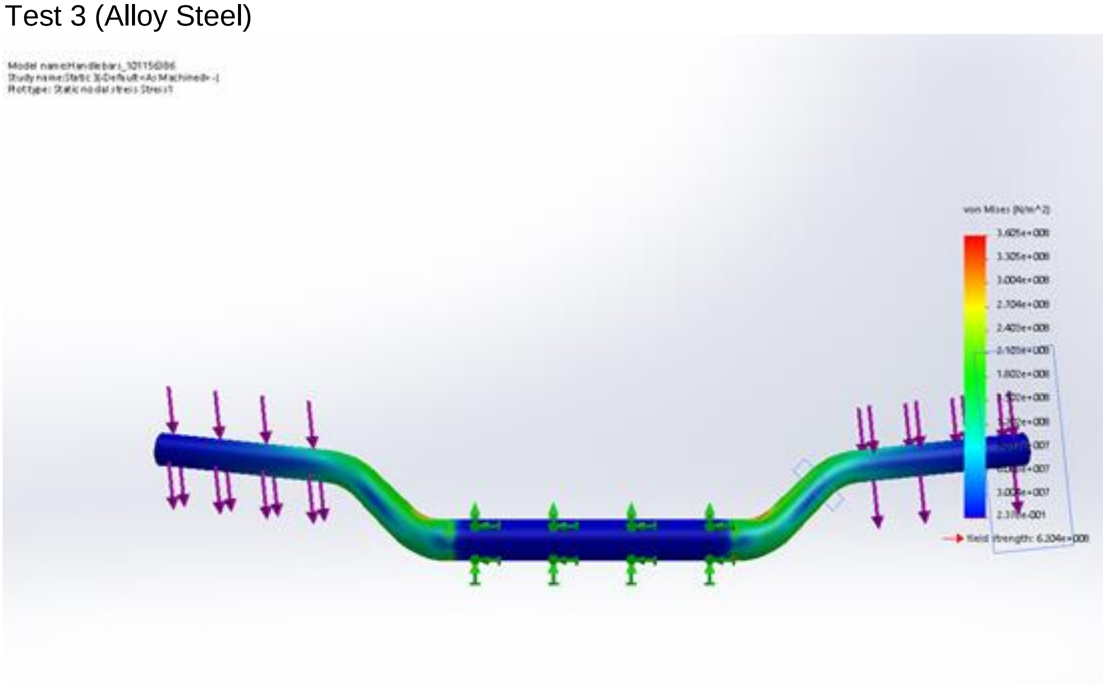


Figure 5

Yield strength- 6.204x10^8 N/m^2, von Mises max- 3.605x10^8 N/m^2

Test 1 showed that the plain carbon steel material was not strong enough. The yield strength required was significantly less than the max von Mises stress. This material would not be suitable for our design as it could result in failure and user injury.
The second test using 7050-T7651 aluminium proved more successful. The max stress was approximately 1.2x10^8N/m^2 lower than the yield strength of the material (figure 4). This material would provide a safer experience for the user.
Alloy steel also proved suitable for our purpose. It was significantly stronger than the other 2 materials with a yield strength 2.6x10^8N/m^2 higher than the max stress (figure 5).
The deciding factor between the aluminium and alloy steel would be weight in our case. A lighter material would mean an easier to ride scooter, and an increased feel in turning ability. The aluminium bars weighed 485g (figure 6), while the alloy steel bars weighed in at 1319g (figure 7). At roughly triple the weight, alloy steel was not going to a suitable material for this build.

Mass properties of Handlebars_101156386
Configuration: Default<As Machined>
Coordinate system: -- default --

Density = 0.00 grams per cubic millimeter

Mass = 484.69 grams

Volume = 171267.72 cubic millimeters

Surface area = 114589.46 square millimeters

Mass properties of Handlebars_101156386
Configuration: Default<As Machined>
Coordinate system: -- default --

Density = 0.01 grams per cubic millimeter

Mass = 1318.76 grams

Volume = 171267.72 cubic millimeters

Surface area = 114589.46 square millimeters

4.3.3 Conclusion

A strong and lightweight material for the most vital part of the cockpit was essential to this scooter project. The bars have been proven to withstand a worse case scenario without undergoing any damage, ensuring the rider is safe at all times.

