

GNG5140 Revised Prototype Analysis and Test Results

Assignment E Modular Ultralight eV Prototyping

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Abstract

UO Super mileage is a student organization at the University of Ottawa that competes in the highly regarded Shell Eco-Marathon program. The aim of the club is to design and build the most energy-efficient electric vehicle possible and to provide undergraduate and graduate students with the opportunity to enhance their engineering skills through hands-on experience. Over the years, the team has taken part in the prototype car category, which involves creating smaller vehicles that only require functional components and don't have any added features. However, more recently, they have stepped up to the urban concept category, where they face new design and production challenges such as optimizing the manufacturing process to create the chassis frame adapters. The process must be robust, economical and efficient in terms of material usage, among other important factors.

Our group, which is part of the Engineering Design course (GNG5140) at the University of Ottawa, will be providing support to the UO Super mileage club in selecting the most suitable manufacturing process for their vehicles. In this report, we begin by clearly defining the design problems and presenting some examples of existing solutions for reference. Additionally, we provide comprehensive technical information on the various manufacturing processes that will be evaluated and compared in order to determine which is the best fit for the club's needs in terms of design, mechanical requirements, and budget constraints.

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List of Acronyms

1 Introduction

The University of Ottawa's SAE Supermileage team has constantly worked to improve its energy-efficient automobiles. We have been tasked with finding alternate ways of spare part production that are cost effective, time efficient, and simple to learn. We are focused mostly on traditional manufacturing techniques, from which we will methodically seek inspiration and work towards the needs of our Super mileage team. We gathered public materials from multiple SAE Supermileage teams and determined the processes employed, such as water jet cutting, CNC machining, Additive fabrication, and casting. Some pieces must be extremely exact, and their production will be beyond the scope of this project. We had a thorough discussion with our team members and decided to focus more on casting processes (with possible future development) and, secondly, the process of additive manufacturing. We will be able to best develop a better solution and bring about a revolutionary change in low-cost manufacturing using the information gained from the collected resources.

2 Global Solution Concept

The following flow chart illustrate overall solution process.

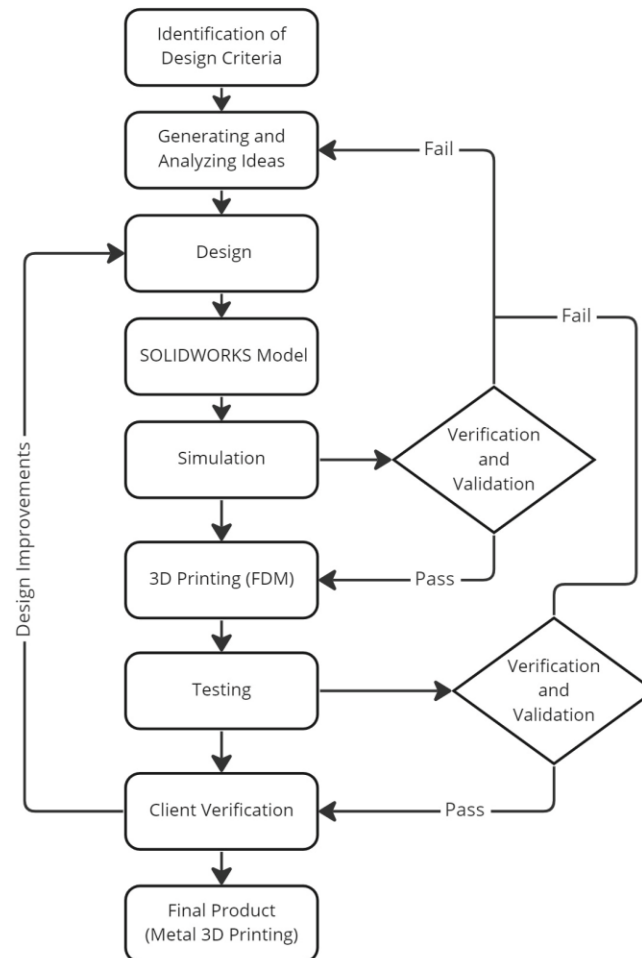


Figure 1: Global Design Concept

The design is the design of semi-permanent joints for the frame of a super-milage car.

The design concept provided us with the overall reduction in the weight of the joint and facilitate design of joint with mounting features. Hence, this design concept is good enough and doesn't require any changes in the design process.

