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EleCycle

Project 1 Report: Group 11

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Introduction

As the world transitions from fossil fuels to green energy, electricity is the first thing that comes to mind. There has been a huge surge in electrical transportation production and design over the last few years. It has becoming apparent that manufacturers are trying to design more fuel economic and zero emission transportation. There are huge industries for uses of electric transportation such as vehicles, bikes, buses and all sorts of transportation. When it comes to motorcycle there hasn't been much of a push to standardize electrical methods of application. EleCycle aims to create a two wheeled electric motorcycle which will be capable of traversing through an urban environment. The key design aspects we focused on was a motorcycle that would carry a maximum of two passengers, equipped with a rechargeable battery powering an electric motor that gives you a day’s worth of drivability. Furthermore, we aim for EleCycle to be able to withstand various cyclic and impulse forces.

Information Search Results

Standards and Codes

Canadian Motor Vehicle Safety Standard (CMVSS) classifies EleCycle as an Open Motor-cycle [1]. Using this information, we must follow strict guidelines as listed below to allow the motorcycle to be street legal. There are some guidelines that pertain to gas powered motorcycles such as noise requirements that have not been included.

106-Brake Hoses: Hose connection and protection guidelines in TSD 106 Rev 1.0

108-Lighting System and Retroreflective Devices: Lighting guidelines in TSD 108 Rev 5.0

108.1-Alternative Requirements for Headlamps: Daytime running light

111-Mirrors: must be adjustable and face rearward

115-Vehicle Identification Number: Special Identification number for motorcycle

116-Motor Vehicle Brake Fluids: Motorcycle must comply with brake fluid requirements in TSD 116 Rev 2.0

122-Motorcycle Brake Systems: Motorcycle must comply with breaking requirements TSD No. 122 Rev3.0

123-Motorcycle Controls and Displays: Motorcycle must meet display identification requirements for various cases

205-Glazing Materials: glass must comply with regulated code ANSI/SAE Z26.1

Patents

There are many patents for electrical motorcycles, but everyone shares a basic concept of either a bike design or a scooter design. There are very few electric motorcycles that meet majority of our design specification.

US8789640B2
US20130270026
US20130292198
US2014030572
US20120318600
US20130161107A

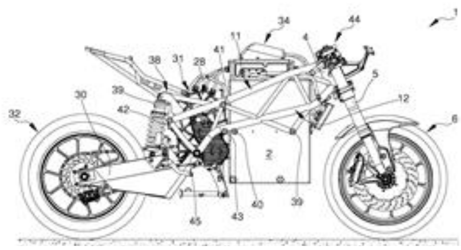

Figure 1: Patent US20130161107A

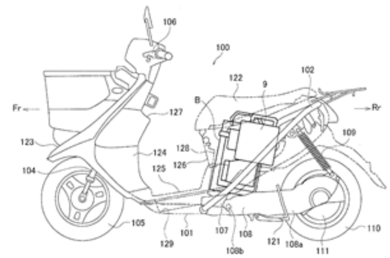

Figure 2: Patent US2014030572

Competitor products and specifications

When taking into consideration the patent research, there are two main types of electric motorcycles. The first is a scooter-based design and second is a bike-based design, both designs usually involve a tube frame chassis. When it comes to the bike design the competitors use a Y shaped tube frame chassis. Whereas, the scooters use a U-shaped hook design with extruding bars for seating and batteries. Most common unwanted specification is that these bikes are beefy and end up being very heavy. When looking at the market we found four direct competitors.

	Vespa Elettrica	**Gogoro Smartscooter 2**	**Monday Motorbikes M1**	**Delfast Prime**
Range (km)	100	110	64	236
Top Speed (kph)	48	56	64	45
Weight (kg)	102	104	77	43
Price (USD)	7000	3200	4500	6000

Table 1: Competitor Products and Specifications

Figure 3: Vespa Elettrica

Figure 4: Gogoro Smart scoter 2

Figure 5: Monday Motorbikes M1

Figure 6: Delfast Prime

EleCycle's Design Specification

- Maintain speeds of 60km/h (Top speed of 70km/h)
- Acceleration around 3.5m/s
- Minimum ground clearance of a ½ foot
- Maximum Height 3.5 feet
- Overall weight <150kgs.
- Low center of Gravity
- Range greater than 100 kilometers
- Carry a maximum of two passengers
- Price less than 4000 USD

When considering our motorcycle design specifications, we believe it is crucial to be able to maintain speeds of 60km/h as it is the average speed around a city. The motorcycle will have a top speed of 70km/h to overtake or get out of rough situations. We believe the motorcycle should have an acceleration of 3.5 m/s from standstill to reach speed in a timely manner whilst still feeling sporty. It must not only maintain this speed, but have a range greater than 100 kilometers. This can be done by having its overall weight less than 150 kilograms and using a high-quality efficient DC motor. This motor will be powered by a series of rechargeable batteries to maintain the speed for more than 100 kilometers. However, majority of the weight will have to be distributed low to the ground, allowing the motorcycle to feel nimble and take turns with ease. This will all be done whilst still having the capabilities of carrying two passengers. Furthermore, we will appeal to the clientele by pricing EleCycle at around 4000 USD.

Description of concept alternatives

Design 1: Dually

This design is inspired by a tandem bicycle. This design involves a single platform for seating with each commuter receiving their own handlebars which will give the driver and passenger complete comfort and stability. Furthermore, this design also has a storage space at the end of the bike which allows for the tie down of various small items from backpacks to grocery. The drivetrain will consist of a motor placed on the bottom frame which will be connected to a gearbox and attached to the wheel using chain. The batteries will be placed in another compartment above the motor and under the seats. The concerns with this design is that it has a very long wheel base and will be heavier than a typical motorcycle. Furthermore, the center of gravity due to the raised batteries will be high which is unwanted for a 2-wheel motorcycle when taking turns.

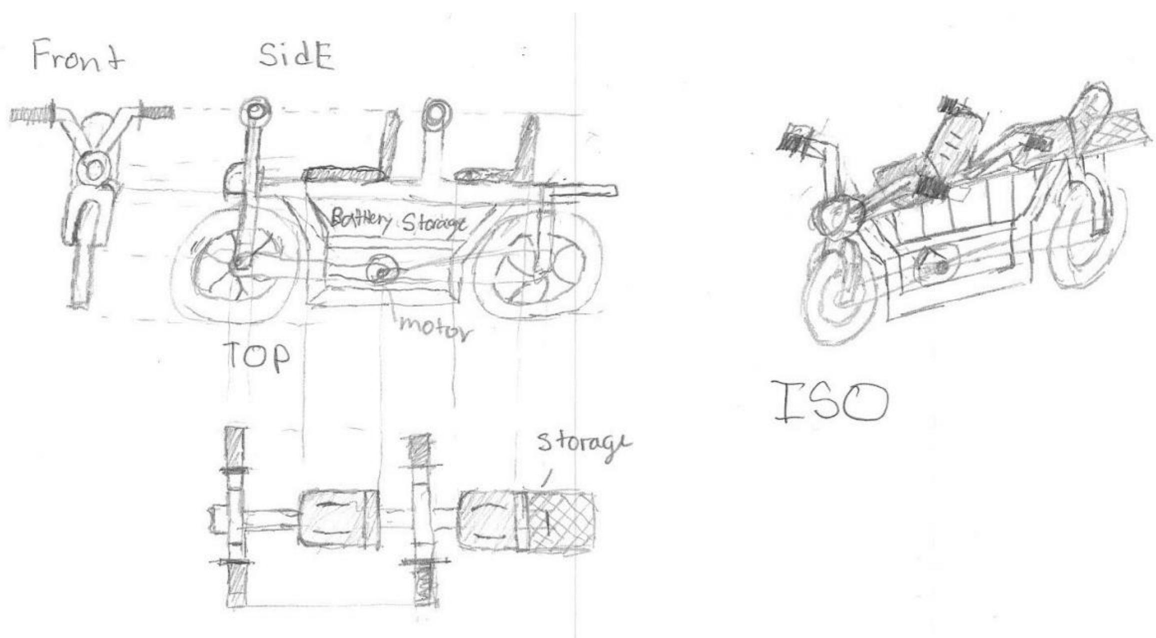

Figure 7: Dually Concept sketches

Design 2: High Rise

The second concept was inspired by a double decker bus. This design involves the usage different elevations for the driver and passenger. This is beneficial as it allows both passengers to have a great view of the surroundings which would be optimal when rode in scenic areas such as the Stanley park in Vancouver. However, the passenger may be a little uncomfortable as it won't have anything to hold onto and may have a difficult time getting on and off the bike. The drivetrain of this design will also use an electric motor attached to a gearbox to limit speed and torque then connected to wheel via chain. The electric motor will be placed majority on top of the rear wheel to allow for more grip when not carrying a passenger. The batteries will be carried in the lower compartment which is optimal as it will lower our center of gravity making this bike be very stable in turns.