Chapter 5 - Chassis

5.1 – Literature Review – Chassis

5.1.1 Introduction

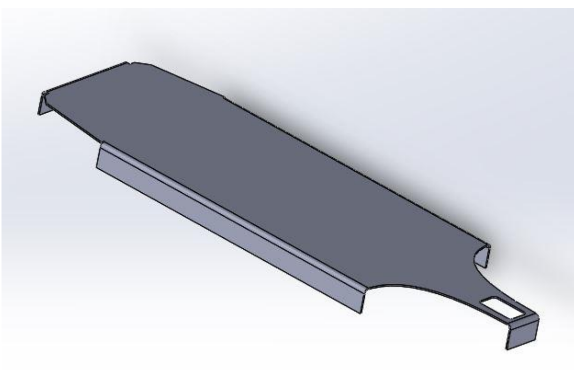
The chassis of any vehicle is the supporting frame, sometimes protection for external/internal parts. Considering a scooter, the chassis would support much of externally added components, and any internal ones, such as wiring.

5.1.2 Components

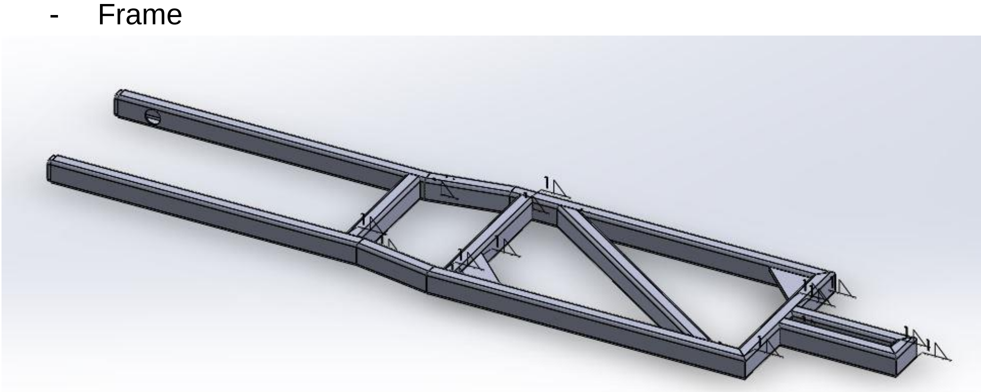
The chassis was crafted with 2 different components.

The frame and the Deck sheet.

- Deck Sheet



- Frame



These parts would need fit together to form a sturdy base capable of going through tough treatment. To prevent any injury to the rider, the chassis must be made from a considerably strong material to a high standard.