But, in the manufacturing phase to reduce the overall project cost, the physical model is first printed using FDM 3D printer and then by metal 3D printer, this modification is presented correctly in the above flow chart.

3 Prototypes and Test

3.1 Revised Drawing

This is the drawing of the revised prototype, which will be used for metal 3D printing after verification with the client.

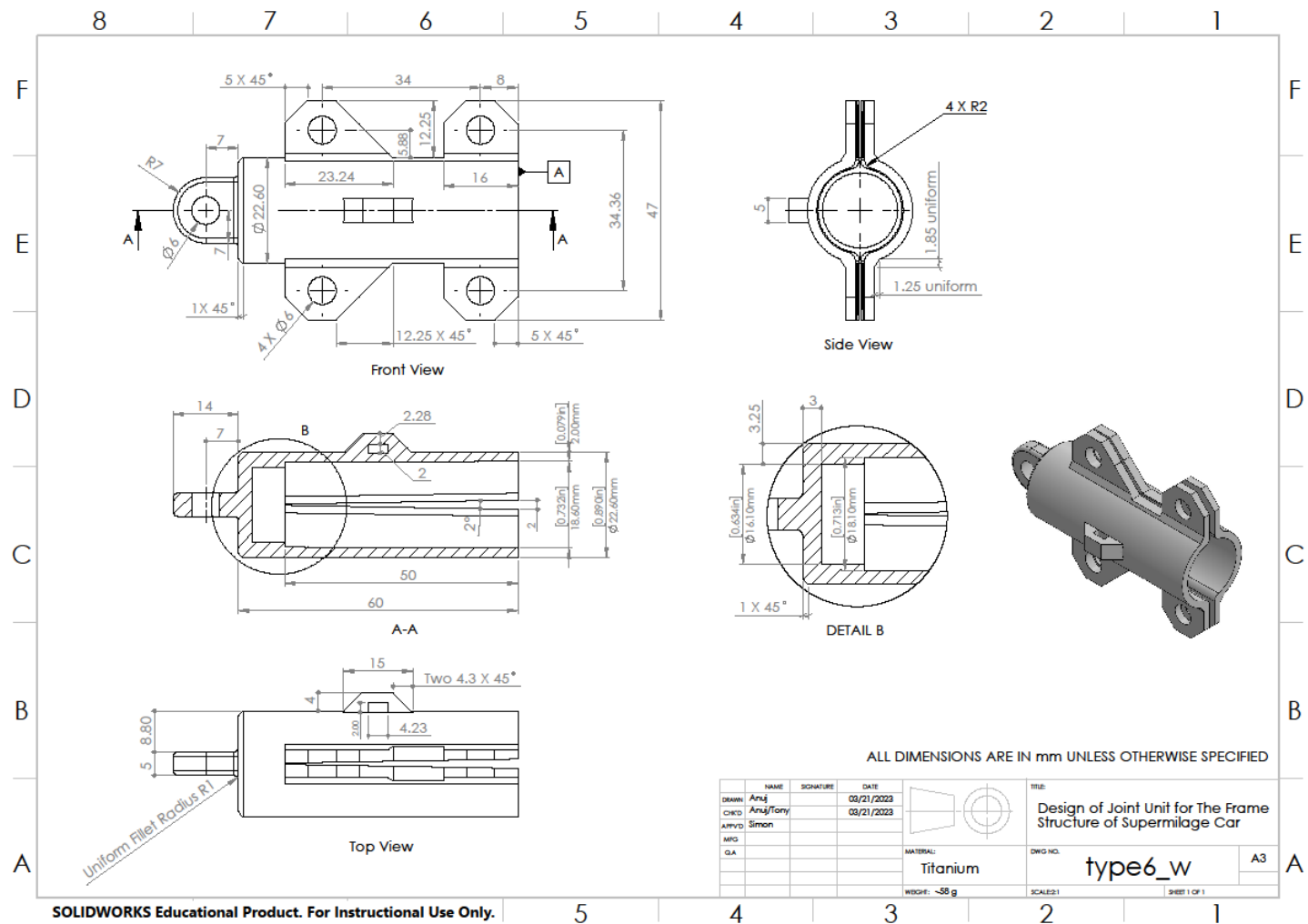


Figure 2: Revised Prototype Drawing

3.2 Revised Prototypes

Prototype shown in figure 3 is old prototype, while prototypes shown in figure 4 and figure 5 are the modified.