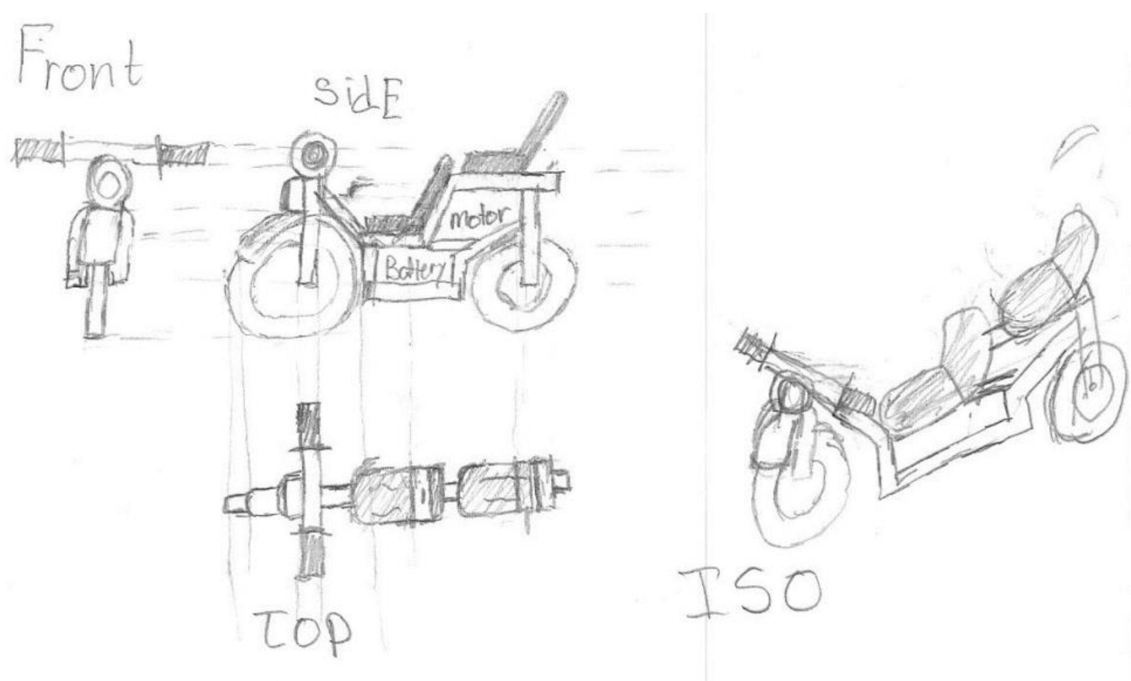

Figure 8: High Rise Concept sketches

Design 3: Streamliner

This design was inspired by a cafe racer. The passenger seating area will be on the same platform but far enough apart where the passenger and driver won't be rubbing up on each other. The Passenger will be sitting directly above the rear wheel increasing weight on the rear wheel which will ultimately increase traction. This seating arrangement will ensure the bike is not high off the ground as is comfortable for both users. The Drivetrain of this motorcycle will also be an electric motor attached to a gearbox and connected to the wheels using chain. The motor will be placed on the lowest platform along with half of the batteries which will lower the center of gravity allowing the bike to feel very nimble, therefore handling very well. The rest of the batteries will be placed over the rear wheel to increase traction. The bike will be connected to the rear wheel from the lower part of the frame rather than on top increasing the structural rigidity of the frame

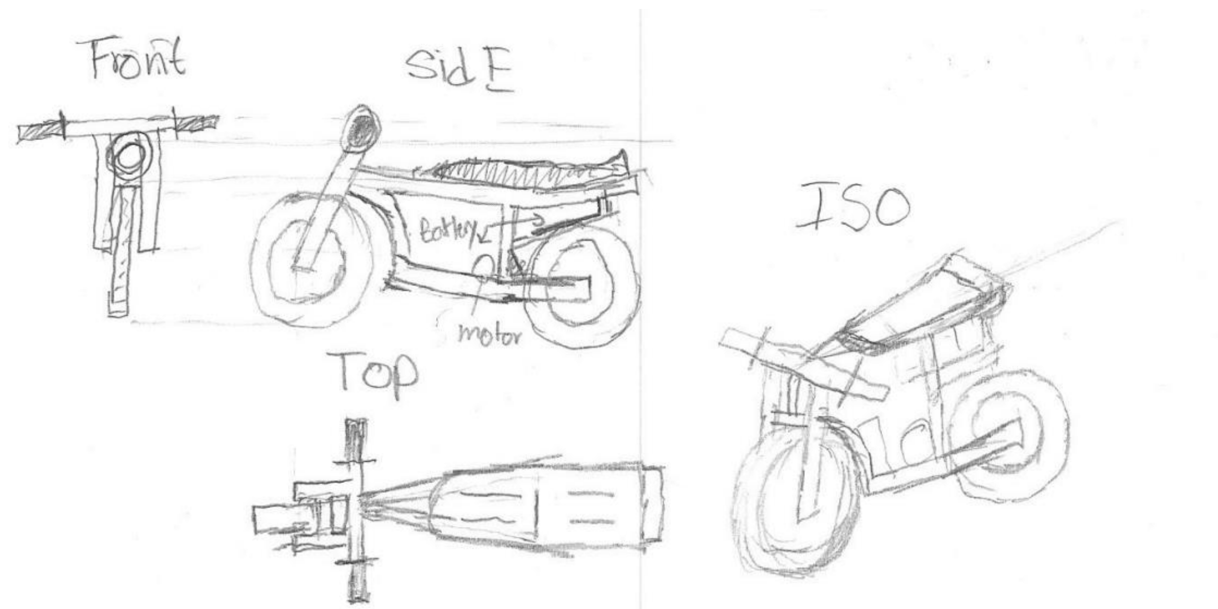

Figure 9: Third design based on Cafe racer

Concept analysis and selection

When comparing three designs, each has their benefits and drawback. There are many methods to analyze each concept, but as a team we decided to create an analyses matrix that will assess the concepts traits. Ultimately the matrix analysis will decide what concept to proceed with.

Cost analysis

The cost of the bike must be low, as we expect our consumer to be a low-middle class individual who may see alternatives to our electric motorcycle. When looking around at the market for an electric powered 2 wheel method of urban transportation we see that an electric scooter can range from 4000-6000$ and an electric bike can range from 2000-4000$. When assessing the cost we need to keep the bike frame cost as low as possible so that we can maximize battery life and capacity. Therefore, to assess the cost we will multiply the approximate linear length of the bike by the cost of tubing. Since we haven't decided a material, yet we will just go with aluminum as the change in material will just change the cost of all proportionally not changing our final assessment.

Concept	**Linear length**	**Cost (per inch)**	**Total cost (USD)**
Dually	324 in	$0.73	$236
Highrise	293 in	$0.73	$213.89
Streamliner	232 in	$0.73	$169.36

Table 2: Bike Frame Cost analysis

When assessing the internals of our bike we decided to go with an EMRAX 118 motor as it has a built in motor controller for variable speed. It also can produce 32kW of continuous power with a peak torque of 90Nm. This motor has a range of up to 6000 RPM so it can achieve speed and maintain it. The battery to couple with this motor is 1100, 18650 cells which have been proven in the electric community. These batteries and the motor will be able to provide 130km of Range. The amount of range this bike produces coupled with the projected cost of bike makes it a direct competitor if not better than our competition.