5.2 Design and Development

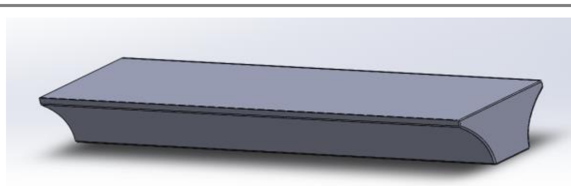
5.2.1 Introduction

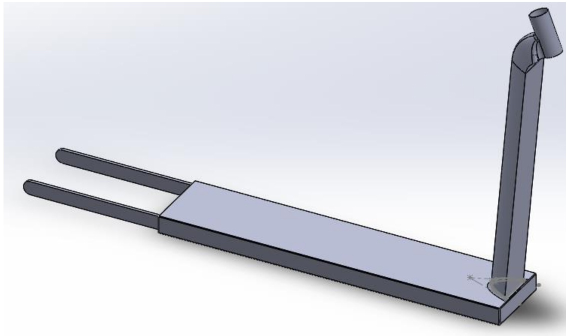
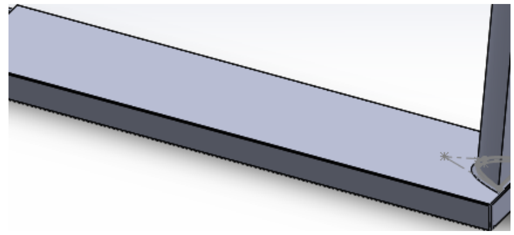
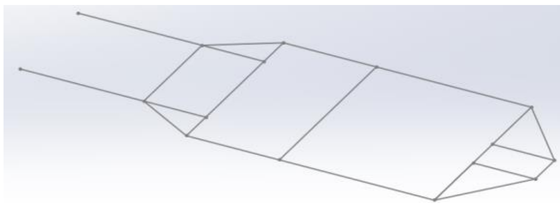
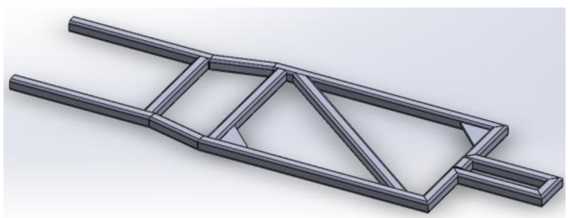
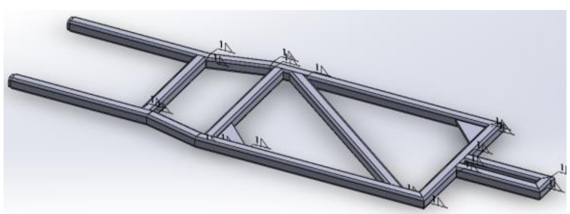
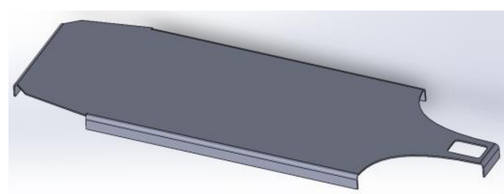
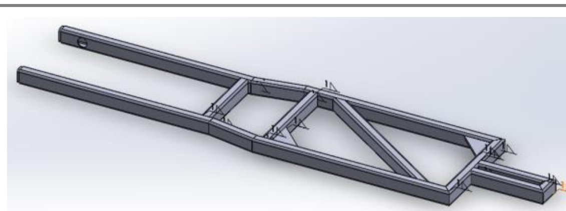
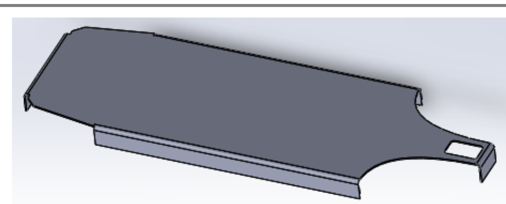
The initial idea for the design of this chassis was to be simple, enable easy access to any interior components, be lightweight and most importantly; robust.

5.2.2 Concept Evaluation

There were various concepts for the frame, and all concepts till the final build shall be discussed, along with reasons for change. The early designs were drastically changed due to structural integrity flaws.
The size of the frame, shape and material used had to be considered, as the entire weight had to be a reasonable value. Also, to considered, as a minor factor, was that the look of the final design had to be aesthetically pleasing, for the scooter to attract buyers.
For the frame to be robust, weldments were the only option, as this enabled it to be lightweight, but still strong, as opposed to using a solid block, or sheet metal plates. Just attaching a deck sheet on top of the frame and keeping the chassis simple to create, would be extremely easy for maintenance, and would open the option for various and very profitable aftermarket designs.
Once all the basic structural design was selected, the ergonomics of the chassis had to be considered. There had to be room for the rider to stand in various positions, while at the same time, not being too bulky.

