Uni-Body Structure For Prototype Vehicle

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***Abstract–* The uni-body structure is an overall body design that allows for a stronger and more rigid material. The monocoque arrangement used in this project was constructed out of a combination of Carbon fiber and Kevlar. The emphasis was placed on having superior stabilization by reinforcing the construction of the roll bar. Furthermore this method yielded exceptional results when dealing with loads, torsional rigidity and ultimately impact protection.**

I. Introduction (Monocoque)

The monocoque design was used to make a sturdy and structurally safe aerodynamic shell. Its construction consisted of a Carbon-Kevlar sheet that was shaped into complex parts. The Uni-body design produced protection for the driver and also helped to reduce the energy consumption upon the vehicle.

To create the body of the monocoque, the first consideration was carbon fiber sheets. Due to the fact that weight is a major factor in the performance of the car the team then started to consider Kevlar as an alternative because of its weight. Carbon fiber is definitely stronger having a higher elastic modulus, but Kevlar is a less dense and lighter providing the strength necessary [7]. A mixed weave of Carbon and Kevlar was available which provides the qualities of both materials without having to conform to one. A mix of these two materials provides stiffness and impact strength which is exactly what was needed.

Solidworks was used as our CAD software to perform the design analysis. The Uni-body material consisted of three layers: two Carbon Kevlar and a center core material of Divinycell H. They were designed separately and then assembled together to resemble a realistic model.

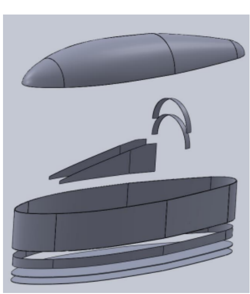

Fig 1: Exploded View of SolidWorks Model

II. Uni-body Simulation

A. Monocoque Analysis

The design was subjected to several loads while the vehicle was in use. It was essential to understand and identify the loads being experienced so that the car could withstand the resulting stresses. The principal loads on the car were supplied by the driver. The driver loads greatly affecting the monocoque were caused by the cornering, accelerating and braking of the prototype. During normal operation of the vehicle we saw vertical displacement from the wheels translated onto the body as directional deformations [7]. These impact loads, component loads and driver loads were loading sources that gave leeway onto precedent simulations.

When taking into consideration the event of a crash, impulse loads were considered on the monocoque because of the probability of dynamic loads caused by sudden deceleration. The loads applied by the driver when entering or exiting the vehicle were also accounted for. One of the most important requirements for the prototype was to have a roll bar that was capable of sustaining 700 Newton force applied directly on it. Several simulations were performed on an equivalent roll bar. The following figures illustrate some of the resulting forces we can virtually see using Solidworks. These simulations were performed with careful consideration of material properties, layers of the material and all forces acting on it, including gravity [4, 6].

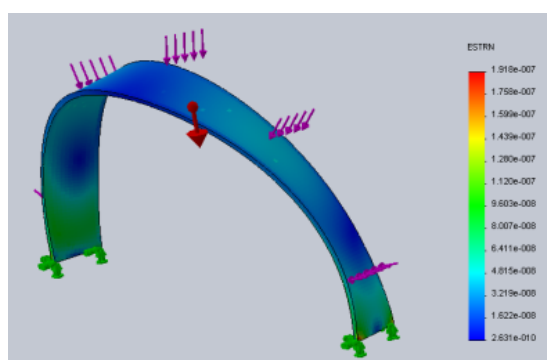

Fig 2: Strain Results of Roll Bar [8]

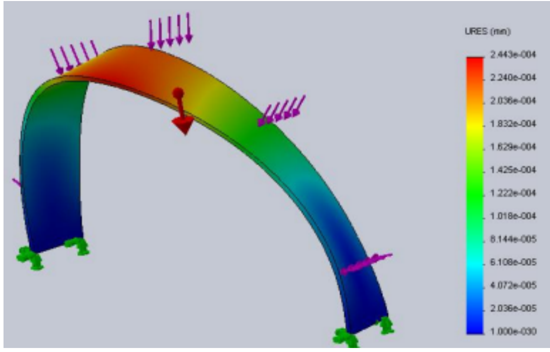

Fig 3: Deflection Results of Roll Bar [9]

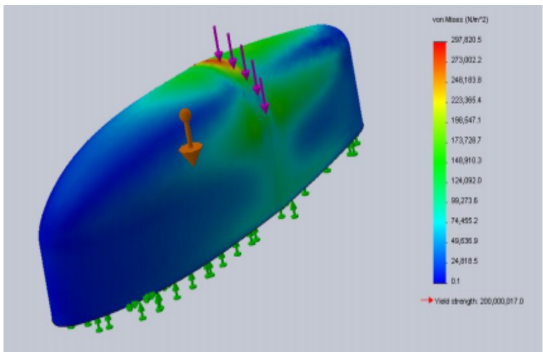
Fig 4: Von Misses Results of Roll Bar

These are the mathematic equations used to solve for strain (1), deflection (2) and Von Misses Stress (3) in the simulation [5]:

$$\varepsilon = \frac{\Delta l}{lo} \Rightarrow \frac{l - lo}{lo} \quad (1)$$

$$\delta = \frac{qL^4}{8EI} \quad (2)$$

$$\sigma_v = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}} \quad (3)$$

Table 1: Monocoque Simulation Results

Formulation	***Maximum***	***Minimum***	***Actual***
Strain	1.918e-007N	2.631e-010N	9.603e-008N
Deflection	2.4e-004mm	1.0e-030mm	2.2e-030mm
Von Misses	297,821N/m^2	0.1 N/m^2	237,002N/m^2