	Battery 18650 cells (1100 pcs)	Motor- EMRAX 188	Tires and rims	Miscellaneous parts	Total
Cost (USD)	1200	1100	400	500	**3140**

Table 3: Bike Internal Cost analysis

Decision Matrix

Since we can see that our first concept "Dually" is very long it equals a higher cost. We cannot only discard a concept due to high cost there must be a matrix to assess other things, for example Dually is very long and creates ultimate passenger comfort. In order to assess which concept is truly the best we must employ the use of a decision matrix which will weigh the importance of each parameter.

Objectives	**Metric**	**Weight**
Affordability	Dollars ($)	20%
Weight	Pounds (lbs)	20%
Overall Volume	Volume (L)	15%
Center of Gravity	Height of Ground (m)	15%
Looks	Group Survey	10%
Battery Space	Meters (m)	15%
Passenger Space	Space (L)	5%

Table 4: Decision Matrix Weights

This matrix reveals that the most important parameter for us was both Affordability and Weight. Since the cost of material is directly proportional to the overall cost and weight of chassis, these two parameters go hand in hand. The second most important parameters where a Low center of gravity, Low Occupied volume and a high amount of battery capacity. A low center of gravity is a crucial parameter as taking turns is much easier with a low center of gravity, where as a high center of gravity may be prone to tipping. The motorcycle must occupy a small footprint so that parking is not a hassle. With a low cost to build more of the budget can be spent on batteries to maximize capacity and battery length. Lastly, the passenger space was the lowest of our prioritization as the rider may not always be carrying a passenger.

			Dually		High Rise		StreamLiner	
Objectives	Metric	Weight	Rating	Score	Rating	Score	Rating	Score
Affordability	Dollars ($)(0=Expenisve)	20%	5	1	7	1.4	9	1.8
Weight	Pounds (lbs)(0=Heavy)	20%	5	1	7	1.4	8	1.6
Overall Volume	Volume (L)(0= Takes up space)	15%	3	0.45	8	1.2	8	1.2
Center of Gravity	Height of Ground (m)(0= high)	15%	2	0.3	9	1.35	9	1.35
Looks	Group Survey (0=Ugly)	10%	8	0.8	9	0.9	7	0.7
Battery Space	Meters (m)(0= No Space)	15%	9	1.35	7	1.05	9	1.35
Passenger Space	Space (L)(0= No Space)	5%	10	0.5	8	0.4	5	0.25
	Overall Score			5.4		7.7		8.25

Table 5: Decision Matrix

Concept Integration and Selection for Further Development.

The Decision matrix embodies the main goals of EleCycle and encompasses everything we believe this motorcycle should have. The matrix has made it clear that the streamliner was the best concept to proceed with. However, the matrix also shows us where the StreamLiner is lacking, which is the passenger space and comfortability. We choose to integrate the elevated passenger seat from the HighRise and extend the passenger seat. This integration will allow the StreamLiner to be an optimal candidate to select for further development.

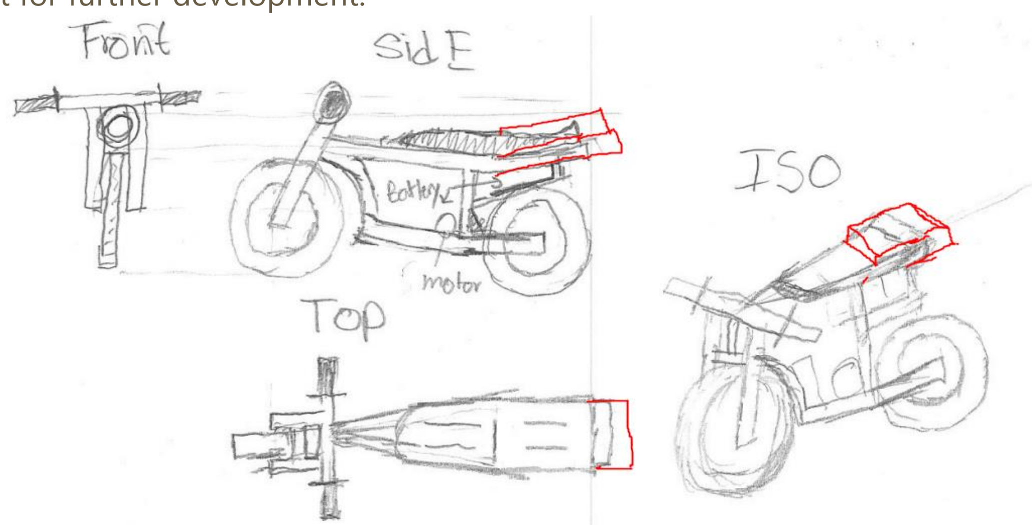

Figure 10: Streamliner Final Evolution

Design & Stress analysis

This section of the report is dedicated to analyzing optimal and critical operating conditions of our chassis design for the EleCycle. The following analysis was carried out for an assumed worst-case scenario of 130 Kg loading condition – 65 kg per person. It was assumed that 80% of the loading condition was distributed across the seat and the rest distributed as axial load, at the handle. In addition, for simplicity all beams are assumed to be solid with equivalent cross-section area of a standard hollow tube, with a known inner and outer diameter. The final chassis design was obtained after several stress analysis and design optimizations.

Preliminary Design

The preliminary chassis design is given in figure 11. The initial design was developed to withstand the worst-case loading condition excluding motor and battery weight. In addition, the material used for the preliminary chassis frame was Aluminum 6061-O (SS). Figures 12, 13, and 14 are the results of FEA, carried out on the preliminary StreamLiner. They represent the Stress distribution, Strain, and Deformation of the frame, respectively.