5.2.3 Design timeline

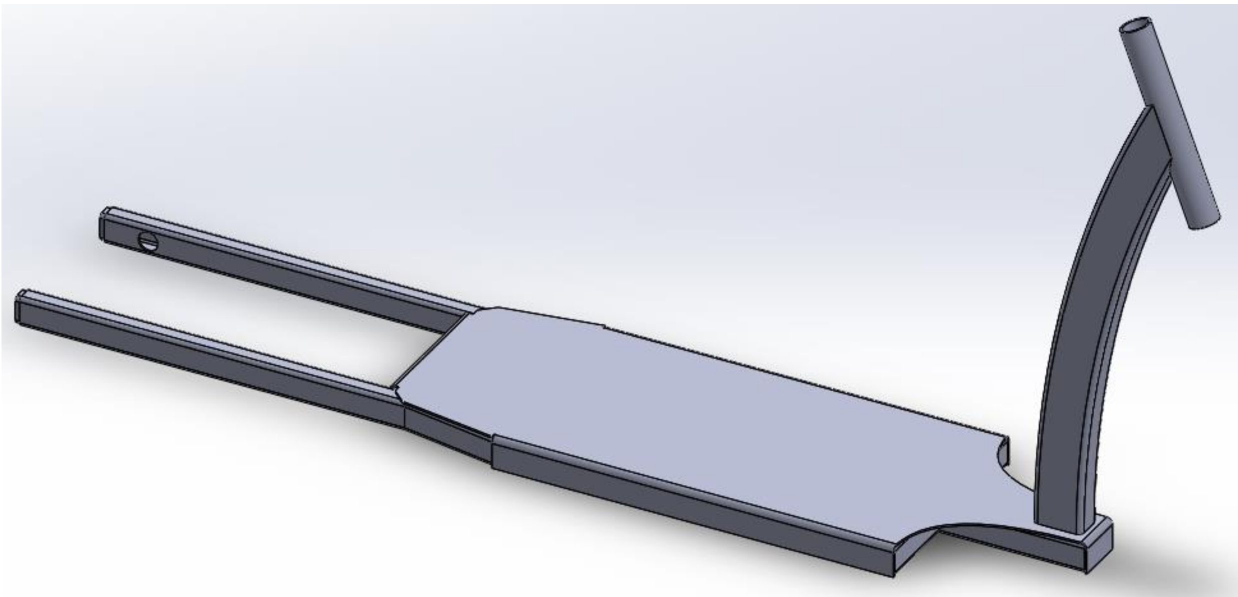
Design	Frame	Deck sheet
1		

2		
3		
4		
5		
6		

The first two designs were just sheet metal frames, with no weldments. This mean that they were very structurally unstable, and would be extremely unsafe for the average adult when just riding. Design 3 was the initial layout for the weldments, and it was adjusted to the basic layout that was used henceforth.

Design 5 was a narrowed down version of design 4, to prevent the scooter from being too bulky, and heavy. The sleeker design 5 also worked well with other components, without looking as awkward as the previous design.

Final Design



Design 6 was the final design. The crossmembers were moved slightly, to adhere to room needed for welding in the joints. A completely different and custom weldment was used for the whole frame; 20x30x2. The dimensions for the weldment, supported the diameter of the wheel axles. The members which support the rear wheel had to be extended, and the width of the edge flanges on the deck sheet had to be extended, to cover the new height of the weldment. All components are welded together. Screw holes were added in the underside of the chassis, to hold the battery casing.

5.2.4 Conclusion

The switch to weldments was imperative, as the chassis was not structurally robust at all. If anything needs to be changed, it would be the size of the weldments, perhaps by increasing the thickness, or the actual size to 30x30 or 30x40.

5.3 Finite Element Analysis

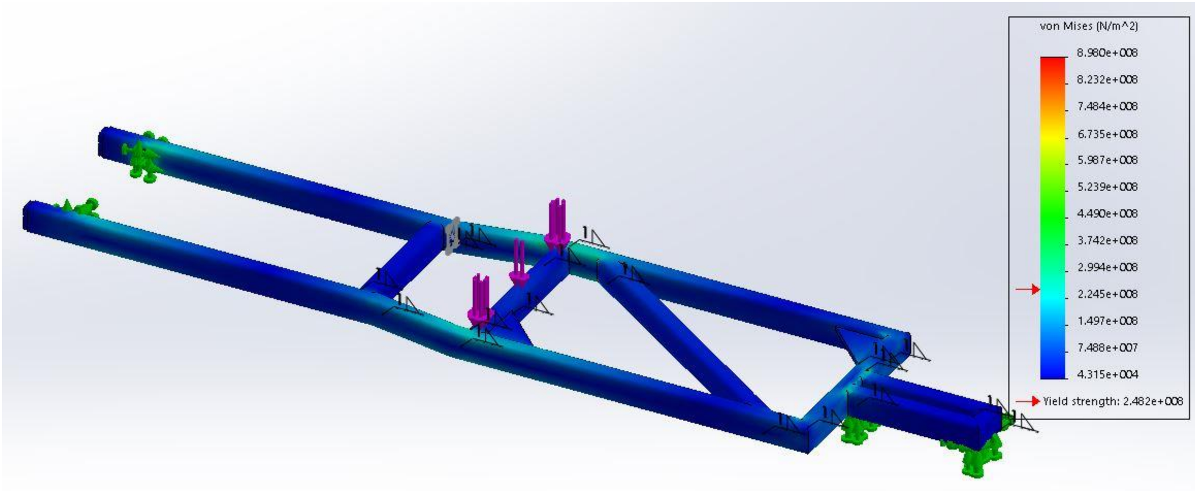
5.3.1 Introduction and validation

Fixture: Rear wheel bearing, and foremost weldment, where the downtube attaches.
Load: Testing for an extreme case scenario: a 100kg person falling about half a metre, would approximately have an impact force of 5000N. The angle of impact is perpendicular to the ground. The weight force would be applied on the centre cross-member by majority.

