GNG5140 Design Research Report

Assignment B
Modular Ultralight eV Prototyping

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Abstract

UO Supermileage 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 Supermileage 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

Acronym	Definition
SAE	Society of Automotive Engineers
CNC	Computer numerical control
CAD	Computer-aided design

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 Design status review

2.1 Review existing user manuals and prototyping

There are several methods used for Modular Ultralight eV Prototyping, some of the most common methods include:

Modular Design: Breaking down the design of the prototype into smaller, interchangeable components or modules that can be easily tested and modified.

Rapid Prototyping: Using technologies such as 3D printing, CNC machining, or vacuum casting to quickly create physical prototypes.

Simulation and Modeling: Using computer-aided design (CAD) software to create virtual prototypes and simulate their performance in real-world conditions.

Material Selection: Choosing the right materials for the prototype, such as lightweight composites or advanced plastics, to optimize its performance and reduce weight.

Testing and Validation: Subjecting the prototype to a variety of tests to validate its performance and identify any potential issues.

Iterative Development: Continuously refining and improving the prototype through multiple rounds of testing and modification.

These methods can be used in combination to create a successful Modular Ultralight eV prototype, and the specific methods used may vary depending on the requirements of the project and the expertise of the development team.

2.2 Project Risk

Project risk is an inherent part of any engineering or design project, and Modular Ultralight eV Prototyping is no exception. Some of the common risks associated with this type of project include:

Technical Risk: The risk that the design or technology being used may not perform as expected or may be too complex to implement.

Schedule Risk: The risk that the project may take longer to complete than expected, leading to delays or cost overruns.

Cost Risk: The risk that the project may cost more than budgeted, either due to unexpected expenses or changes in scope.

Material Risk: The risk that the materials chosen for the prototype may not be suitable for the intended application, or may not be available in the required quantities.

Testing Risk: The risk that the prototype may not perform as expected during testing, leading to the need for additional design modifications.

Regulatory Risk: The risk that the prototype may not meet regulatory requirements, leading to additional costs and delays in bringing the product to market.

To mitigate these risks, it's important to have a thorough understanding of the project requirements, to carefully plan and manage the project schedule, and to have contingency plans in place in case of unexpected issues. Regular risk assessments should also be performed throughout the project to identify and address any potential risks as they arise.

3 Determine needs

Determining the needs for a Modular Ultralight eV Prototyping project involves several steps, including:

Define the project scope: Clearly define the goals and objectives of the project, including any specific requirements or constraints.

Conduct market research: Research the target market to understand the needs and preferences of potential customers, and to identify any competitive products or technologies.

Gather technical data: Gather data on the technical requirements and performance characteristics of the prototype, such as weight, power, and range.

Identify stakeholders: Identify the key stakeholders in the project, including project managers, engineers, suppliers, and potential customers, and engage them in the needs-determination process.

Assess risks and constraints: Assess the potential risks and constraints associated with the project, including technical, schedule, and budget risks, and develop contingency plans to address them.

Develop a project plan: Based on the needs determined in the previous steps, develop a detailed project plan that outlines the scope, schedule, budget, and resources required for the project.

By following these steps, you can ensure that the needs for your Modular Ultralight eV Prototyping project are well defined, and that the project is well-positioned for success.

Table 1 : Customer Need

	Needs	**Importance**
1	The joint should be 3D printed.	4
2	The joints should have features to accommodate different mountings. (Like zip tie mount, threaded holes, latches for the future body panel)	5
3	The joints facilitate easy maintenance and repair of chassis.	4
4	The joints have to be versatile enough to be used for E-bike and super-milage car.	3
5	The joints are affordable.	2
6	The joints shouldn’t be affected by working environment.	4
7	The joints weight is as low as possible	5
8	The joints are designed by considering mass manufacturing aspects.	1
9	The joints material and manufacturing process are in the direction of reducing carbon footprint.	3

4 Specify the metrics

Developing a list of critical metrics for measuring the performance of Modular Ultralight eV solutions is an important step in ensuring the success of the project.

4.1 list of critical metrics

1. Define the project goals: Clearly define the goals and objectives of the project, including any specific performance requirements or constraints.

2. Identify key performance indicators (KPIs): Based on the project goals, identify the key performance indicators (KPIs) that will be used to measure the performance of the prototype.

3. Choose relevant metrics: Choose metrics that are relevant to the KPIs and provide meaningful information about the performance of the prototype.