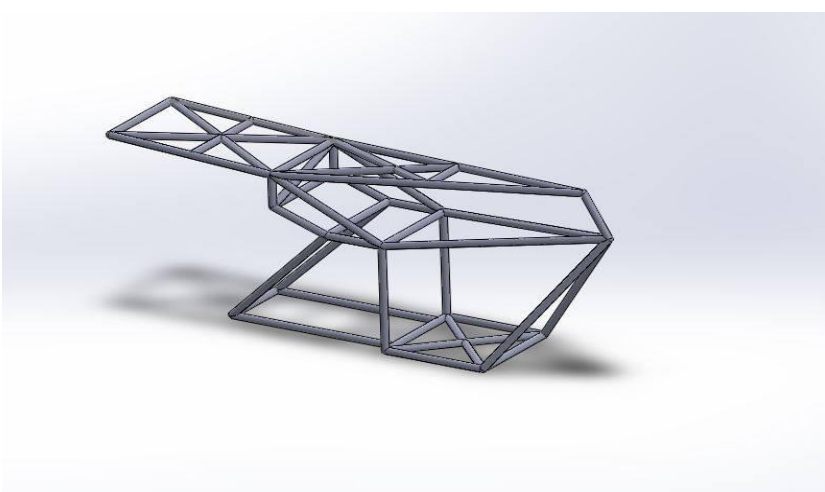

Figure 11: Preliminary Chassis Design

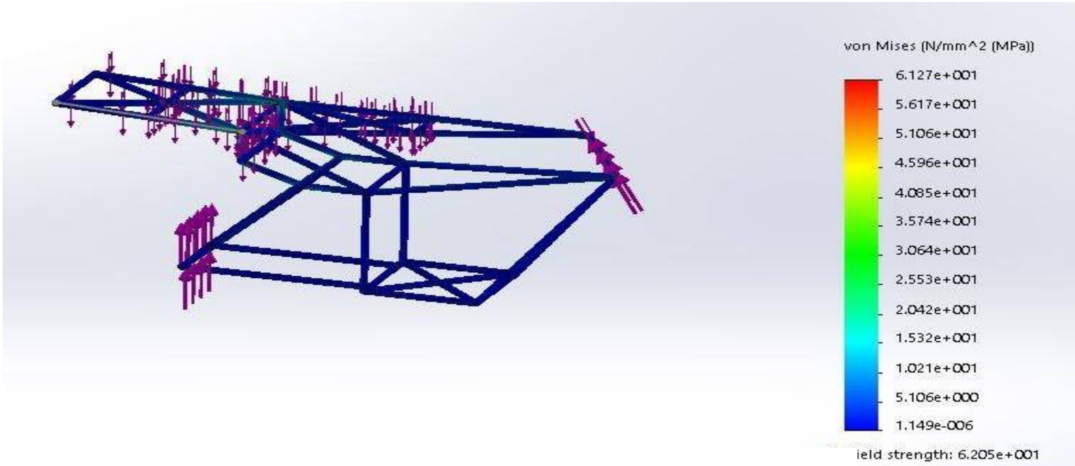

Figure 12: Preliminary Design Stress Analysis

The results of the stress analysis shown above depict that the preliminary design was able to evenly distribute the worst-case loading condition of the chassis frame. The max stress on the preliminary design was 61 MPa, experienced by the beam supporting the suspended backseat. The max stress experienced by the preliminary design was very close to the yield stress of the material chosen, Aluminum 6061-OS. The yield strength of Aluminum 6061-OS is given as 6.205 MPa, as shown by the figure 12. For the preliminary design we assumed that each element in the design had a cross-section area based on a cross-section given by a diameter of 20.1 mm, which is equivalent to a pipe with 1.5′′ outer diameter and 1.25′′ inner diameter.

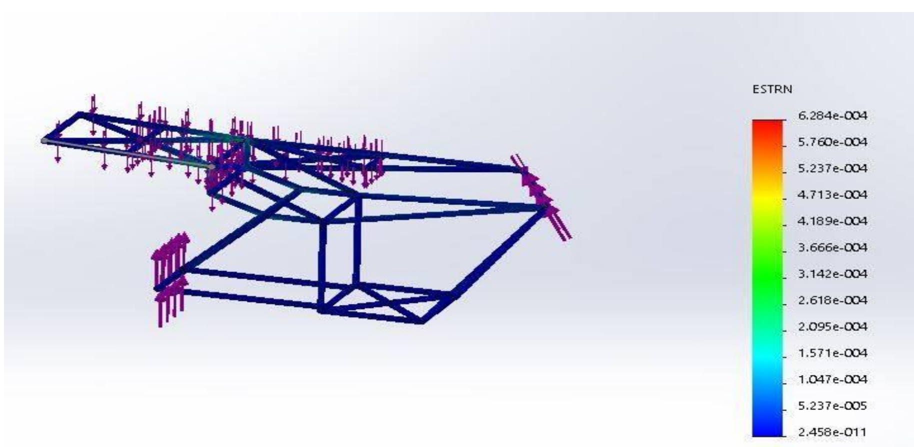

Figure 13: Preliminary Design Strain Analysis

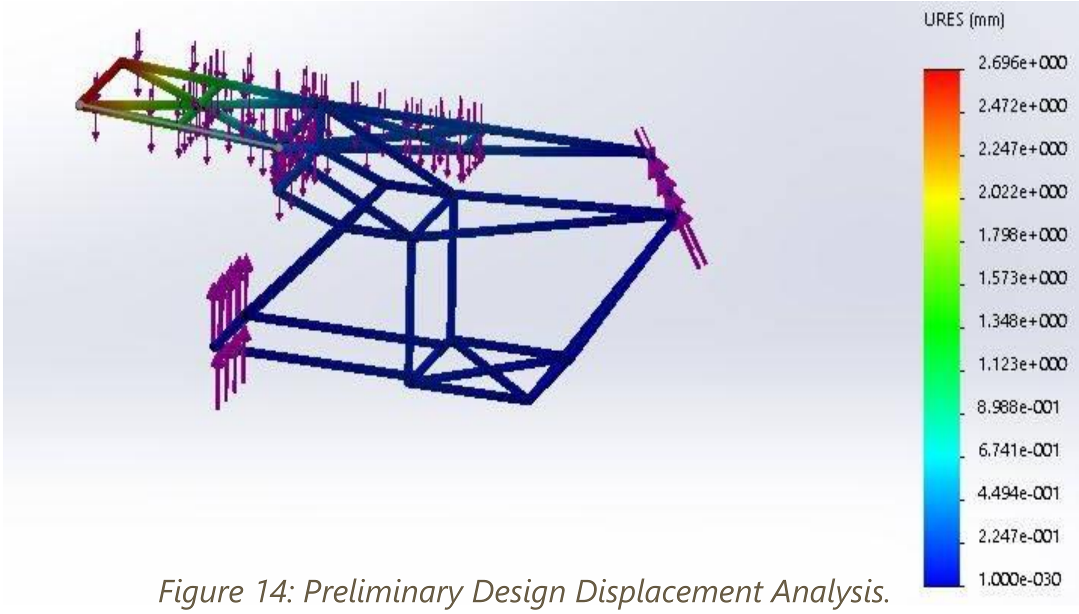

Figure 14: Preliminary Design Displacement Analysis.

Based on the FEA carried out on the preliminary design and the results depicted by figures 12, 13 and 14 we conclude our preliminary design is not safe. We reached this conclusion looking at the factor of safety of our design. Factor of safety of preliminary design is just over 1, which is not a preferred factor of safety in any mechanical structure. There was no restriction on the factor of safety in this project, but to ensure our product had a reasonable life span, a greater factor of safety was our personal requirement. Having a larger factor of safety, allows us to guarantee our investors that their investment will produce a reasonable rate of return on their investment. Moreover, analyzing figure 13 and 14, it can be noted that the maximum strain and deflection in our design is experienced by the backseat. The result is reasonable as our backseat was only support at one end. Therefore, based on the reasons mentioned, the preliminary design required modifications. The following section analyzes version 2 of our design, which improves upon the factor of safety.

StreamLiner – Final Design

The results obtained from FEA carried out on the preliminary design were used to finalize the chassis design for EleCycle's StreamLiner. The preliminary design was modified to increase the factor of safety of our design under the worse-case loading condition. Figure 15 is the CAD drawing of EleCycle's final chassis design.

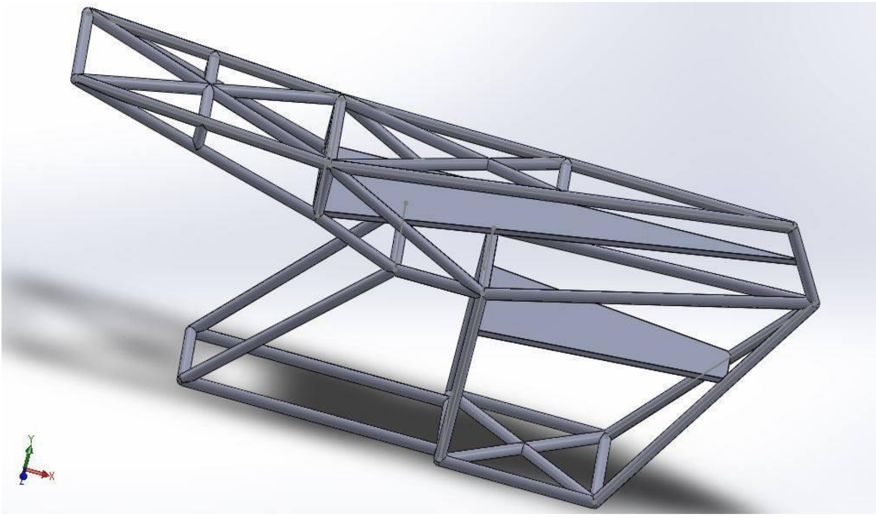

Figure 15: Streamliner –Final Design Chassis

The improvements made to the preliminary design are shown by figure 15. The main goal of modification was to increase the factor of safety. This objective was achieved by changing the material of the chassis and adding elements to support the backseat. Moreover, the improved design also considers the weight of the battery and motor, in addition to the worst-case loading condition. The battery used in the StreamLiner weighs 50 Kg. Each cell has a diameter of 18 mm diameter and a height of 65 mm. The battery has 1100 cells, the weight of battery is distributed over two planks, with majority of the load supported by the lower plank. The motor weighs 10 Kg and its weight is distributed over the lower diagonal beams – region below the lower plank. The material of the chassis frame was changed to Aluminum 6061-T6, which had a higher yield strength. The yield strength of Aluminum 6061-T6 is 275 MPa, an increase in yield stress by 213 MPa.

