SAE Mini Baja 2014-2015

By
Ahmed Alnattar, Neil Gehr, and Matthew Legg
Team 11

Engineering Analysis

Document

11-21-14

Submitted towards partial fulfillment of the requirements for
Mechanical Engineering Design I – Fall 2014

Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86001

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Introduction

The team's goal is to design a manufactural frame that will last through the SAE competition's dynamic events. Since the weight of last year's baja has been a concern to our client Dr. Tester, the frame team would like to design a frame that is light in weight and small in size. Also, we want to build a mini baja vehicle that outperforms last year's baja vehicle, and have the roll cage ready for testing by Dec. 7st.

After the last report, the frame team provided two possible final designs for the frame. They were generated using SolidWorks and would be tested in the same program as well. This report provides a detailed analysis of the two frames. It will go over four possible scenarios that the frames will be tested under, along with all the calculations for each scenario. Based off the Factor of Safeties, the final design will then be chosen and presented to the client, Dr. Tester.

Timeline

The timeline from last report has been slightly adjusted. Due to lack of materials, a prototype frame will not be able to be built. Which has been taken out of the chart. The updated Gantt chart is below in *Figure 1.*

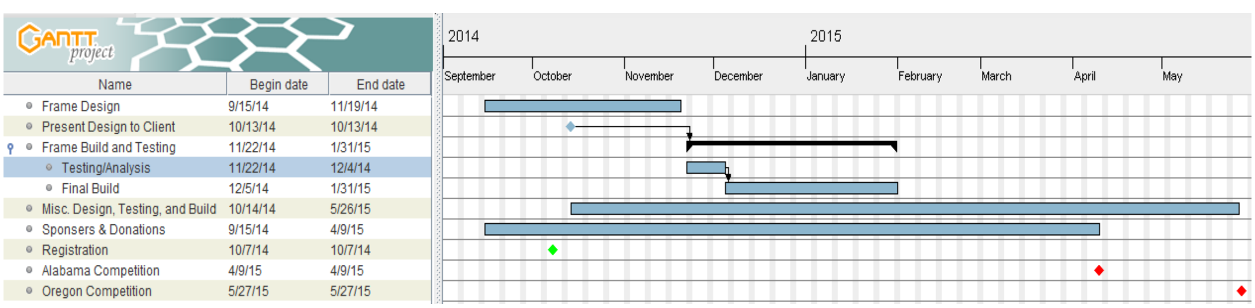

Figure 1: Updated Timeline

Frame Designs

Below, are the descriptions of the two frames, Front Supported and Front Bracing, along with figures for visual representation.

Front Supported Design

The Front Supported frame was designed to be compact and light in weight. It is made designed with 1’’ diameter 4130 chromoly steel with a wall thickness of 0.12’’ which is the smallest piping allowed in competition. The 2014 Baja frame has a width of 36 inches and length of 90 inches, while the Front Supported frame has a width of 44 inches and a length of 76 inches. Along with smaller dimensions, it’s mass of 158lbs which is 100lbs less than the previous Baja’s frame. The Front Supported frame can be seen below in *Figure 2.*