4. Establish a baseline: Establish a baseline for each metric by measuring the current performance of existing solutions or by defining the desired performance for the new solution.

5. Monitor performance: Regularly monitor the performance of the prototype using the chosen metrics to track progress and identify any areas for improvement.

Table 2 : Metrics

Metrics	Needs		Importance	Units
1	2,4,6	Strength	5	N/mm2
2	4,6	Impact Resistance	4	N/mm2
3	7	Total Mass	5	Kg
4	5,1	Cost	3	$
5	2,4	Maximum Speed of vehicle	4	Km/h
6	4,3	No. of tubes that need to be joined.	5	No.
7	4,3	Diameters of tubes	5	mm

The reasons for using critical metrics in Modular Ultralight eV Prototyping include:

1. Improved decision-making: By measuring performance using relevant metrics, you can make informed decisions about the design, development, and testing of the prototype.

2. Better visibility: Using metrics provides visibility into the performance of the prototype, allowing you to quickly identify any issues or areas for improvement.

3. Increased efficiency: By tracking performance using metrics, you can optimize the design and development process, reducing time and resources needed to bring the product to market.

4. Improved communication: By using a common set of metrics, you can ensure that everyone involved in the project is using the same language and has a shared understanding of the project's performance.

5. Increased accountability: By using metrics to measure performance, you can hold all project stakeholders accountable for their actions and decisions, leading to better outcomes for the project.

4.2 Areas for improvement

There are several areas for improvement that can be identified by monitoring the performance of a Modular Ultralight eV prototype using critical metrics. Some of these areas include:

Design: The design of the prototype may not meet the performance requirements or may be too complex to manufacture, leading to improvements in the design.

Materials: The materials chosen for the prototype may not be suitable for the intended application, leading to the need for alternative materials.

Manufacturing: The manufacturing process may be inefficient or not cost-effective, leading to improvements in the manufacturing process.

Testing: The prototype may not perform as expected during testing, leading to the need for additional design modifications or improved testing procedures.

Regulatory compliance: The prototype may not meet regulatory requirements, leading to additional costs and delays in bringing the product to market.

User experience: The prototype may not meet the needs and preferences of potential customers, leading to improvements in the design and user experience.

By monitoring performance and identifying areas for improvement, you can optimize the design, development, and testing of the Modular Ultralight eV prototype, reducing costs, and improving the overall quality of the product.

5 technical and user benchmarking

#Metrics	Needs	Metrics	Importance	Units	Dragonplate	leevalley	Kesoto
1	2,4,6	Strength	5	N/mm2	Aluminum 310	PVC 52	316SS 580
					Plastic56-60	-	-
2	4,6	Impact Resistance	4	N/mm2	276	8	240
3	7	Total Mass	5	Kg	0.5	0.2	0.8
4	5,1	Cost	3	$	22	20	17
5	2,4	Maximum Speed of vehicle	4	Km/h	<100	<90	<80
6	4,3	No. of tubes that need to be joined.	5	No.	7	6	6
7	4,3	Diameters of tubes	5	mm	3	4	3

6 Marginal and Ideal Values

#Metrics	Needs	Metrics	Importance	Units	Marginal value	Ideal value
1	2,4,6	Strength	5	N/mm2	>580	>840
2	4,6	Impact Resistance	4	N/mm2	>240	>700
3	7	Total Mass	5	Kg	<0.8	0.2
4	5,1	Cost	3	$	15-25	17-20
5	2,4	Maximum Speed of vehicle	4	Km/h	<80	<100
6	4,3	No. of tubes that need to be joined.	5	No.	<7	6
7	4,3	Diameters of tubes	5	mm	3-4	3

7 Final Specifications

#Metrics	Needs	Metrics	Units	Value
1	2,4,6	Strength	N/mm2	>700
2	4,6	Impact Resistance	N/mm2	>270
3	7	Total Mass	Kg	<0.65
4	5,1	Cost	$	<25
5	2,4	Maximum Speed of vehicle	Km/h	<90
6	4,3	No. of tubes that need to be joined.	No.	>6
7	4,3	Diameters of tubes	mm	3-4