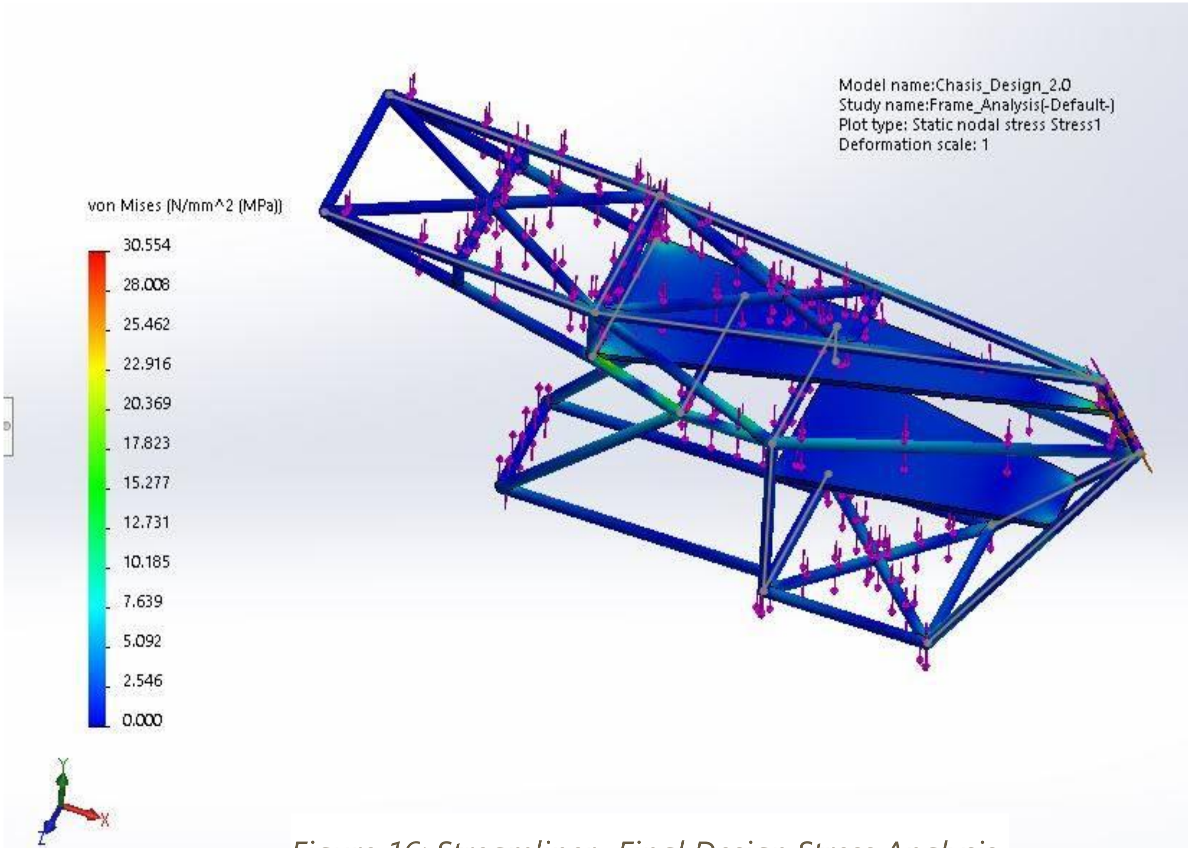

Figure 16: Streamliner -Final Design Stress Analysis

The results of the stress analysis shown above depict that the improved design was able to evenly distribute the new worst-case loading condition of the chassis frame. The new worst-case loading condition includes 2 riders, motor and battery weight. The max stress on the improved design was 30.6 MPa, experienced by the beam supporting the top battery plank. The max stress experienced by the improved chassis design is far from the yield stress of the material chosen, Aluminum 6061-T6. For the improved design we assumed that each element in the design had a cross-section area based on a cross-section given by a diameter of 20.1 mm, which is equivalent to a pipe with 1.5′′ outer diameter and 1.25′′ inner diameter.