The purpose of this prototypes is to conduct the physical testing: Fit testing and Zip tie testing.

Following modification were done on the previous prototype.

1. To reduce the mass, topology analysis was performed on SOLIDWORKS, which resulted in reduction of approximately 30% mass and hence, the cost.
2. Also, to achieve uniformity we changed the hole of M8 to M5 (indicated below).
3. Reduction in the diameter as the diameter of the tubes used in the frame-based design is smaller than expected.
4. At the end, mounting feature is added in the unit, this difference can be seen in figure 3 and figure 4.

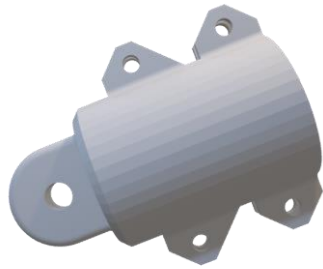


Figure 4: Prototype Deliverable D

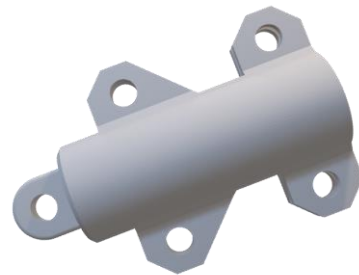


Figure 3: Prototype without Mounting Feature

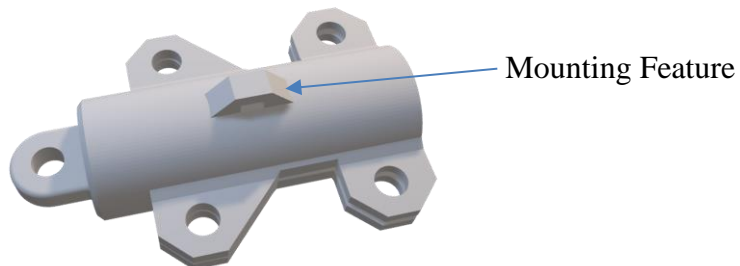


Figure 5: Prototype with Mounting Feature


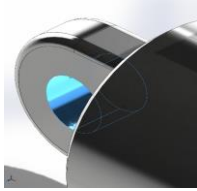
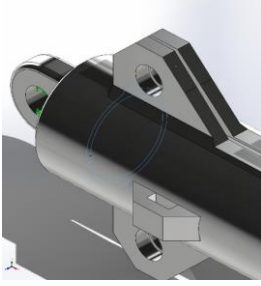
3.3 Testing

If the part doesn't deform or the stress is relatively small comparing to the material strength, then the part is considered pass the test, if the value is way off the strength, then it is failed the test in simulation.

3.3.1 Test 1

In the simulation, considering the worst-case scenario is that the impact load and the direct load are simultaneously acting on the joint, so we set the loading force as 7,000N (Appendix A).

Table 1: Revised Prototype Test 1: Material Properties and Constraints [1]

Model Reference	Properties
	<p>Name: TI64(3DP)</p> <p>Model type: Linear Elastic</p> <p>Isotropic</p> <p>Yield strength: 7.3e+08 N/m²</p> <p>Tensile strength: 8.45e+08 N/m²</p> <p>Elastic modulus: 1.048e+11 N/m²</p> <p>Poisson's ratio: 0.31</p> <p>Mass density: 4,318.06 kg/m³</p> <p>Shear modulus: 3.189e+08 N/m²</p>
	<p>Entities: 1 face(s)</p> <p>Type: Fixed Geometry</p>
	<p>Entities: 1 face(s)</p> <p>Type: Apply normal force</p> <p>Value: 7,000 N</p>

