Carbon Fiber Monocoque Chassis Redesign

Team 1

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In recent years, the automotive industry has focused on decreasing the carbon footprint caused by fuel emissions. The Supermileage Team is an SAE affiliated club at NIU that designs, fabricates, and competes internationally for the most fuel-efficient vehicle in order to address this problem and reduce their carbon footprint. The goal of the carbon fiber monocoque chassis redesign was to develop a new vehicle that increases fuel efficiency through weight optimization and aerodynamics in order to achieve 2,000 mpg, which would beat the team’s current record of 1,888 mpg. The vehicle's aerodynamics and weight were optimized through iterative CAD designs and simulated in ANSYS Fluent CFD. Due to time constraints of making such a large mold at a sponsoring company, the vehicle will be fabricated after the semester concludes. With the optimized design selected, the fabrication will consist of five negative molds made from high-density foam including the top half, bottom half, two front wheel fairings, and the rear hatch. The negative molds will allow for carbon-fiber layers to have a smooth exterior surface using the resin infusion (vacuum bagging) process. For the core strength, the carbon fiber shell will be attached to a Nomex sandwich core. Nomex panels consist of Aramid honeycomb laminated with carbon fiber sheets on each side allowing for exceptional shear transfer and strength. The overall combination of the carbon fiber shell and Nomex panel, along with intermediary layers such as CNC machined foam core, will allow for a successful carbon fiber monocoque chassis.

Keywords - Ansys Fluent; carbon fiber; CFD; monocoque; Nomex honeycomb sandwich panel; resin infusion; supermileage

I. INTRODUCTION

It is known that the primary contributors to energy loss after the powertrain in supermileage vehicles are rolling resistance and drag force [1]. The carbon fiber monocoque chassis redesign addresses both of these issues in-depth by focusing on the exterior shell of the car to address aerodynamic drag and side load. Additionally, the estimated weight reduction from designing a fully composite body is expected to reduce rolling resistance through a 28% body weight reduction and an 11% overall weight reduction.

The carbon fiber monocoque redesign spans a wide range of mechanical engineering foci including CAD, parametric design studies using computational fluid dynamics and finite element analysis, and design for intricate yet feasible mold fabrication. The new vehicle design maintains compatibility with Supermileage subsystems in addition to focusing on reducing the overall size of the vehicle, decreasing the coefficient of drag, minimizing weight, increasing driver visibility, and maintaining a high degree of safety.

This project also allows the team to integrate past design considerations that were not physically allowable in the old vehicle chassis, such as increased turning radius and wider tires and rims for reduced rolling resistance. Furthermore, the monocoque redesign allows for future proofing of the vehicle such that other subsystems can be implemented when needed. Overall, the carbon fiber monocoque chassis redesign provides the Supermileage team the ability to implement changes that minimize energy losses for nearly all subsystems.

II. SUMMARY OF DESIGNS

The final carbon fiber monocoque chassis design follows a specific set of criteria set forth by the NIU Supermileage Team as well as the competitions attended, including SAE Supermileage and the Shell Eco-Marathon. The Shell Eco-Marathon competition requirements include vehicle dimensions such as maximum height (1000 mm), minimum track width (500 mm), wheelbase (1000 mm), height-to-track width ratio (< 1.25), maximum width (1300 mm), maximum length (3500 mm), and maximum weight (140 kg) [2].

Following the aforementioned requirement, it was decided that three approaches should be used to design the vehicle. The first is a recreation of the vehicle geometry that the team has used since 2010 due to its previous success and ability to accommodate all of the current vehicle’s subsystems. The second is a design that is influenced by the PAC-Car II from ETH Zurich, which was the world’s most fuel-efficient vehicle from 2007-2018 [3]. This design takes the general airfoil profile and top profile of the PAC-Car II and modifies the critical areas needed to accommodate Supermileage’s current subsystems. Design two acts more as an intermediary step between the current body and the desired body design. The third design is a combination of the current Supermileage vehicle and the PAC-Car II geometries to create the most optimal body.

![Design 1](image1.jpg) ![Design 2](image2.jpg) ![Design 3](image3.jpg)

*Figure 1: Alternative vehicle design overviews*
All three designs were analyzed using Ansys Fluent (computational fluid dynamics simulations) to estimate the aerodynamic properties of each design (Figure 2). This analysis method consisted of importing the geometry into Ansys, processing the geometry into a mesh, and solving the computation problems constrained within boundary conditions to determine the fluid responses as the car is moving. The overall element size of the meshes were between 2–3 cm with between 4–4.5 million cells per mesh. The simulations used the Shear Stress Transport (SST) k-ω with an inlet velocity of 25 mph and ran for 250 iterations to reach a convergence of at least $10^{-6}$. In addition to the simulations, each design was evaluated on the basis of footprint, weight, ground clearance, wheel fairing size, nose cone geometry, and tail design. From these categories, Design Three was selected.

### III. Fabrication

**Material Selection**

The main shape of the vehicle will be created by 3k 2x2 twill weave carbon fiber infused with high strength infusion epoxy. Attached to the shell will be a CNC machined piece of Rohacell 31 IG-F high strength-to-weight ratio foam. Attached to the foam will be a 1.5" thick Nomex honeycomb panel in which all subassemblies will mount to. A portion of the CNC machined foam can be seen in Figure 3 below.

![Figure 3: CNC machined Rohacell 31 IG-F foam](image)

The entire vehicle stack-up can be seen in Figure 4, in which the carbon fiber shell is cyan/transparent, with the machined foam in red and Nomex in black stacked on top.

![Figure 4: Vehicle material stack-up (side view)](image)

An aluminum tubing roll hoop and firewall was also created to protect the driver from the engine and transmission systems. All components will be attached to the Nomex panel through the use of custom 6061-T6 AL potted inserts. These inserts are designed to allow for high strength epoxy to flow around them when inserted into the Nomex panel, creating an extremely durable mounting location. The potted inserts and firewall can be seen in Figure 5.

![Figure 5: Potted insert (left) and firewall (right)](image)

### IV. Results and Discussion

The entire vehicle CAD can be seen in Figure 6. The turning radius has improved from 32 ft to 24 ft (20% improvement), the center of gravity is 2 inches lower, the frontal cross-sectional area was reduced by 15%, the side cross-sectional area was reduced by 3%, the body weight was reduced by 28% and overall weight by 11%. Many features were added such as removable wheel fairings in case of damage, lip and groove mating features for all joining surfaces of the body, and a high level of modularity such that all internal subsystems can be redesigned if desired.

![Figure 6: Full carbon fiber monocoque vehicle](image)

### V. References


### VI. Acknowledgments

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