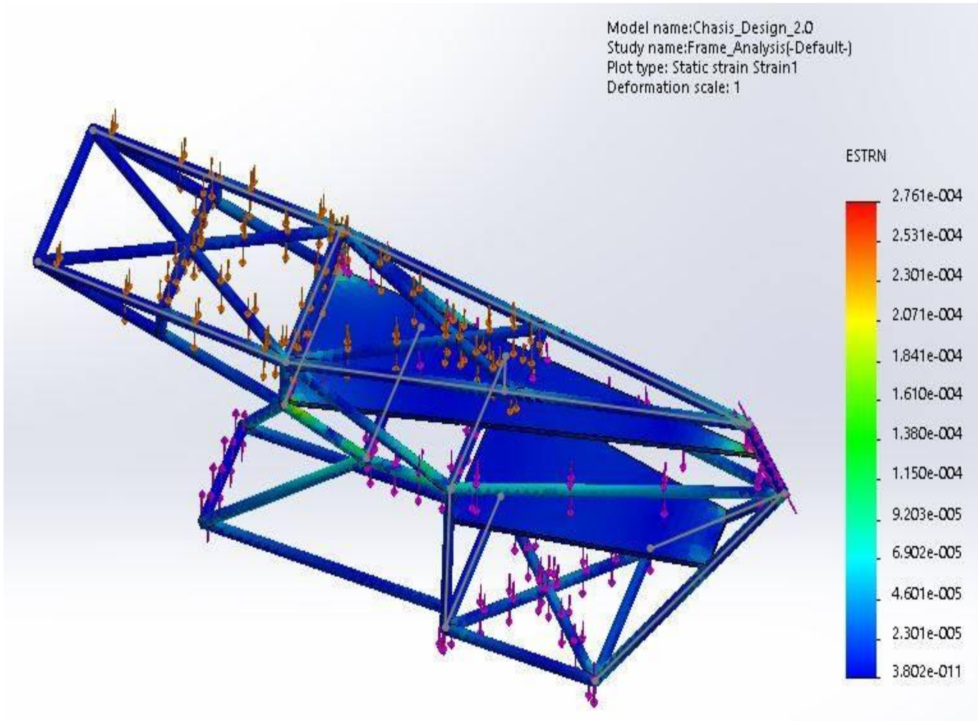

Figure 17: Streamliner -Final Design Strain Analysis

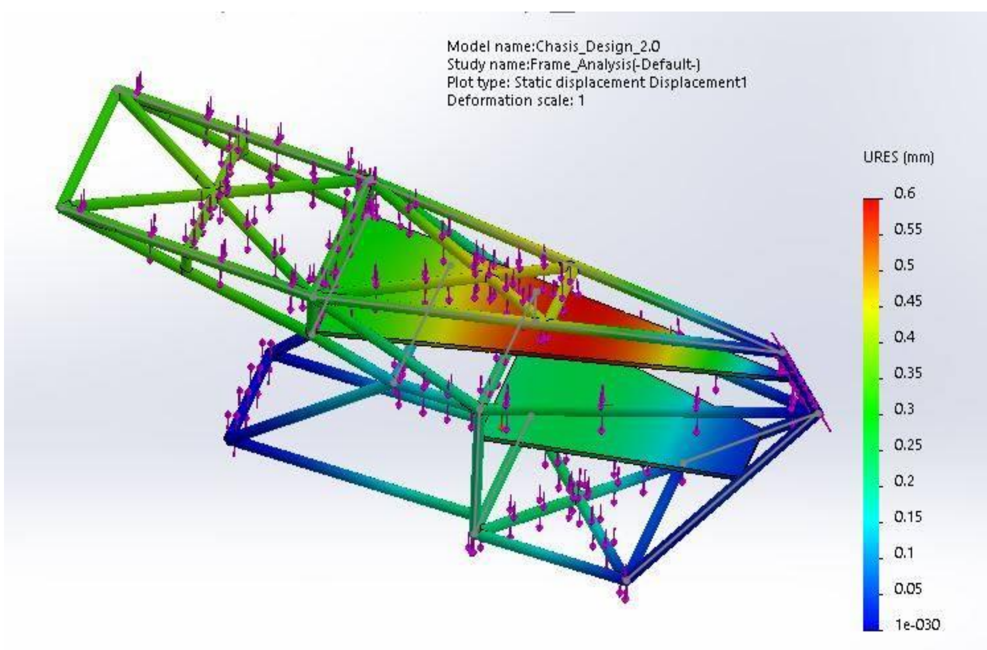

Figure 18: Streamliner -Final Design Deformation Analysis

Based on the FEA carried out on the improved design and the results depicted by figures 16, 17 and 18 we conclude our improved design has achieved structural safety. We reached this conclusion by looking at the factor of safety of our design. Factor of safety of improved design is 10. Recalling that there is no restriction on the factor of safety in this project, but our personal design goal was to obtain a factor of safety greater than 2, to ensure our product had a reasonable life span. Moreover, analyzing figure 17 and 18, it can be noted that the maximum strain and deflection in our design is no longer at the backseat – the preliminary chassis design issue. The maximum strain and deflection now occur at the top battery shelf due to our chosen shelf width of 10 mm. However, the maximum strain in the design is lower than the strain at the elastic limit of Aluminum 6061-T6. Therefore, based on the results and rational mentioned, the improved design has achieved over the desired factor of safety 3.

The finalized chassis frame in figure 15 experiences fluctuating cyclic loading. Therefore, it's customary to carry out a fatigue failure analysis to determine the safety of our frame. The fatigue failure analysis could easily be carried out by SolidWorks Simulation tool. However, due to the max stress in our frame being less than minimal stress considered by SolidWorks Fatigue Stress simulation tool, SolidWorks Simulation cannot be utilized to determine the safety of our design by considering cyclic loading. Therefore, hand calculations were carried out to carry out fatigue failure analysis. Namely, we employed the Goodman Method to determine the safety of our StreamLiner chassis frame by considering the average stress and actual stress amplitude of our frame design. The results of the hand calculations carried out are discussed in the following text, the hand calculations can be found in the Appendix A.

Fatigue Failure Analysis - StreamLiner

The Goodman method was utilized to determine the safety of our chassis design in this project. The Goodman method and the Stress analysis figure of the final chassis frame using FEA were used to determine the cross-section area of our pipes.

The hand calculations for our design safety and stress concentrations are included in Appendix A. Based off the results from the Goodman method, our chassis design is safe as the maximum stress experienced by the frame was less than the actual endurance limit of Aluminum 6061-T6, and the average stress experienced by the frame was less than the ultimate tensile strength of the material. The Goodman method plot for our design safety is shown below.

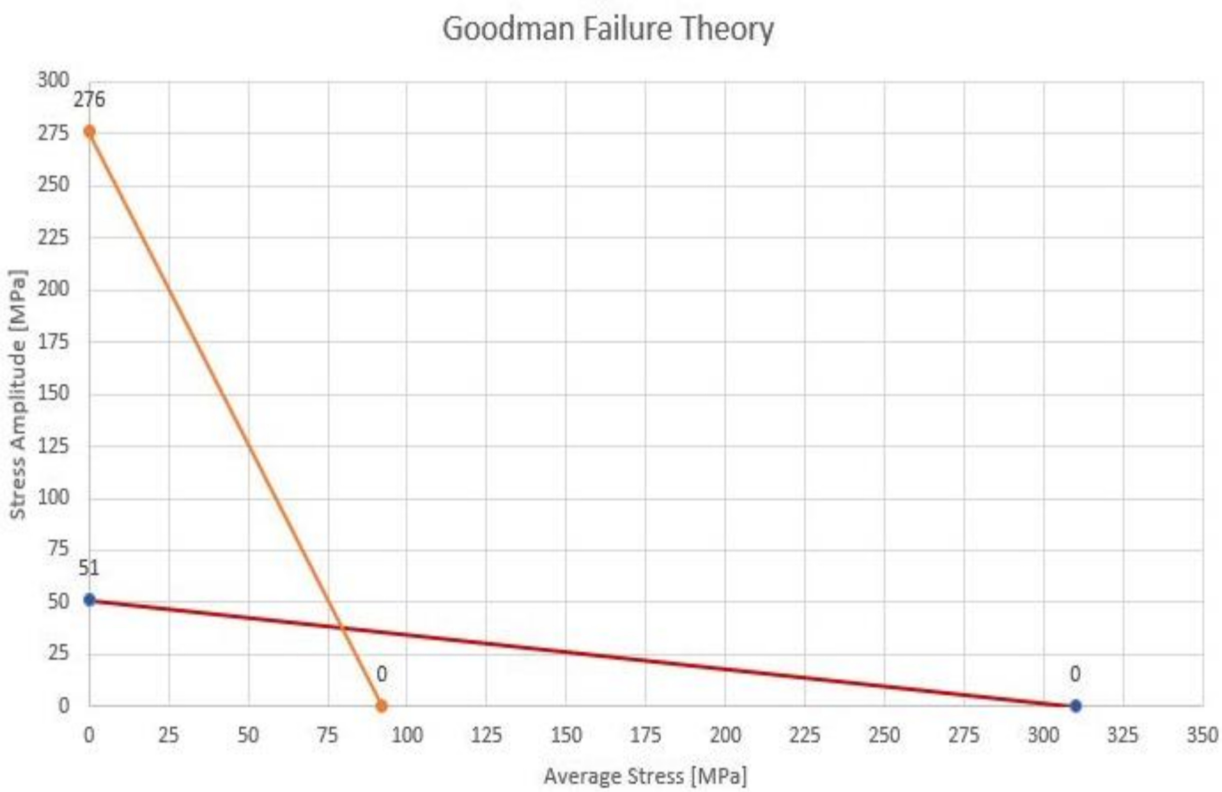

Figure 19: Goodman Failure Theory

The region enclosed by the two curves is the safest design. Hence, our design is safe as our stress amplitude and average stresses are as follows.

Stress amplitude = σ_a = 15.3 MPa < 51 MPa

Average Stress = σ_m = 15.3 MPa < 92 MPa

Where,

51 MPa = $S_n{}'$ = Actual Endurance Limit of our Frame.

$$92\text{MPa} = \frac{S_y}{K_t} = \frac{Yield\ Strength\ of\ Frame}{Stress\ Concentration\ of\ Frame}$$

In addition, the Goodman failure theory was also employed to determine the stress concentration of our chassis pipes. According to the Goodman method, the stress concentration in our frame design was less than 3.16. This suggested that using the stress concentration plots for different round shafts, the dimensions of our frame pipes can be selected provided the stress concentration was less than 3.16. The calculations for these conclusions are included in the Appendix A.

The actual endurance strength of the chassis frame was calculated as shown in the Appendix A. Due to lack of information about the properties of Aluminum 6061-T6 in the textbook, the parameters for endurance strength calculation were determined by using the textbook and some online resources. The sources are cited in the references and some of the justifications are as follows. For our material the material factor C_m was approximated using the given C_m table in the textbook for steel due to lack of sources. S_n was obtained from and online source, the website is cited in the references.

Material Selection

Using CES Edupack software we created a matrix that graphed viable materials for our bike design see Appendix B. From a list of material selected based on density, price, Fatigue Strength etc., aluminum alloys have properties which should be enough to endure the load. The choice of material for the chassis is 'Aluminum 6061 - T6'. The material has high strength and is very light which makes it a good choice for the trusses.

