Design Proposal for MIME Capstone Design 2018-19
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Team # 122

Design and Manufacturing of an Urban Concept Vehicle Body for the Shell Eco-Marathon

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1. Project Scope

The American Society of Mechanical Engineers (ASME) at Oregon State University (OSU) has requested a new body to be designed and manufactured to go on their Urban Concept vehicle, which will compete in the Shell Eco-marathon [3] in April 2020. The new design will be made out of carbon fiber, providing the team with a lightweight, sleek, and strong body. This project is being requested so that ASME may improve the functionality of the Urban Concept Vehicle in the form of improved aerodynamics, a lightweight, aesthetically pleasing design, and a body that can be remade should the need arise. The design team will meet these needs and create a finished project that will be a strong competitor in the Shell Eco-Marathon. Along with the project, there may be setbacks caused by outside sources that the team needs to be aware of, primarily in the form of the ASME team making any sort of modifications to the vehicle that they have not yet outlined or planned.

2. Research and Previous Solutions

In terms of researching, the team has two main areas they are focusing on: the shape of the body and the manufacturing processes of carbon fiber. The primary determinant for the body shape will come in the form of aerodynamic efficiency. As well as the shape of the body, a deep understanding of manufacturing carbon fiber is necessary. For this, it is vital to look at what previously mentioned shapes are manufacturable with the materials at hand, as well as ensure the body meets other constraints outlined by either the ASME team or the Shell Eco-marathon rules. It is also important to know how to properly construct carbon fiber molds, lay the carbon fiber on these molds, and then separate the mold from the completed body.

Another key component of research is the evaluation of previous solutions to a similar problem. In the case of manufacturing a car body from carbon fiber, ASME currently has a vehicle competing in the prototype division of the Shell Eco-marathon [2], and Global Formula Racing (GFR) [1] has a wealth of experience in manufacturing with carbon fiber. As well as this, a wealth of information is on the internet in the form of classes and educational videos to learn the basics of manufacturing carbon fiber components, one example utilizing wood to create a structural lattice that then allows them to create a mold [4], similar to how team 122 plans to create a mold.

3. Stakeholders and Team

The success of this project is important for the OSU ASME team, the primary customer, to compete with their current Urban Concept vehicle. The team advisor, Dr. Chris Hoyle, is the primary sponsor and key stakeholder of the project and will oversee the progress the team is making towards completion. The members of the manufacturing team, team 122, are Brian Blasquez, Jake Rocker, Mitchell Brown, Ryan Doyle, Cody Bloomfield and Yin Sing Lee. This team is made up of four mechanical engineering students, and two students with a double major in mechanical as well as manufacturing engineering. The team will be splitting up research for 10 weeks into their primary interests and strengths, while working with each other to make sure their ideas converge on a single, optimal design. After the completion of research and design, the team will work together to complete the manufacturing of the body before the competition.

4. Constraints, Risks, and Assumptions

4. 1 Constraints

The design of the new body will need to meet expectations of both the stakeholders as well as the competition rules. Some constraints in the project include:

- Competition rules. It is important to ensure the body meets specific dimensions, has certain attributes, such as properly sized doors and lights, and is of quality construction to maximize points.

- Timeline, budget, and materials. The team will need to have the body ready for the competition in April, needs to be completed under a budget of $3500, and must construct the body with carbon fiber.
- Limited experience. No team member has worked with carbon fiber, so simplifying the process as much as possible is absolutely necessary.

4.2 Risks

In the manufacturing of carbon fiber, the biggest risk is in ensuring the process is done correctly. For example, a previous team worked on a similar project in which they needed to complete a carbon fiber body for the ASME team and ended up failing due to the mold and body not separating, rendering the body unusable. Another risk is meeting the required timeline for completion. With only 10 weeks to complete the manufacturing, the process will need to be refined enough to meet the timeline and be approached carefully to minimize setbacks from possible mistakes in the process.

4.3 Assumptions

To ensure the project is completed successfully, team 122 will need to make a few assumptions, namely in materials and maximizing work efficiency. These two assumptions are that the carbon fiber used to construct the body will be free, provided through ASME, and that members of ASME will be willing to help in the manufacturing process. With the carbon fiber being donated, it will be more feasible to meet the budget demands set by the sponsor, and having ASME members to help with manufacturing will ensure the time constraints will be met.