Materials:

Cast Carbon Steel

Elastic Modulus	2e+011	N/m^2
Poisson's Ratio	0.32	N/A
Shear Modulus	7.6e+010	N/m^2
Mass Density	7800	kg/m^3
Tensile Strength	482549000	N/m^2
Compressive Strength		N/m^2
Yield Strength	248168000	N/m^2
Thermal Expansion Coefficient	1.2e-005	/K
Thermal Conductivity	30	W/(m·K)
Specific Heat	500	J/(kg·K)
Yield Strength- 2.48*10^8 N/m^2 **Von Mises max- 8.98*10^8 N/m^2**		

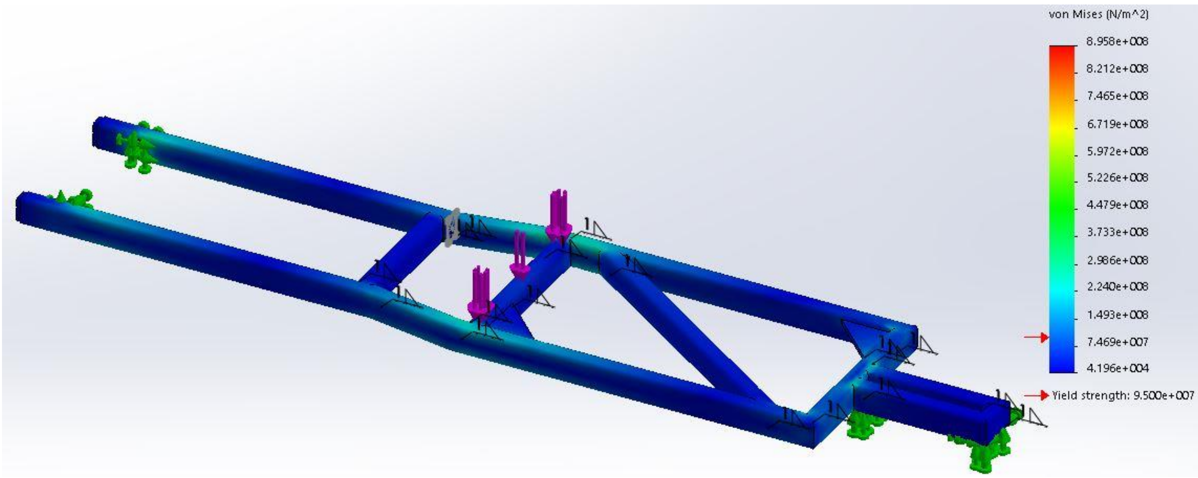


Aluminium 7075-O (SS)

Elastic Modulus	7.19999992e+010	N/m^2
Poisson's Ratio	0.33	N/A
Shear Modulus	2.689999969e+010	N/m^2
Mass Density	2810	kg/m^3
Tensile Strength	219999997.9	N/m^2
Compressive Strength		N/m^2
Yield Strength	94999999.42	N/m^2
Thermal Expansion Coefficient	2.4e-005	/K
Thermal Conductivity	173	W/(m·K)

Specific Heat	960	J/(kg·K)

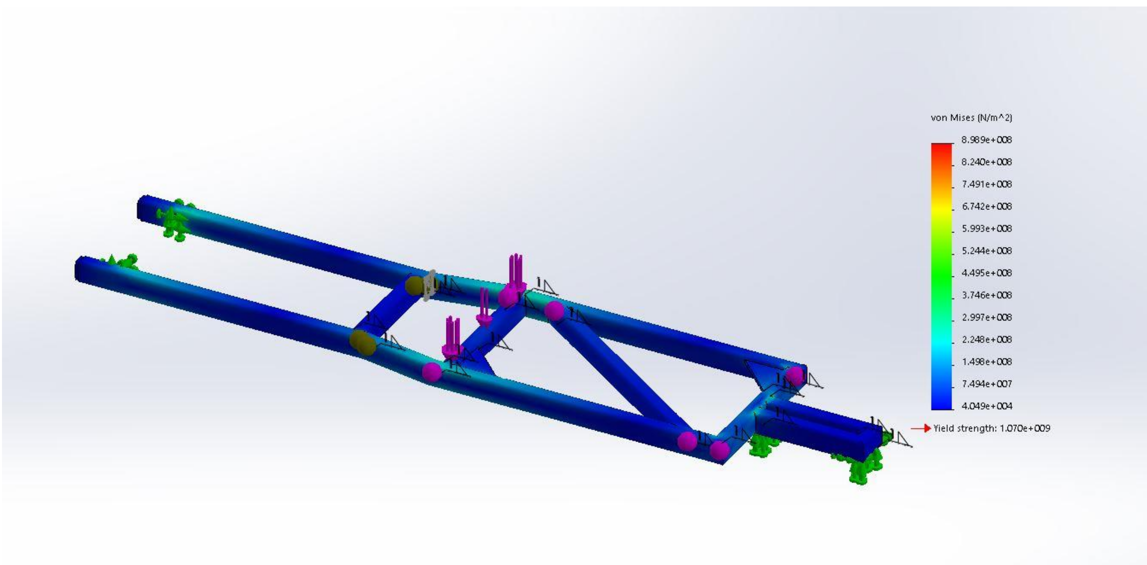
Yield Strength- 9.5*10^7 N/m^2
Von Mises max- 8.958*10^8 N/m^2