Material Properties	**Value**
Ultimate Tensile Strength	45000 psi
Elongation at Break	12% (D = 1/12 inch)
Modulus of Elasticity	10000 ksi
Fatigue Strength	14000 psi
Shear Strength	30000 psi

Table 6: Material Selection

Streamliner Final Assembly

The final motorcycle consists of the streamliner chassis design version 2.0 with a seat wheels and handlebars using screws and fasteners.

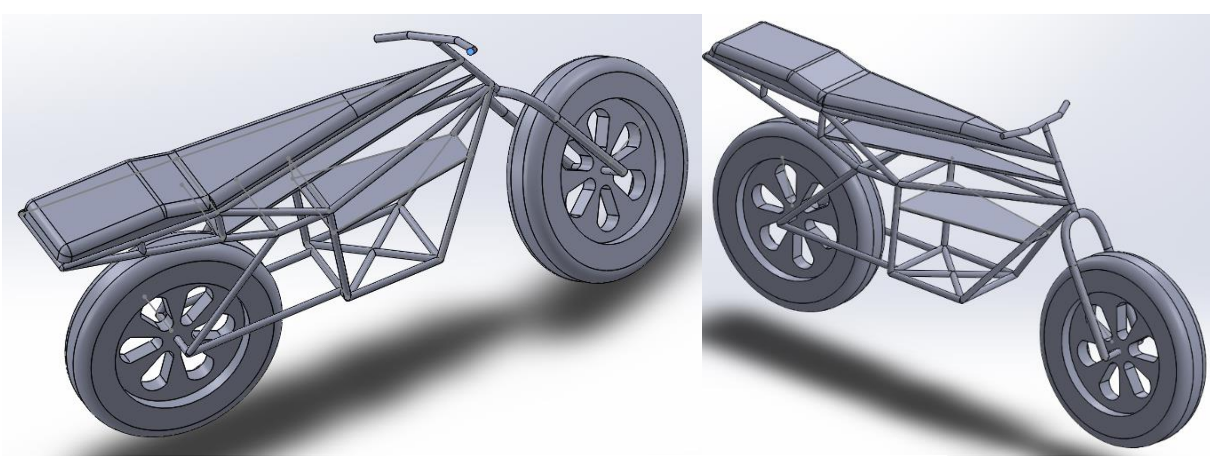

Figure 20: Final Streamliner Assembly

Conclusion

When considering how our team set out with a goal to design and build a motorcycle to meet our design goals, it seems we have surpassed expectations to the design of EleCycle's first ever electric motorcycle, Streamliner. This final design has gone through many iterations for it to be a viable option and live up to the daily wear and tear which ultimately result in various cyclic and impulse forces. The key design aspects we focused on are to create a motorcycle that would give you a days' worth of drivability using rechargeable batteries and an electric motor, whilst still being able to carry a maximum of two passengers. Providing all this in an affordable package with no hidden fees is what we have strived for.

When considering how well EleCycle has been designed there aren't many recommendations that can be given to its design. Thinking of general recommendations, we believe for our next iteration of streamliner we would like for it to be a highway capable motorcycle. Otherwise we believe EleCycle has presented its best design for an electric motorcycle.

References

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Appendix A- Fatigue Failure Calculations

③ Goodman & Gerber failure the

The failure theory is designed for cyclic fluctuating loading.

i.e. $\sigma_a \neq 0$ & $\sigma_m \neq 0$ ← your mean stress is NOT zero!

In this failure theory, it is assumed that we already know: S_n', S_u, S_y } from previous lecture!

for Goodman theory:

$$\frac{K_t\sigma_a}{S_n'} + \frac{\sigma_m}{S_u} < 1 \left(\text{or } \frac{1}{N}\right)$$

For Gerber criterion;

for Goodman theory:

$$\frac{K_t\sigma_a}{S_n'} + \frac{\sigma_m}{S_u} < 1 \left(\text{or } \frac{1}{N}\right)$$

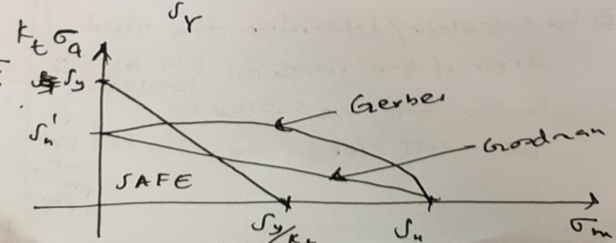
For Gerber criterion;

$$\frac{K_t N\sigma_a}{S_n'} + \left(\frac{N\sigma_m}{S_u}\right)^2 < 1$$

Prevent low cycle yielding:

$$\frac{K_t\sigma_{max}}{S_y} \text{ and } \frac{K_t\sigma_{min}}{S_y} < 1 \left(\frac{1}{N}\right)$$

$$\Rightarrow \frac{K_t(|\sigma_m| + \sigma_a)}{S_y} < 1$$



Failure theory ~~Form~~ Hand calculations for

↳ or used to determine the ~~two~~ different pipe x-sections that can provide the same max stress ~~at~~ as shown by the FEA analysis.

max stress based off the FEA analysis:

$\sigma_{max} = \cancel{310} \; 30.6 \text{ MPa}$ → For a pipe cross-section of

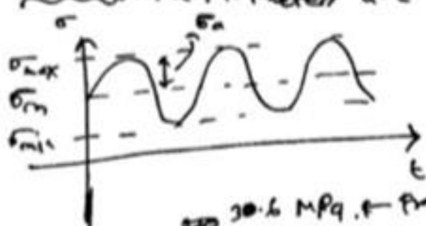
$\sigma_{ultimate} = 310 \text{ MPa}$

$\sigma_{yield} = 276 \text{ MPa}$.

For our material: Aluminum 6061-T6

$$\boxed{\text{Safety factor: } \hookrightarrow = \frac{310 \text{ MPa}}{30.6 \text{ MPa}} = 10 = N.}$$

We employ Goodman Failure theory to determine the stress concentration of design for cyclic fluctuating loading. The parameters are as follows:



~~310~~ 30.6 MPa ← from FEA!

$\sigma_{max} = \cancel{\frac{65 \text{ kg} \times 2 g}{A_{pipe}}} \; \cancel{\frac{130 \text{ kg} g}{A_{pipe}}}$

We assume worse case scenario of two people with weight of 65 kg each. Our FEA analysis has shown ~~that~~ that our design can stand far more than 65 kg. But we will use 65 kg/person for ~~the~~ an example calculation.

$\cancel{\sigma_{min} = \frac{65 g}{A_{pipe\ x\text{-}section}}}$; Minimum ~~Eqn~~ load. $= \sigma_{min} = 0$

$\therefore \sigma_m = \sigma_{average\ stress} = \frac{\sigma_{min} + \sigma_{max}}{2} = \cancel{\quad}$

$\sigma_a = \sigma_{max} - \sigma_{average}$ ~~...~~
$= 15.3 \text{ MPa}$.

↳ ~~Goodman failure theory.~~

~~$k_t \sigma_a$~~

$S_n' = S_n C_m C_{st} C_R C_s$

$S_n = 140 \text{ MPa}$ ← From same

$C_m = 0.5$;

$C_{st} = 1$;

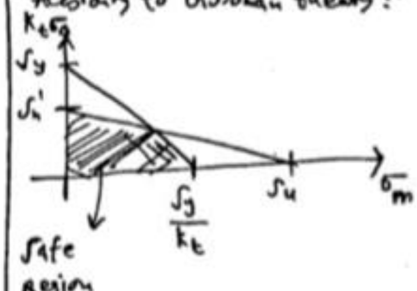
$C_R = 0.81$

$C_s = 0.9$

$\therefore S_n' = 51 \text{ MPa}$.