5. Design Process

5.1 Understanding the Problem

To begin the design process, it is important to first understand the problem statement. There are three primary factors that went into understanding the design for the carbon fiber body:

- The Shell Eco-Marathon rules.
- Evaluating the current car and comparing it against other cars in the competition.
- Requirements outlined by the ASME president and the project advisor, Dr. Hoyle.

The competition rules outlined dimensions as well as accessories that need to be on the car. Comparing the current car to other cars in the competition, it was important to note where the new body could be most improved, which was in decreasing the weight of the car, as a steel tube frame is much heavier than a full carbon fiber body. Finally, ASME and Dr. Hoyle need the body to be finished prior to the competition in April and require that the body be made from carbon fiber. From these customer requirements, design ideas could begin, and were broken down into three categories: the shape of the body, the manufacturing process, and mold construction.

5.2 Designing the Body

Throughout design, two primary factors were at the forefront of decision making: the shape of the body and the manufacturing process. Beginning with the shape of the body, aerodynamics became the baseline for how the car would look. Based on research, the "ellipse" [5] showed itself to be the optimal shape, with an oval shape dominating the front and rear. With this in mind, team 122 could begin creating different body styles that mimicked aspects of the ellipse while including other key design factors. Next, it was important to look at how the shape might be manufactured. The most important consideration is to ensure that the body can be pulled out of the mold when manufacturing is complete, meaning the mold cannot have any obstacle that may block the carbon fiber from being pulled out. To meet this requirement, the body will need to be split into multiple molds, then combined prior to placing it on the car. There were a few options when deciding how to split up the body:

- Down the centerline, meaning there will be a seam running lengthwise down the middle of the car
- A top a bottom portion
- More pieces, the most optimal being a piece covering each wheel, then a fifth to cover the driver cab area

Splitting into two portions gives the advantage of needing to make less molds, which means less time making molds and recombining carbon panels later. Five molds would give the advantage of giving capability to create more complex shapes, and if a mold fails only a portion of the car will need to be recreated.

5.3 Manufacturing Process

Manufacturing carbon comes with a large set of challenges, with one of the most prevalent being which type of carbon fiber the body will be made out of. The GFR team uses what is called prepreg carbon fiber, which needs to be refrigerated. There is also dry carbon, with both uniaxial and biaxial construction. Dry biaxial carbon is the easiest to work with while also being a very strong type of carbon fiber. The GFR team also has a large amount of excess honeycomb, a material used for structure between layers of carbon. However, this can only be used on prepreg carbon fiber. If used on the dry carbon, it will absorb all the resin and the process of hardening would not happen. ASME uses a foam core, and while not as strong, could provide enough strength for a body, and would make manufacturing with dry carbon much simpler. Another important aspect to the carbon layup process is how the resin enters the carbon fiber. Dry carbon needs a resin infused in the weave to reach its maximum strength, and there are a few ways to do this. One is to paint it on with sponges. This works by laying down a layer of carbon, painting the resin onto it, then laying another layer and repeating until all layers are laid. This is a very straight forward method, however, there is only a 110-minute window of working with the resin before it hardens too much, which poses high amounts of risk. Another method is to lay all the carbon fiber layers, then vacuum seal the mold in a bag, then use a vacuum pump to suck the resin through the carbon fiber. This essentially eliminates the 110-minute time constraint, but the setup becomes much more important, as there is a high risk of the resin not fully saturating the carbon fiber.

5.4 Designing the Mold

Mold construction is the first step in creating a good finished product, and there are many methods to create a mold that works well. First, there are male and female molds. Female molds have the advantage of giving a good surface finish to the carbon fiber on the outside surface, whereas male molds give a good inside surface finish. Male molds, on the other hand, have the advantage of being easier to produce, as with a female it is necessary to first build what is called a plug, which is essentially an initial male mold used to make the female mold. When creating a plug, wooden ribs can be used to create a general shape for the plug, then a foam will be used to fill the gaps between the ribs. There are two types of foam which can be used for this, expanding foam and a sculpting foam. With expanding foam, it is very easy to fill the gaps, but this material can be hard to sand, so getting a good surface finish requires the extra step of applying and sanding body filler. Sculpting foam may be harder to fill in large gaps, but getting down to a good surface finish is much easier.

5.5 Putting it all Together

With the three categories outlined, the next step was to use tools such as a design decision matrix and a decision tree to converge on the single best solution. The design decision matrix takes each design alternative and compares them against the customer requirements. Then, the option that best meets these requirements will be chosen as the final design. Next, a decision tree was used to determine how well the best body shape, manufacturing process, and mold design would go together, and whether or not putting them together was feasible or if there were better options.

