Tubular Space Frames for Off-road Vehicle Applications

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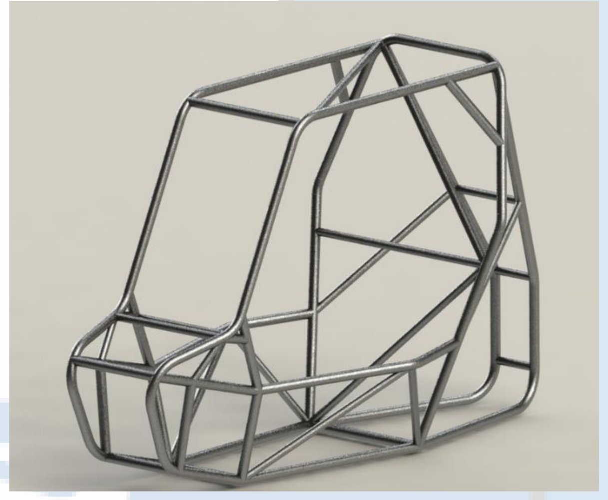
Space Frame Concepts

Following extensive conceptual design work, three designs were chosen as possible solutions. These concepts were modeled using SolidWorks 2014.

Concept 1

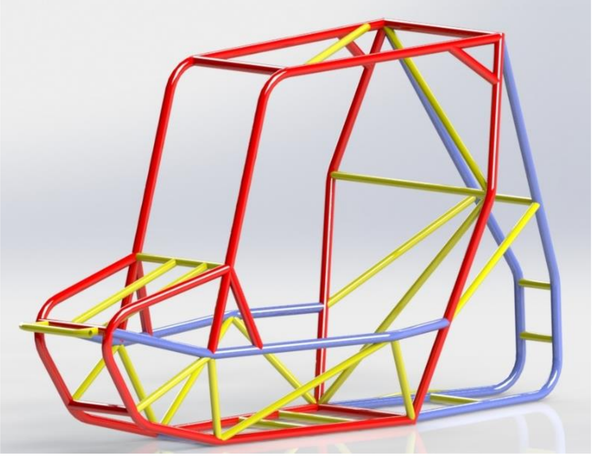


This design was created as a miniaturized version of the 2013 frame design due to the success of that design. The cockpit length was shortened by 5 inches.

Concept 2

The second concept was radically different due to the in-swept Rear Roll Hoop members. This design change was projected to greatly reduce firewall drag forces.

Concept 3



The final concept possessed many design changes from the previous designs. These changes included triangulated front suspension mounting tubes, a 4 member Rear Roll Hoop, and a smaller firewall frontal area.

Testing and Analysis

To determine which of these concepts would be fabricated and assembled, a series of simulations were conducted using SolidWorks 2014 to determine the weight, complexity, and strength of each concept using a variety of tools within the program.

Overall Weight and Complexity

SolidWorks 2014 contains a tool which determines the weight of a part or assembly if a material density is assigned to the parts. For this simulation, 4130 steel was chosen and the density of 4130 was applied to all of the frame members. The table below was used to determine which frame was the best choice based on weight, sub assembly fitment, and approximate assembly time.

Concepts	Weight (lb)	Assumed Assembly Time (predicted using previous experience) (hours)	Sub Assembly Fit	Total (lowest is best)
Concept 1	52.3	450	0	0
Concept 2	60.8	500	1	0.222014925
Concept 3	56.5	450	1	-0.063432836

Impact Factors of Safety

SolidWorks 2014 also contains a tool which will determine the factor of safety for a given loading and set of constraints on an assembly. The following table shows the factors of safety for a variety of situations.

Impact \ Model	K-14	A-11	C-11	2013 Model
Frontal Impact	0.7	0.85	0.67	0.69
Side Impact	0.71	0.84	0.46	0.44
Frontal Rollover 1	3.8	5.6	0.6	1.6
Frontal Rollover 2	4.7	7.1	4.8	3.6
Frontal Rollover 3	4.7	6.9	4.8	2.8
Side Rollover 1	1.3	1.4	4	1.1
Side Rollover 2	0.34	0.75	0.54	0.73

*** For the numbered scenarios, 1 is the initial impact, 2 is at 45 degrees, and 3 is completely rolled over. 3 was left out for the Side Rollover due to its similarity with the Frontal Rollover 3 analysis. ***

Typically, factors of safety below 1 are unacceptable, but for this case these loadings would be fairly impractical to design for because they would result in an overall heavier frame, along with an impact deceleration of about 50 g's imparted to the driver, which would be very uncomfortable in a five-point safety harness.

Implementation

After extensive analysis, Concept 3 was labeled the clear winner and chosen to be built and tested. The frame tubes were bent and cut at VR3 in Ontario, then assembled and TIG welded here at UB by the design team.

The above picture shows the space frame after assembly and welding. The assembly process and sub-assembly fitment was as anticipated from the SolidWorks analysis.

Conclusions/Future Work

This frame has proven to be far superior to the previous design for many reasons. The new design not only allowed for better sub-system fitment but was also lighter and easier to assemble. Also, because less tube bends were out of plane, the cost and time for the tubes to be fabricated at VR3 was significantly decreased compared to the previous design.

Due to unavoidable delays, the physical testing on the frame has yet to be completed. The design team would like to perform torsional stiffness tests, impact force tests, and durability/lifespan tests in the near future.

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