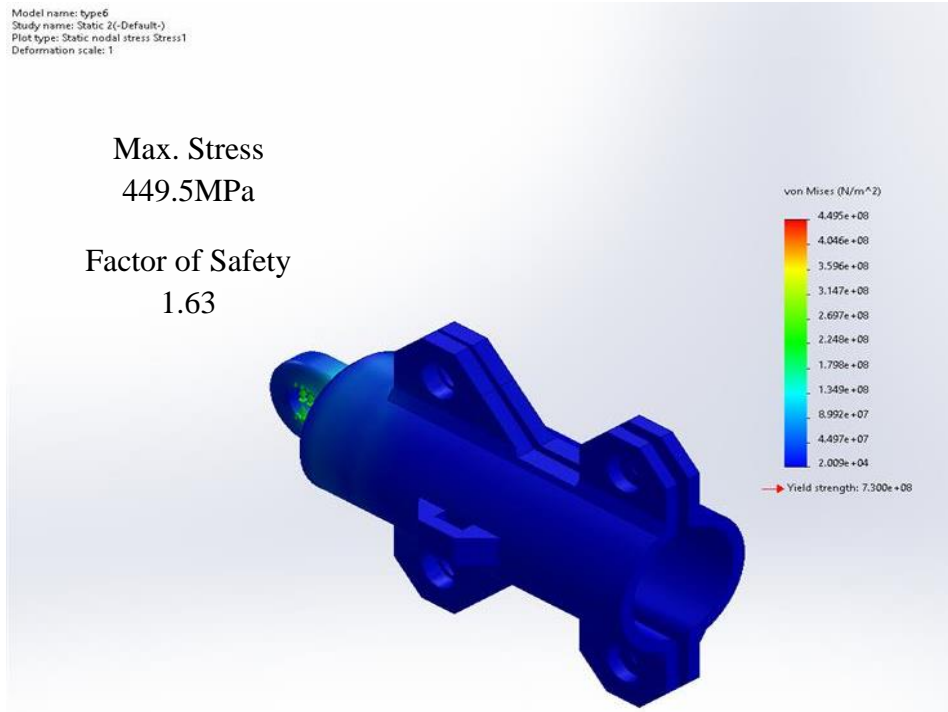


Figure 6: Revised Prototype - Stress Result

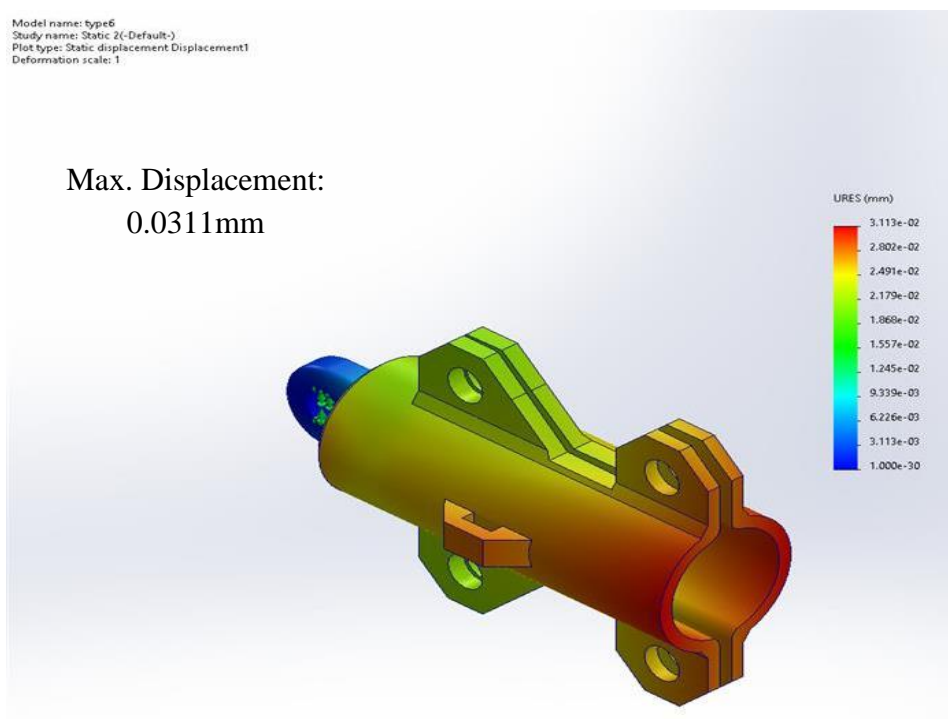
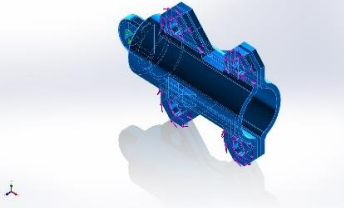
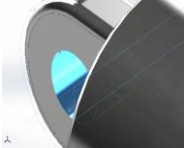



Figure 7: Revised Prototype - Displacement Result

3.3.2 Test 2

In the first iteration, we have applied the impact load and the direct load. For this next iteration tightening force [2] of bolt was considered to test the joint.