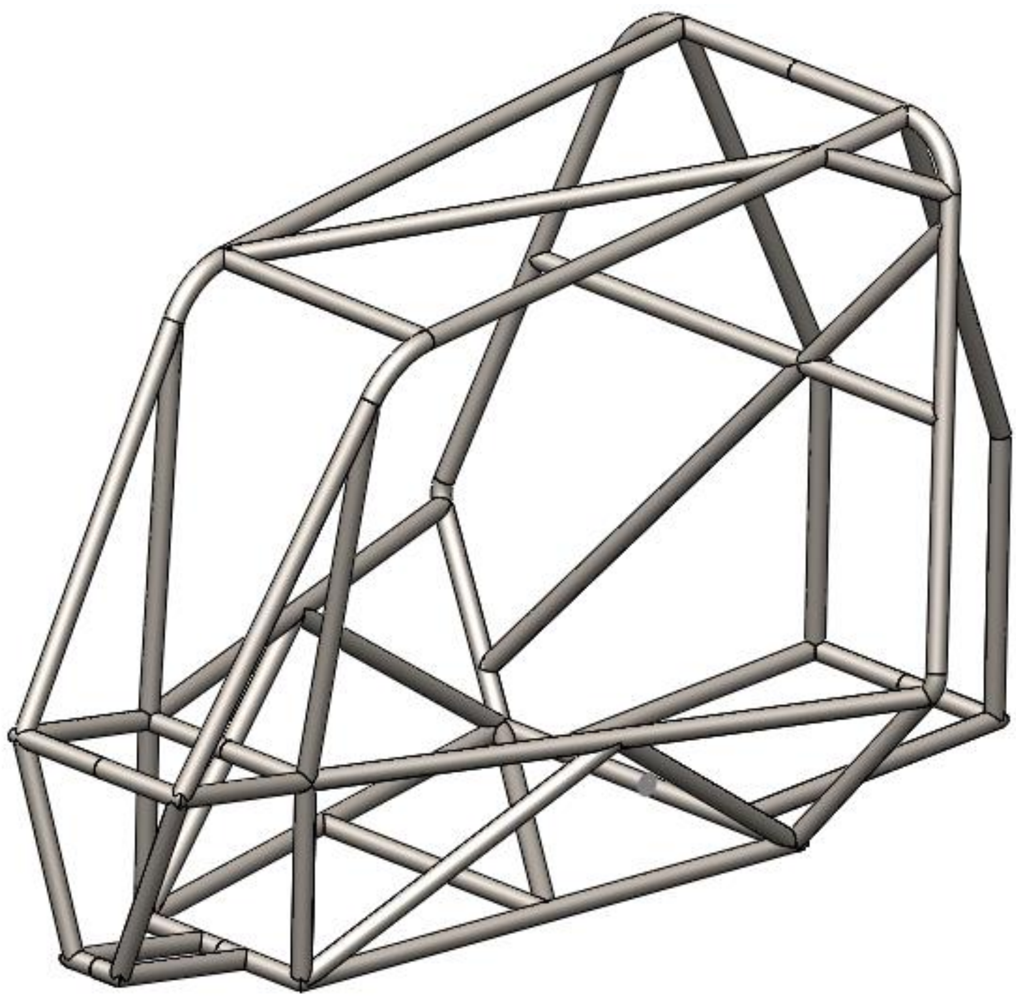

Figure 2: Front Supported Frame Design

Front Bracing Design

The front brace design frame includes the minimum amount of members required by the rules from SAE. The purpose of having as little as possible is to make the frame as lite as it can be while still performing well under dynamic forces. It is a better choice over a rear bracing design as it helps distribute the weight from the rear of the vehicle to the front. This frame is going to be built with chromoly 4130 steel tubing for the primary and secondary members. Both the primary and secondary members will have an outer diameter of 1 inch and a wall thickness of 0.76” and 0.93” respectively. This frame design has an approximate weight of 154 pounds with a width of 29.75 inches and a length of 76 inches compared to last year’s frame design weighing 250+ pounds with a width of 36 inches and length of 90 inches. The design still allows for the driver to be safe from harm in case of a crash, and does not over cramp the driver of the vehicle.