6. Design Solution

For the final design solution, an aerodynamic body shape was chosen that provided optimal shapes for manufacturing. For the manufacturing process, dry carbon fiber with a foam core laid out with the resin infusion method was chosen. This is because it is a relatively simple, cheap method, and there is a wealth of knowledge at OSU on how it is done. Finally, a female mold will be used, and sculpting foam used to make the plug. This will allow for fine tuning of the shape as well as an ideal surface finish on the outside of the body. From the decision design matrix, the top designs were chosen, and using the decision tree, the combination of those designs could be verified, leading to convergence on the final design. The final design is shown in figure 1.

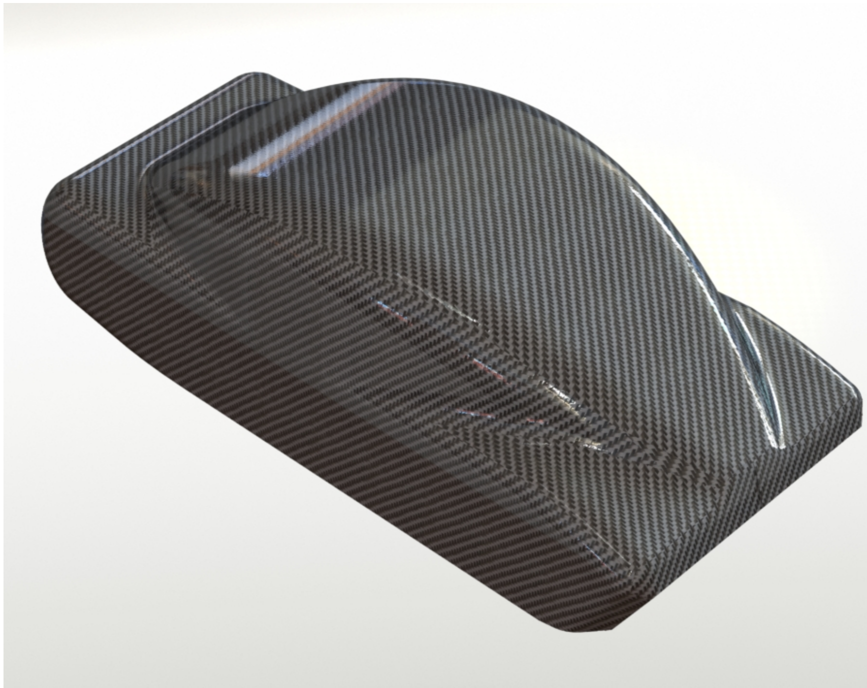

Figure 1. Final Carbon Fiber Body Design

7. Conclusion

In April 2020, the OSU ASME chapter will compete in the Shell Eco-marathon with their Urban Concept vehicle, which will have a newly completed carbon fiber body. The focus for the body will be in making it lightweight, aerodynamic, strong, and manufacturable. It is important that the team meet constraints and risks, such as passing competition rules, meeting a timeline, budget and materials requirement, and ensuring the manufacturing process is completed with minimum setbacks. It will be important to complete this project for Dr. Hoyle as well as the ASME team and meet criteria of the competition. To meet all important requirements, the carbon fiber body will be built using an ellipse shape, dry carbon fiber composite with resin infusion, and in a female mold which will be built with a male plug.

8. References

[1] “About Us.” (n.d.). *Global Formula Racing - GFR*, <https://www.global-formula-racing.com/en/about-us> (Oct. 23, 2019).

[2] Finn, J. (2016). “‘Beaver Bolt Racing’ Electric Car Debuts at Eco-Shell Marathon.” "Beaver Bolt Racing" Electric Car Debuts at Eco-Shell Marathon | Mechanical, Industrial, and Manufacturing Engineering | Oregon State University, <https://mime.oregonstate.edu/“beaver-bolt-racing”-electric-car-debuts-eco-shell-marathon> (Oct. 23, 2019).

[3] “Shell Eco-marathon.” (n.d.). Shell Global, <https://www.shell.com/make-the-future/shell-ecomarathon.html> (Oct. 23, 2019).

[4] 8, C. F. · D. (2016). “DIY Custom Carbon Fiber Fenders Built from Scratch.” COMMON FIBERS – DIY BLOG, <http://carbonfiber.life/?p=31> (Oct. 31, 2019).

[5] F. M. White, Fluid Mechanics, Seventh. New York, NY: McGraw-Hill, 2009, Table 7.2 (Page 489).