Ti 6Al 2Sn 2Zr 2Mo 2Cr 0.25Si Alloy (Titanium Alloy)

Elastic Modulus	1.230000018e+011	N/m^2
Poisson's Ratio	0.33	N/A
Shear Modulus	4.599999975e+010	N/m^2
Mass Density	4650	kg/m^3
Tensile Strength	1160000029	N/m^2
Compressive Strength	1169999978	N/m^2
Yield Strength	1070000004	N/m^2

Thermal Expansion Coefficient	9e-006	/K
Thermal Conductivity	7.8	W/(m·K)
Specific Heat	500	J/(kg·K)
Yield Strength- 1.07*10^9 N/m^2 **Von Mises max- 8.989*10^8 N/m^2**		



The tests with Cast-carbon steel and Aluminium 7075-O were not strong enough, as the yield strength was less than the maximum Von Mises Stress. This would have caused the material to fail under that extreme case of load and fail. The last test, using a 86% titanium alloy, Ti 6Al 2Sn 2Zr 2Mo 2Cr 0.25Si, was successful. As a frame built out of this alloy won't fail under such an extreme case, this would be safe during use for an average user.

Mass properties of body7
Configuration: Default<As Machined>
Coordinate system: -- default --

Density = 0.00 grams per cubic millimeter

Mass = 531.17 grams

Volume = 531168.77 cubic millimeters

Surface area = 528556.36 square millimeters

Another perk to using this Titanium alloy, is that it makes the frame extremely lightweight, but still strong. Weighing about half 500g, it would be beneficial for a scooter that can be moved around without much effort from the user.

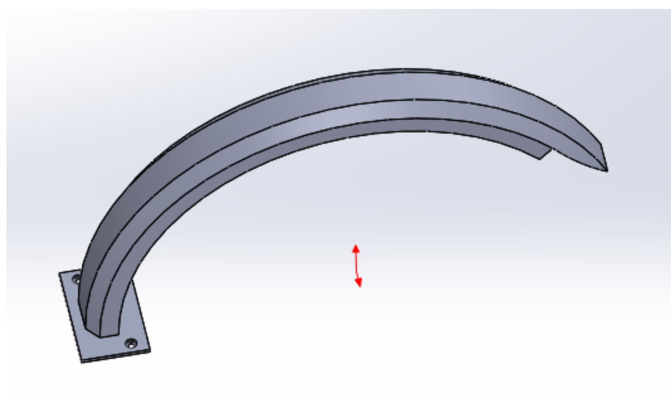
5.3.2 Conclusion

The goal for the chassis was to be strong yet lightweight, and with the successful titanium alloy, this is possible. An extreme scenario was tested, to provide a buffer in the stress of an average everyday use.

Chapter 6: Auxiliary components

6.1 Mudguard

The most obvious reason for fitting mudguards is that they'll keep gunk and water from flying up and getting all over you, keeping drier.
Use mudguards and less water and grit gets flicked up from the road onto your glasses or into the face of the rider behind you, so it's good news in terms of vision
To make the Front and Rear Mudguard following considerations were taken into account.