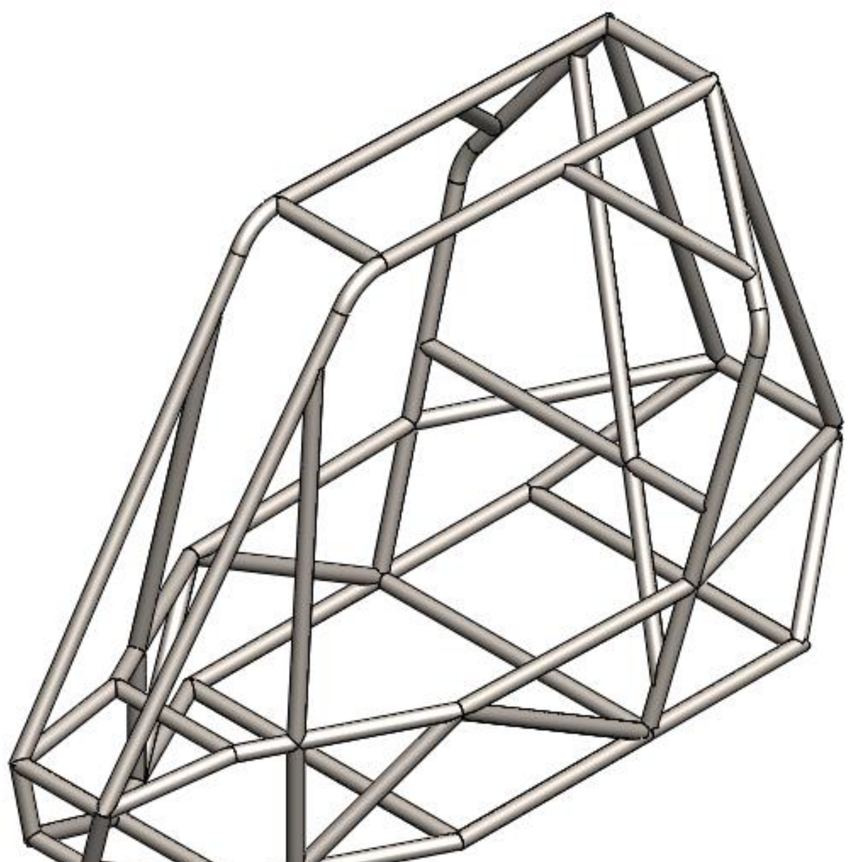

Figure 3: Front Bracing Frame Design

Testing and Calculations

For the two final designs of the frame, our frame team used SolidWorks Simulation to test the stresses, the displacement, and the overall factor of safety for the design upon impact. The frame team wanted to run a Finite Element Analysis (FEA) to determine the weakest areas on the frames. This analysis allows us to make any necessary changes before building the actual frame while ensuring the maximum safety for the driver along with the frame being light in weight. In order for our frame team to achieve a high quality of frame, the team needs to test the frame design for multiple scenarios to ensure the safety of the driver. Therefore, the frame analysis was based on applying four different simulation studies on the two frames, and each simulation study describes different scenario of collisions. The scenarios tested were drop test, front impact, rear impact, and side impact. The figure below shows the drop test scenario.