Table 2: Revised Prototype Test 2: Material Properties and Constraints [1]

Model Reference	Properties
	<p>Name: TI64(3DP)</p> <p>Model type: Linear Elastic Isotropic</p> <p>Yield strength: 7.3e+08 N/m²</p> <p>Tensile strength: 8.45e+08 N/m²</p> <p>Elastic modulus: 1.048e+11 N/m²</p> <p>Poisson's ratio: 0.31</p> <p>Mass density: 4,318.06 kg/m³</p> <p>Shear modulus: 3.189e+08 N/m²</p>
	<p>Entities: 2 face(s)</p> <p>Type: Fixed Geometry</p>
	<p>Entities: 4 face(s)</p> <p>Type: Apply torque</p> <p>Value: 7 N.m</p>

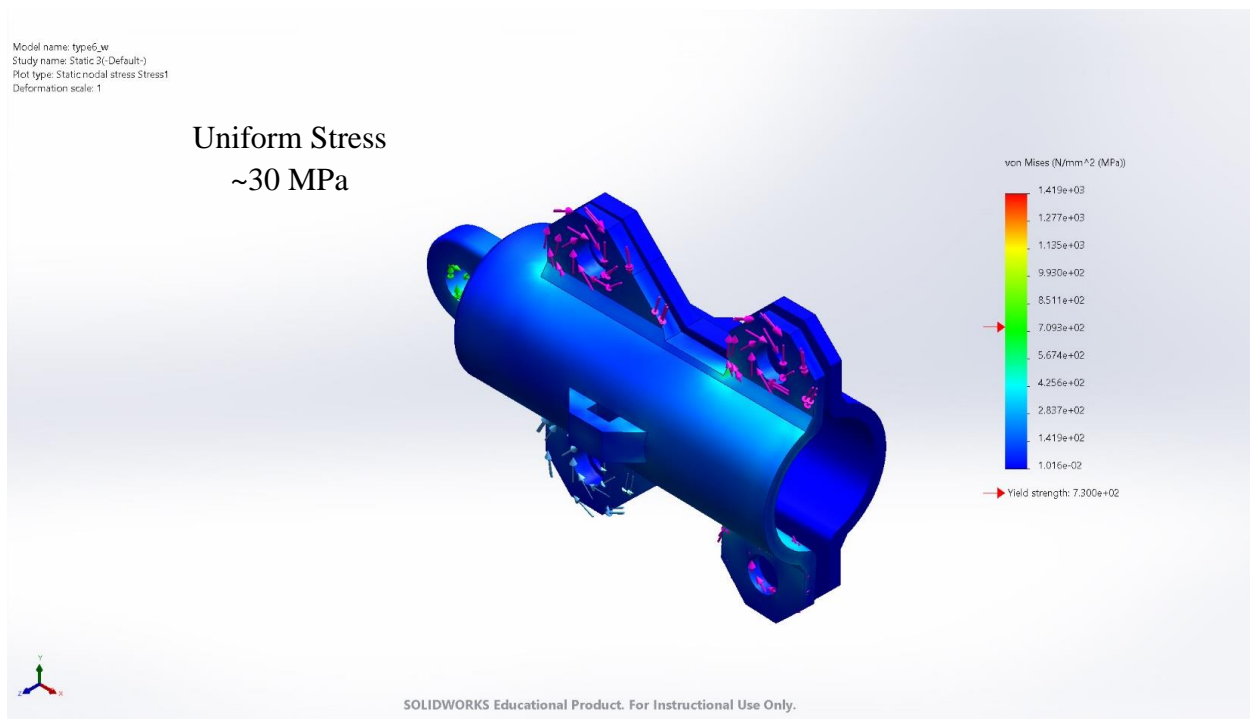


Figure 8: Modified Unit - Stress Result

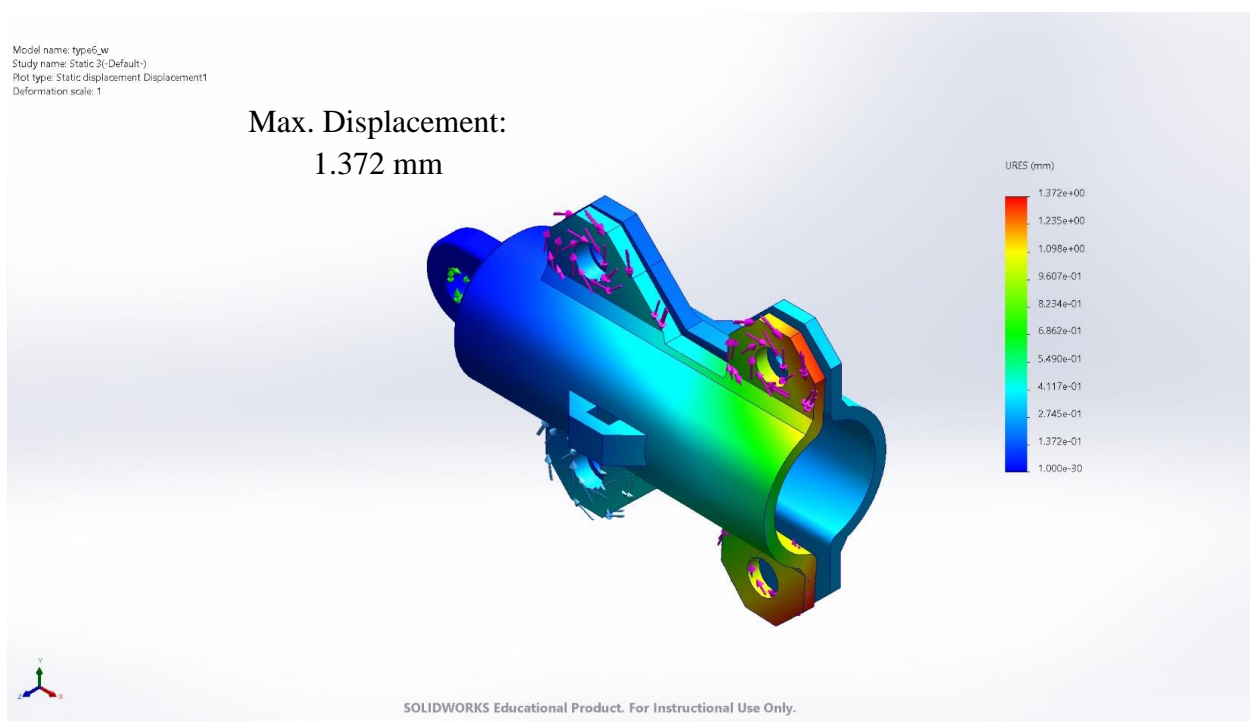


Figure 9: Modified Unit - Displacement Result

3.3.3 Fit testing

The whole idea was to estimate the fit by first creating the assembly of joint unit and tube without any bolts and nuts and then to pullout the tube from the unit.

Firstly, if the tube won't go inside the unit means the existing fit is interference fit. Secondly, if the tube is inserted and retracted easily without any force (force near to zero) then the existing fit is clearance fit.