8 Future prototype testing plan

1. Define the objective: Clearly define the objective of the test and what you want to achieve from it. This objective could be to determine the strength, durability, and performance of the joint design under different loads and conditions while also reducing the overall weight of the vehicle.
2. Select the test method: Based on the objective, select the appropriate test method. This could be a fatigue test, tensile test, or a combination of both. In this case, it might be appropriate to perform both fatigue and tensile tests to evaluate the joints' performance over time and under varying loads.
3. Prepare the test setup: Set up the test apparatus, including the load application system, data acquisition system, and instrumentation to measure the response of the joints under load. Ensure that the test setup accurately simulates real-world loading conditions.
4. Conduct a pilot test: Perform a pilot test to verify the setup and ensure that the measurements are accurate. This test should involve applying loads to the joint and verifying that the measurements match the expected results.
5. Perform the fatigue tests: Conduct fatigue tests on the prototype using the selected test method and instrumentation. Apply cyclic loads to the joint and collect data on the response of the joints under different loads and conditions. Evaluate the joints' performance over time and determine their fatigue life.
6. Perform the tensile tests: Conduct tensile tests on the prototype using the selected test method and instrumentation. Apply a tensile load to the joint and collect data on the response of the joint under load. Evaluate the joints' performance under tension and determine their maximum load-carrying capacity.
7. Weigh the prototype: Weigh the entire prototype after the tests are completed to determine the overall weight of the vehicle with the new joint design.
8. Analyze the results: Analyze the data collected during the tests to evaluate the performance of the joint design. Compare the results with the design specifications and identify any areas for improvement. Evaluate the reduction in weight achieved with the new joint design compared to the original welded joint design.
9. Report the findings: Prepare a report summarizing the findings of the tests and make recommendations for improvements to the joint design based on the results.
10. Implement the improvements: Based on the findings, make any necessary changes to the joint design and conduct further testing to verify the improvements.

Methods:

1. Tensile testing: Conduct tensile testing on the prototype to evaluate its performance under tension. Compare the maximum load-carrying capacity of the prototype to the target specification and determine if it meets the desired requirements.
2. Fatigue testing: Conduct fatigue testing on the prototype to evaluate its performance over time and under cyclic loads. Compare the fatigue life of the prototype to the target specification and determine if it meets the desired requirements.
3. Physical inspection: Physically inspect the prototype and evaluate the appearance and quality of the joints. Compare the joints' appearance and quality to the target specification and determine if they meet the desired requirements.
4. Finite element analysis (FEA): Use FEA software to simulate the performance of the prototype under different loads and conditions. Compare the results of the simulation to the target specification and determine if the prototype meets the desired requirements.
5. Testing with real-world loads: Test the prototype with real-world loads and conditions to evaluate its performance in actual use. Compare the performance of the prototype to the target specification and determine if it meets the desired requirements.
6. Comparison with previous prototypes or existing products: Compare the performance of the prototype with previous prototypes or existing products that have similar joint designs. Evaluate the performance of the prototype in comparison to the other designs and determine if it meets the desired requirements.
7. Customer feedback: Collect customer feedback on the prototype and compare it to the target specifications and performance requirements. Evaluate customer feedback to determine if the prototype meets the desired requirements.

The most optimal method for evaluating the performance of an electric vehicle (EV) frame prototype and comparing it to the target specifications and performance requirements will depend on several factors, including the type of joint design, the desired outcome, and available resources. However, a combination of methods is often recommended to provide a comprehensive evaluation of the prototype.

In general, finite element analysis (FEA) and testing with real-world loads are often considered the most optimal methods for evaluating the performance of an EV frame prototype. FEA provides a numerical simulation of the prototype's performance under different loads and conditions, allowing you to identify areas for improvement before conducting physical testing. Testing with real-world loads provides a more accurate evaluation of the prototype's performance in actual use and can confirm the results of the FEA simulation.

Tensile testing and fatigue testing are also important methods for evaluating the strength and durability of the joint design. Physical inspection can be used to evaluate the quality of the joints and ensure that they meet the desired appearance requirements. Customer feedback can provide valuable insight into the real-world performance of the prototype and help identify areas for improvement.

In summary, the most optimal method for evaluating the performance of an EV frame prototype will depend on the specific requirements of the project, but a combination of FEA, real-world testing, tensile testing, fatigue testing, physical inspection, and customer feedback is often recommended to provide a comprehensive evaluation of the prototype's performance.

9 Conclusions and Recommendations for Future Work

In conclusion, casting has been a widely used process for many years, but our goal is to find ways to reduce costs while maintaining the quality of the final product. At the same time, we are exploring the relatively new field of additive manufacturing, which offers a range of implementation methods. By investigating both casting and additive manufacturing methods, we hope to determine the most suitable method based on specific metrics and customer needs.

10 Bibliography