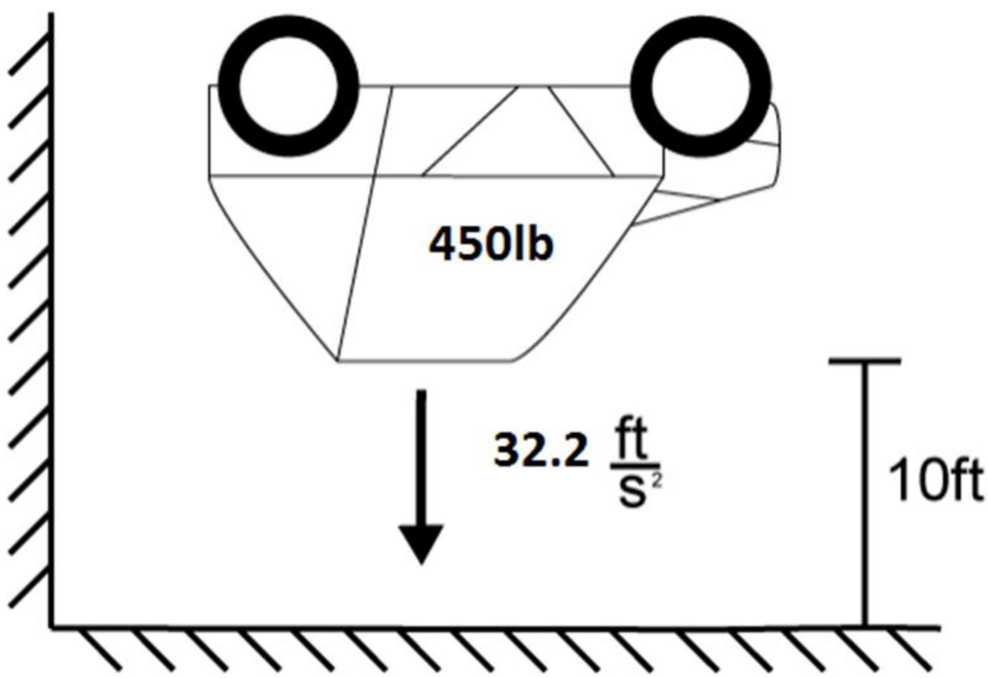

Figure 4: Drop Test Scenario

For the frame drop test (*Figure 4*), it was assumed that the vehicle rolled over and landed upside down from a height of 10 feet. In addition, the weight of the baja is 450lbs and the impact time is 0.1 seconds. In order to analyze the frame in a rollover scenario, the following equation needed to be used to determine the force of impact.

$$F = m \cdot \frac{\sqrt{2gh}}{t}$$

$F = total\ force\ (lbf),$

$m = object\ mass\ (lbm),$

$g = acceleration\ of\ gravity\ ({}^{ft}/_{s^2}),$

$h = drop\ height\ (ft),$

$t = impulse\ drop\ test\ time\ (s).$

In order to run the drop test simulation study and receive better test results, the team had to define the applied force on the chosen beams. This force is the total force Equation (1) divided by the total length of members force is applied to. Thus, this force can be illustrated as,

$$F_a = \frac{F}{l}$$

$F_a = applied\ force\ \left(\frac{lbf}{in}\right),$

$F = total\ force\ (lbf),$

$l = total\ length\ of\ members\ force\ is\ applied\ to (in).$

For the remaining impact test scenarios to be conducted on the frame in the SolidWorks simulation studies, a different method to calculate the total force is needed. The total force used to analyze the front, rear, and side impact tests is different than what is used in the drop test. This method was applied to all the remaining three simulation studies. Our front, rear, and side impact simulation studies were tested based on assuming a vehicle weight of 450lbs, an initial impact velocity of 25mph, and an impulse impact test time of 0.2 seconds. In order to analyze the frame experiencing front, rear, and side impacts, a mathematical calculation is needed to calculate the total force. From the total force the team can then determine the applied force to be used for testing the various impact scenarios. As a result, the following equation is obtained.

$$F = m \cdot \frac{V_0}{t} \tag{3}$$

$F = total\ force\ (lbf)$,

$m = object\ mass\ (lbm)$,

$V_0 = initial\ impact\ velocity\ \left({}^{ft}/_{s}\right)$,

$t = impulse\ impact\ test\ time\ (s)$.

In order to run the different impact test simulation studies and receive accurate test results, the team has to define the applied force on the chosen beams. This force is basically the total force Equation (3) divided by the total length of members the force is applied to. Thus, this force can be illustrated as,

$$F_a = \frac{F}{l} \tag{4}$$

$F_a = applied\ force\ \left(\frac{lbf}{in}\right)$,

$F = total\ force\ (lbf)$,

$l = total\ length\ of\ members\ force\ is\ applied\ to (in)$.