During our testing, initially the tube was gone inside the unit easily, but at the end there was forced required to push it forward. And while pulling it out, the force required was more comparing to pushing force and hence, the fit is interference fit.

3.3.4 Zip Tie Testing

In this testing our goal was to establish that whether the zip tie will pass through the mounting features or not.

3.3.5 Comparison Between Expected and Actual Results

Table 3: Comparison Between Expected and Actual Result




















		Expected Result	Actual Result
1	Strength	> 580 MPa	780 MPa
2	Diameter of The Tube to be Join	1/2", 5/8"	1/2"
3	Max Speed	45 Km/h	Safe to Impact Loading
4	Weight of Vehicle	300 Kg	Safe to Direct Loading
5	Recommended Weight of Vehicle	100 Kg	Safe to Direct Loading
6	Maximum No of tubes at joint	< 8	Not done
7	Corrosion Resistance	✓	✓
8	Fit	Transition	✓
9	Zip Tie Testing	Zip pass through mounting feature	✓

3.4 Things remaining

1. Prototyping our design with 3D Metal Printer
 - a. Find appropriate apparatus to perform the test.
 - b. Record the result.
2. Perform pull test with the metal printed part.
 - a. Verifying the design with client.
 - b. Check if the design is printable or compatible with studio system 2.