III. Construction of the Prototype

A. Shaping the Mold

For the assembly of the body, a three dimensional skeleton was produced as a base for the mold on the prototype. Once satisfied with the flow simulations and stress analysis produced on Solidworks, we printed out section views of the vehicle at a 1:1 scale in order to set up the mold that consisted of a combination of plywood and foam. The figures below display the end product of the foam skeleton of the body. After it was shaped to our design a layer of primer was applied to maintain the integrity of the mold. Then after it dried, wax was applied on it to have a nice smooth non-adhesive surface so that the group could apply the Carbon-Kevlar Fiber material to the body. The team applied 2 layers of the Carbon-Kevlar fiber material with a center core material to provide strength and robustness to the body [1].


Fig 5: Foam Skeleton

B. Priming the Mold

The next step was to fix any uneven type of curvature present in the shaping phase of the project. Hence the team painted the body with a priming agent to cover any existing imperfections. Moreover the gaps left after applying the primer were covered with "Bondo" filler and then painted over once more. Lastly before applying the Carbon Kevlar material 7 layers of mold release wax were applied to facilitate the removing of the Uni-Body.


Fig 6: Priming the Body

C. Laying of Carbon-Kevlar Material

For this process it was very important to maintain the mold at ambient temperature in order for the curing process to be completed accordingly. The group first applied the inner layer of fiber material onto the mold. Polyester Boatyard Resin was used for its high strength purposes as the adhesive to join the fiber layers [2]. After the first layer was applied a time frame of 24 hours was waited before moving onto the foam material. The Laminate Bulker Divinycell Dviniymat was placed as the sandwiched layer otherwise implemented as the I-beam layer were the strength and rigidity was exemplified [3, 5, and 7]. The resin was applied onto the core material, making sure that is was fully submerged within the cracks and crevices of the core materials, and applying even layers throughout the body. After this step was completed the team gave the mold 48 hours in order to cure completely. Lastly, the group applied the exterior fiber onto the core material the same way as the first layer, completing our mold.

Fig 7: Three Step Process Laying Carbon-Kevlar Material

D. Evaluation of Specimen

Before the construction process began an initial load examination was performed on a Poly Foam wrapped with Carbon Kevlar to validate if the tensile and yield strength properties were sufficient to withstand the forces [5]. A rectangular model of laminate was completed in order to understand the manufacturing process and to test different core materials. The Poly foam material that was chosen was not suitable for the surface due to its thickness and not malleable properties. The blocks were simulated by a replicated version of a three point bend test providing the information as to the deflection in relation with the load of the model. The core of the specimen failed with 120 Newton's of force which is much less than required.

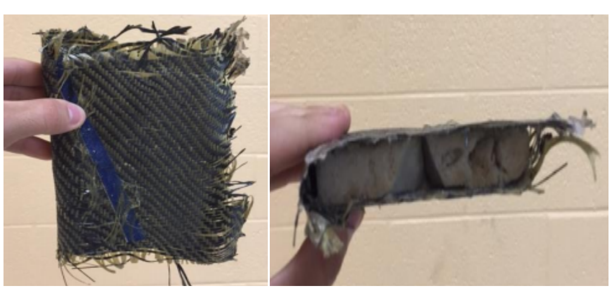

Figure 8: Front and Side View of Carbon Kevlar and Poly-Foam

IV. Cost Analysis

A. Expense Calculation

Table 2: Cost Analysis

Cost Analysis	***Price***
Body	
Carbon Kevlar	$400.00
Formula Five Mold Wax Release	$26.38
Divinymat H60 3mm 4lb density foam	$69.99
Divinymat H60 5mm 4lb density foam	$28.31
Duratec, Primer, Styro-Shield	$141.89
Tarp, Blue	$4.20
Spreader, Poly 6	$1.72
Mixing Tip Static	$1.85
Tub, Poly Mix&Measure 2 1/2 quart	$2.30
Tub, Poly Mix&Measure 5 quart	$1.59
Polyuetherane Foam 2lb density	$24.00
Divinymat, H60 3, 4lb foam	$92.92
Acetone, Gallon Can	$16.21
Brush, Chip, Throw Away	$4.74
Roller Cover, Mohair Solvent Resistant	$7.40
Polyester Boatyard Resin, Gallon Jug	$60.90
Sanding Pads (80-100 grit)	$15.00
15 Paint Brushes	$15.00
Silicone Adhesive	$25.00
Plywood	$50.00
White Polyethylene Foam	$100.00
Insulating Foam Sealant	$35.00
Bond Filler (1 pound)	$30.00
Polyester Resin/ MEK hardener	$35.00
Overall Sum	***$1,189.40***

V. Conclusion

In conclusion the Uni-Body structure/ monocoque design proved to be a strong and weight reduced alternative in regards to the conventional body-chassis combination. This type of prototype was capable of sustaining more than 700 Newton's of force applied. Its characteristics illustrate how modern engineering and design can be optimized through key characteristics. The Carbon Kevlar/ DivinyCell foam wrapping implemented highly durable stress and strain qualities once it was united with the polyester resin solution [5]. It is more than evident that future vehicles and automobiles shall incorporate Uni-Body designs for their practicality and overall efficiency.

Fig 9: 896 Newton Strength Testing

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