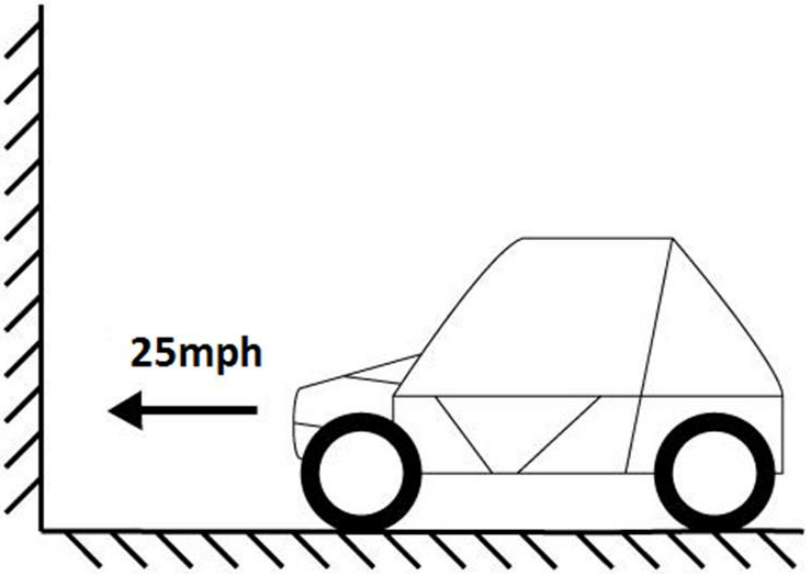

Figure 5: Front Impact Scenario

In *Figure 5*, the front impact scenario is shown as if the 450lb baja vehicle would collide at an impact velocity of 25mph into a wall. The applied force distribution is applied at the front members of the vehicle, while the rear-end members of the vehicle are chosen to be fixed.

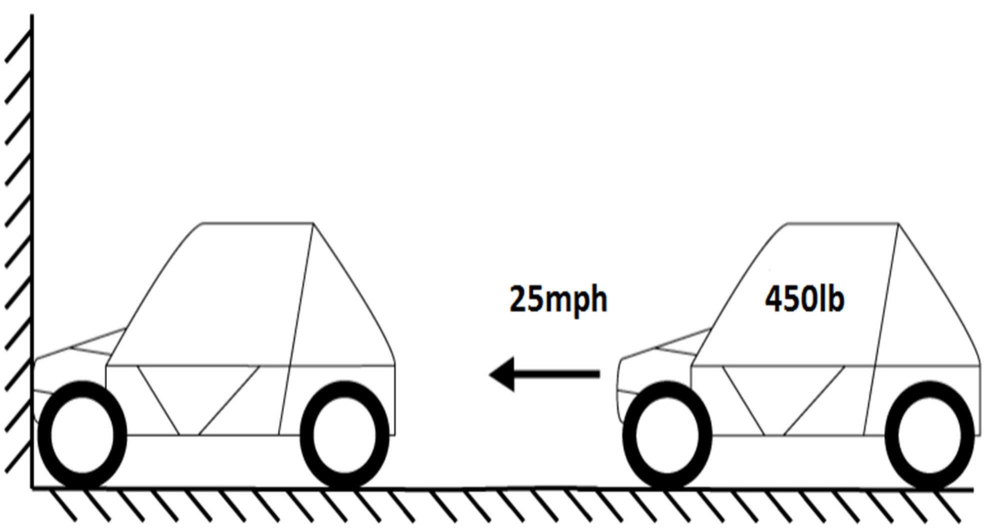

Figure 6: Rear Impact Scenario

Figure 6 illustrates the impact scenario of the baja vehicle being hit by 450lb baja vehicle from the rear end. This scenario can be described as if an approaching vehicle collides with the baja vehicle from the rear at an initial impact velocity of 25mph. The applied force distribution is applied at the rear end members of the vehicle, while the front of the baja vehicle is chosen to be fixed.