4 Project Plan

Below is the updated project plan.

1	▼ Modular Ultralight eV Prototyping - A		 In Progress	11/01/2023	18/04/2023	
2	▼ 1. Initiation					
3	Team Contract	Anuj Shah	 Completed	11/01/2023	20/01/2023	10d
4	▼ 2. Planning					
5	2.1Setting up Project and Goals	Sina Ghazali	 Completed	24/01/2023	26/01/2023	3d
6	2.2Budget	Tony Tsang	 Completed	24/01/2023	26/02/2023	34d
7	2.3Communication Plan	Vishwadath Ayyappan	 Completed	20/01/2023	23/01/2023	4d
8	2.4Risk Management plan	Anuj Shah	 Completed	24/01/2023	27/01/2023	4d
9	2.5Project Plan(PD A)	Sina Ghazali	 Completed	13/01/2023	19/01/2023	7d
10	▼ 3.Execution					
11	> 3.3PD B	Tony Tsang	 Completed	24/01/2023	30/01/2023	
15	> 3.5 PD C	Sina Ghazali	 Completed	08/02/2023	16/02/2023	
19	> 3.6 PD D	Anuj Shah	 Completed			
34	3.7 Client meet 3	Anuj Shah	 Completed	08/03/2023	10/03/2023	
35	▼ 3.8 PD E	Vishwadath Ayyappan	 Completed	13/03/2023	22/03/2023	
36	> 3.8.1 Revised prototype analysis	Tony Tsang	 Completed	13/03/2023	20/03/2023	8d
38	3.8.2 Design and analysis reports	Vishwadath Ayyappan	 Completed	16/03/2023	22/03/2023	7d
39	Using 3D Metal Printer	Tony Tsang, Anuj Shah	 On Hold			
40	3.1 PD A:Client Meeting Preparation	Anuj Shah	 Completed	16/01/2023	18/01/2023	3d
41	3.2Client Meet1	Vishwadath Ayyappan	 Completed	24/01/2023	24/01/2023	1d
42	3.4 Client meet 2	Anuj Shah	 Completed	16/02/2023	16/02/2023	1d
43	3.9 PD F: Final Project Presentation	Tony Tsang, Anuj Shah	 New		29/03/2023	

5 Conclusion and Recommendations

The report provides the details about the Revised prototype and the simulation results of the same.

The following conclusion and recommendation are drawn from the results,

1. In the first test our design is passed with the factor of safety of 1.63.
2. In the second test, we have applied the tightening torque and observed that the uniform stress is acting on the part with value of around 3.147×10^{-2} MPa, which is very less than the yield strength of titanium.
3. Also, there is an 8.6×10^3 MPa value but that is just a worst-case scenario which will not act regularly. It is occurring at the place where we are clamping the part with bolts and nuts. So, It will not affect the performance of the part.

6 Bibliography

- [1] "Desktop Metal," [Online]. Available: <https://www.desktopmetal.com/uploads/BMD-MDS-Ti64-210803>.
- [2] "The Engineering ToolBox," [Online]. Available: https://www.engineeringtoolbox.com/bolt-torque-load-calculator-d_2065.html.

7 Appendix

Direct loading

Weight 300Kg

Gravity takes 10

And we take half as a safety measure.

Direct loading

$$\begin{aligned}F_{direct} &= mg \\m &= 300 \text{ kg} \\g &= 10 \text{ ms}^2 \\F_{direct} &= \frac{300 \times 10}{2} \\F_{direct} &= 1,500 \text{ N}\end{aligned}$$

Impact

45km/h- to 5 km/h in to sec

Weight is 300 including driver

$$\begin{aligned}F_{impact} &= m \frac{v - u}{t} \\m &= 300 \text{ kg} \\v &= 45 \text{ km/h} \\u &= 10 \text{ km/h} \\t &= 2 \text{ s} \\F_{impact} &= 300 \frac{45 - 10}{2} \\F_{impact} &= 5250 \text{ N} \\F_{total} &= F_{direct} + F_{impact} \\F_{total} &= 6750 \text{ N} \approx 7000 \text{ N}\end{aligned}$$