$S_y = 276 \text{ MPa}$
$S_u = 310 \text{ MPa}$

According to Goodman theory:



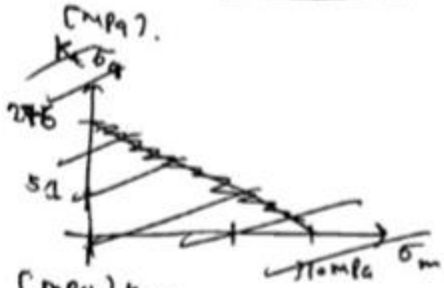
To calculate K_t:

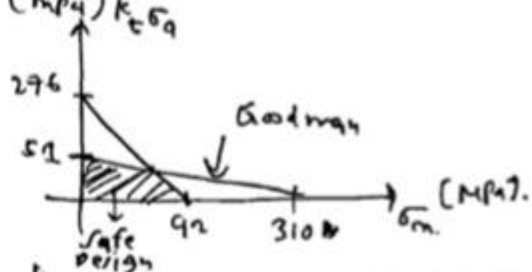
$$\frac{k_t \sigma_a}{S_n'} + \frac{\sigma_m}{S_u} < \cancel{\tfrac{1}{N}} \; 1$$

$$K_t < \left(\cancel{\tfrac{1}{N}} \; 1 - \frac{\sigma_m}{S_u}\right) \frac{S_n'}{\sigma_a}$$

$\therefore \boxed{K_t < \cancel{0.06} \; 3.16}$

~~K_t~~ ↓ ~~cross-section~~ stress-concentration of pipe x-~~section~~ cross-section!





$K_t\sigma_a \Rightarrow K_t = 3.00$ b/c $\boxed{K_t < 3.16}$

$\sigma_a = 15.3$ MPa

$\therefore K_t\sigma_a = 45.9$ MPa $<$ 51 MPa.

&

$\sigma_m = 15.3$ MPa $<$ 92 MPa

∴ our design falls within shaded region.

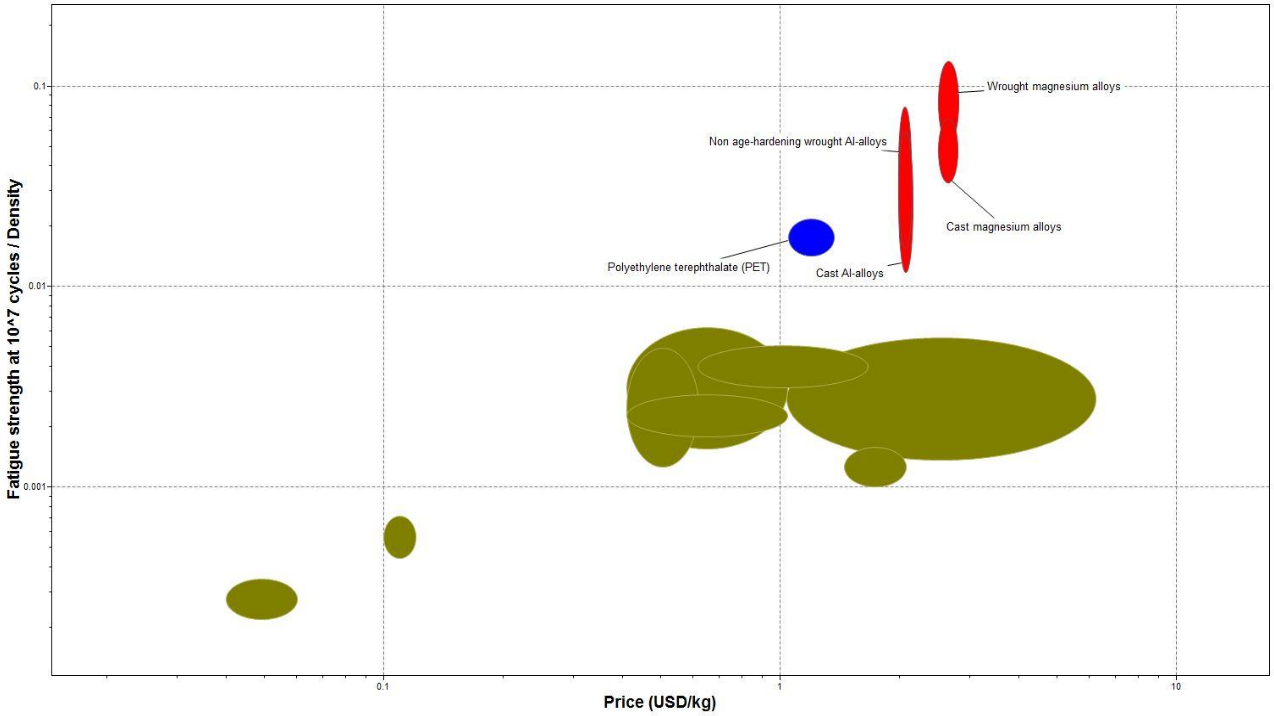
We can conclude that our design for the chassis is safe..

And we will ~~assume~~ take safety factor of 10.

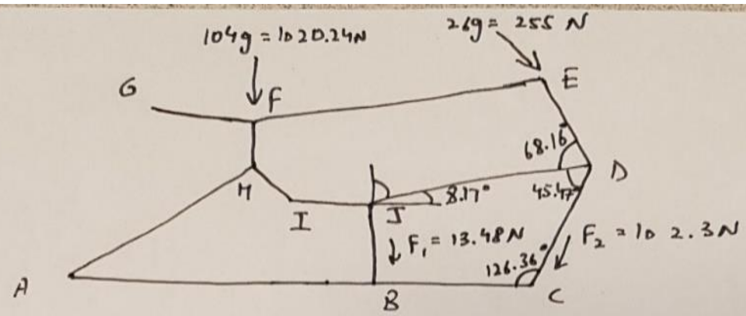
- Our $\overbrace{\text{stress concentration}}^{K_t}$ is going to be anything less than 3.16.

- Based on this stress-concentration inequality, we can use a wide range of cross-section areas of our pipe & ensure that the our design remains in the shaded safe region.

Appendix B- Material Selection (CES Edupack)

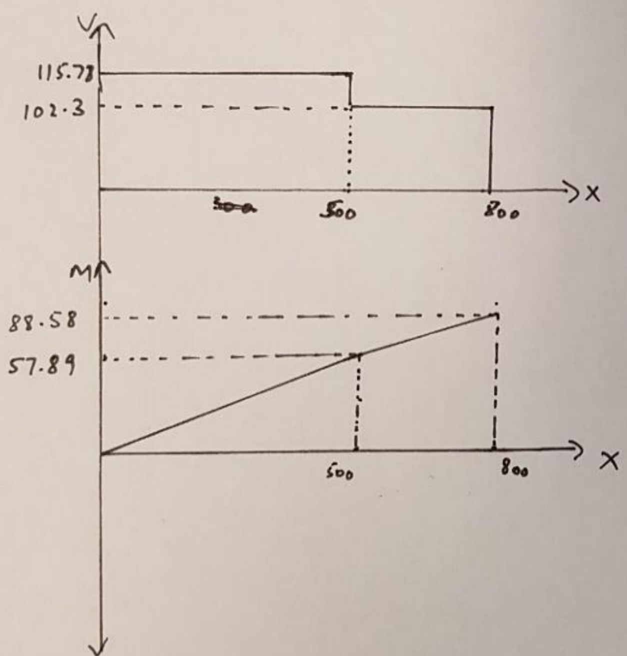


Appendix C- Stress Analysis



$$F_{A_x} = F_2 \cos(180 - 126.36) = 60.7\,N$$

$$F_{A_y} = F_1 + F_2 \sin(180 - 126.36) = 115.78\,N$$



$$\vec{F_2} = \vec{F}_{E \to D} \times \cos(180° - 68.16 - 45.47) = 102.3\,N$$

$$\vec{F}_{E-D} = 26g = 255\,N$$

$$\vec{F_1} = \vec{F}_{D \to J} \times \sin(8.17°) = (26g \times \cos(68.16°)) \times \sin(8.17°) = 13.48\,N$$