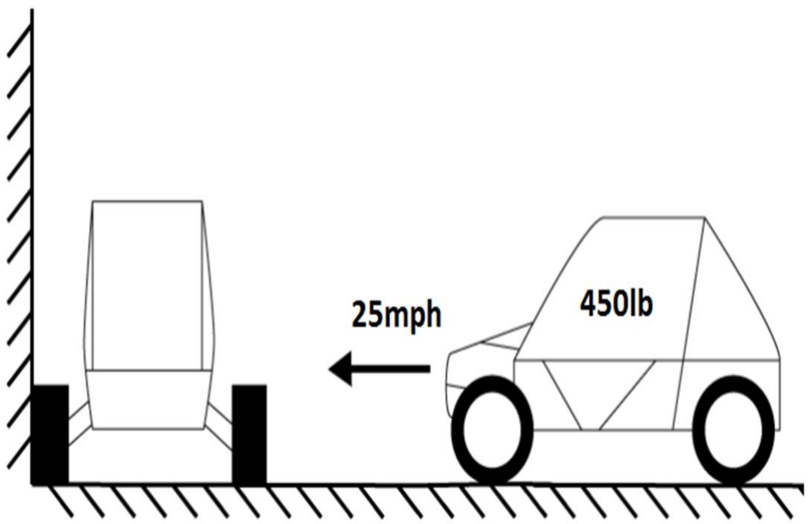

Figure 7: Side Impact Scenario

Figure 7 illustrates the impact scenario of the baja vehicle being hit by 450lb baja vehicle from the side. This scenario can be described as if a vehicle collides with the baja from the side at an initial impact velocity of 25mph. The side impact test using SolidWorks is performed by placing an applied force distribution to the members on one side of the vehicle in a plane, while the members on the other side of the vehicle are set to be fixed.

Simulation Results

The results generated for the two frames are discussed below, the images generated in SolidWorks are shown in the Appendix. The factor of safety of the frame has to do with the material being used and the configuration the members are in when a load is applied. The material of both is 4130 chromoly steel with a yield strength of 66ksi. The following table shows the factors of safety for the two frames for each of the tests that were completed.

Table 1: Factor of Safeties from the Simulation

Factor of Safety		
Tests	**Front Supported**	**Front Bracing**
Drop Test	2.7	4.3
Front Impact	4.7	3.6
Rear Impact	4	3.5
Side Impact	2	68

As seen from the values obtained for the factors of safety, both vehicles exceed a required FOS value of two, but the Front Bracing design out performs the Front Supported design.

Deformation of members is also a major concern for the safety of the driver since crushing the driver is a possibility. In the table below, the maximum deformation for the two frames can be seen for each of the tests that were completed.

Table 2: Maximum Deformation from the Simulation

Maximum Deformation (in.)		
Tests	**Front Supported**	**Front Bracing**
Drop Test	0.265	0.103
Front Impact	0.28	0.034
Rear Impact	0.113	0.051
Side Impact	0.198	0.005

As seen from the values obtained for the deformation, both frames have an extremely small maximum value of deflection proving that both designs are capable of protecting and insuring the safety of the driver. The front bracing design is shown to deflect less.

The concentration of stresses that the frame members receive are important to know so that the failure points may be assessed in the most extreme scenarios. In the table below, the maximum stress for the two frame can be seen for each of the tests that were completed.

Table 3: Maximum Stress from the Simulation

Maximum Stress (ksi)		
Tests	**Front Supported**	**Front Bracing**
Drop Test	25	15.3
Front Impact	15.4	18.7
Rear Impact	16.7	19.2
Side Impact	33.5	0.98

As seen from *Table 3*, the Front Supported frame experiences higher amounts of stress than the other frame. This would have to due to the frame having less supporting members in high stress areas. The Front Bracing frame out performs the Front Supported frame

Conclusion

Both frame designs have shown to be worthy designs for the baja vehicle and the competitions it must endure. Though only one can be chosen to build, the results tell us that the front bracing design is the better frame to go with. The front bracing design has a higher factor of safety and less overall weight. With considerations to the suspension and drivetrain teams, the final design of the frame will be slightly different, but they will not change enough to alter the integrity of the frame.

The next steps that need to be taken are to design and build a seat for the driver, and construct the frame. Also presented will be added components from the drivetrain and suspension team for a finalized design to present to the client, Dr. John Tester.