6.2 Rear Mudguard

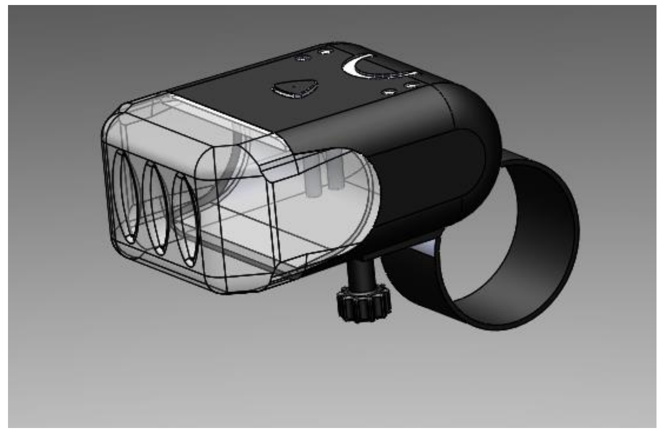
To make the rear mudguard the first thing was to make sure that the diameter of the rear mudguard should be greater than the diameter of the rear wheel assembly so the wheel doesn't crash into bumper.
In our design we connected the bumper to chassis through bolts.

6.3 Front Mudguard

For the Front it was made exactly in the same way and it bolted with the fork so the height remains adjustable.

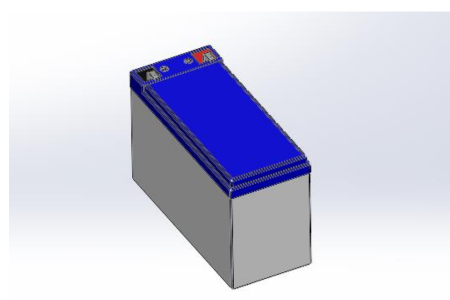
6.4 Front Light

Bike Light is illumination attached to bicycles whose purpose above all is, along with reflectors, to improve the visibility of the bicycle and its rider to other road users under circumstances of poor ambient illumination. A secondary purpose is to illuminate reflective materials such as traffic. A third purpose is to illuminate the roadway so that the rider can see the way ahead.
In our Project we have chosen LED flashlights using rechargeable batteries because of it's simplicity, availability and less price



The Front was downloaded from Grabcad but we made few change to the front light because the diameter of our handle bar was 30.2 mm and the internal diameter of light holder was 40 mm so we reduced the inner diameter which changed the shape of light as well.

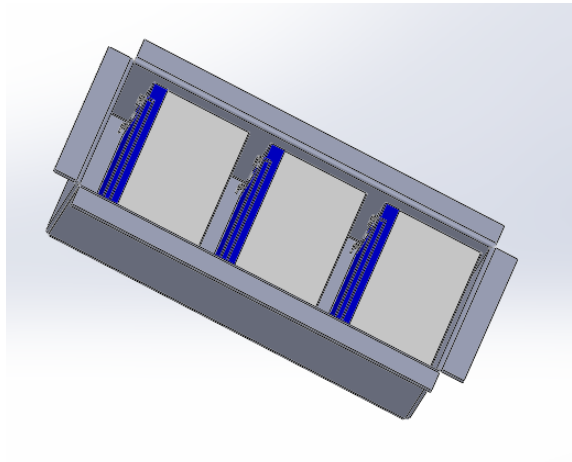
6.5 Battery and Battery Casing



The lead acid battery is simple and inexpensive to manufacture. There are many lead acid batteries manufacturers, OEM, such as Leoch Battery. Having been used over more than 140 years, lead acid batteries are reliable, mature secondary batteries, globally manufactured and therefore a widely understood technology. When used correctly, they are very durable and dependable. Their self-discharge rate is among the lowest of rechargeable battery systems. Capable of high discharge rates, the lead acid battery is able to deliver the bursts of energy that are required to start an engine.

Lead acid batteries are environmentally sound in that they are recycled at an incredibly high rate. Today, 98% of lead acid batteries are recycled. With low maintenance requirements, the lead acid battery includes no memory and no electrolyte to fill on the sealed version.

Three 7 amp hour 12 Volt batteries were chosen for the scooter.



Battery Casing

The battery casing is really important in order to hold the batteries in place and it should be strong enough

Chapter 7: Conclusion

The final scooter design was successfully completed and delivered on time. The team worked well together with all members completing assigned tasks. Unfortunately the VR section of the project was unsuccessful. Time constraints and difficulties with the model and computers forced us to abandon this section. However group members were able to experience VR and what it has to offer engineering and design visualisation. The end product of the project is a scooter that will hopefully appeal to the off road and mountain bike market.

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