References

[1] http://www.youtube.com/watch?v=gAwVya8AfyM

[2] SAE Design and Analysis Project with SolidWorks Software

[3] SAE Mini Baja Frame Analysis 2013

Appendix

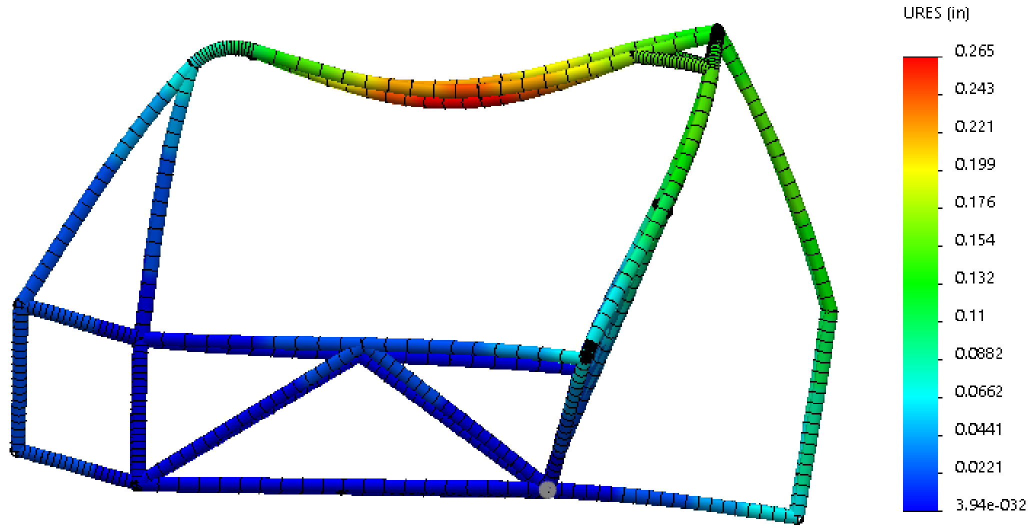

Figure 8: Front Supporting Deformation Simulation Results from Drop Test.

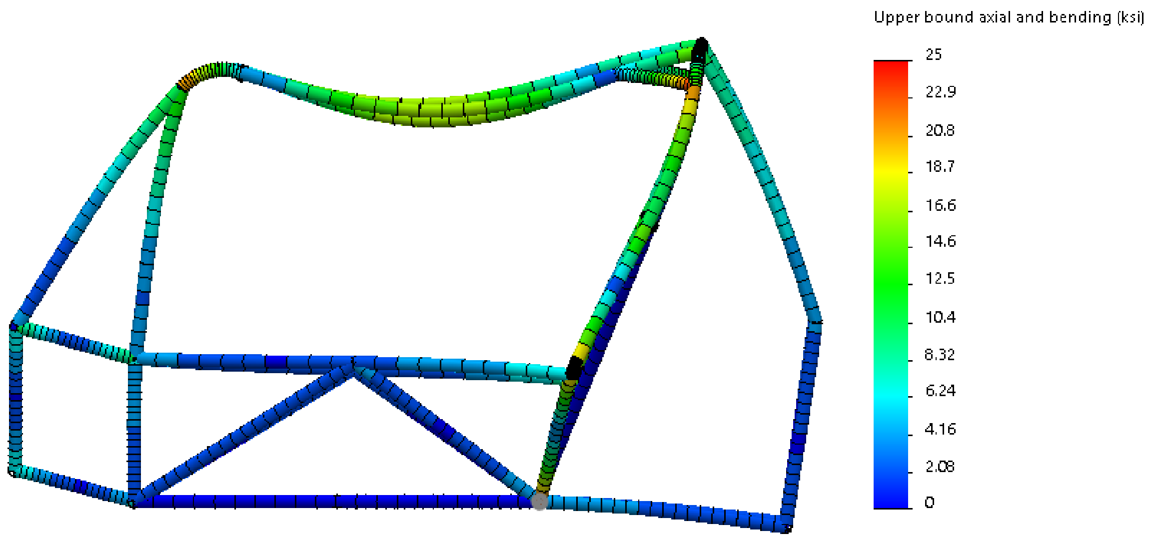

Figure 9: Front Supporting Stress Simulation Results from Drop Test.

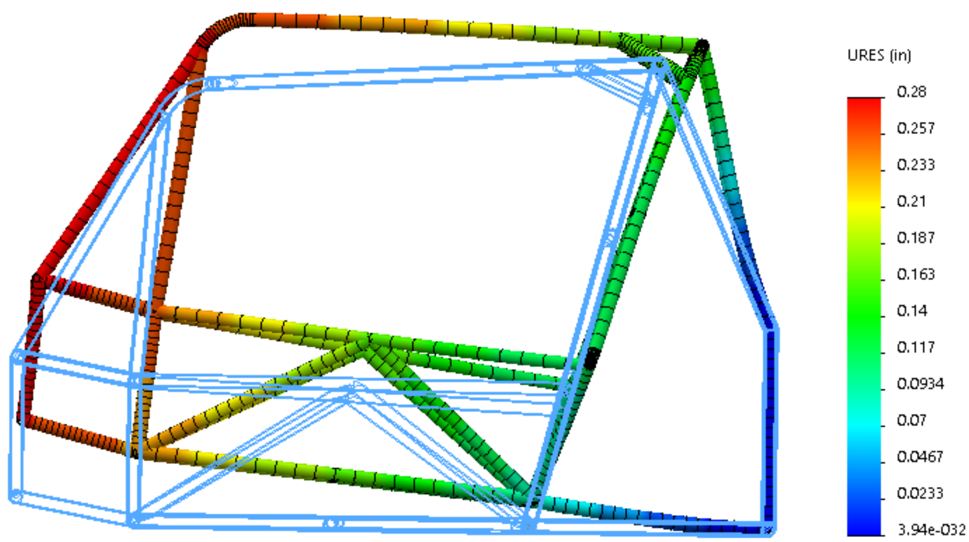

Figure 10: Front Supporting Deformation Simulation Results from Front Impact Test.

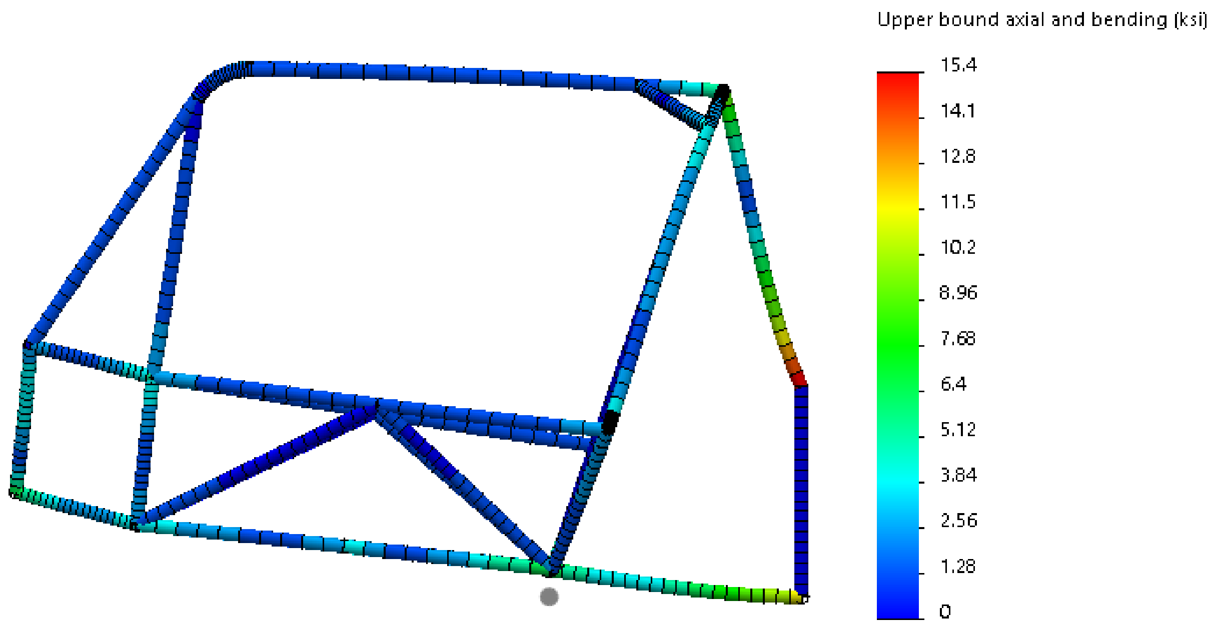

Figure 11: Front Supporting Stress Simulation Results from Front Impact Test.

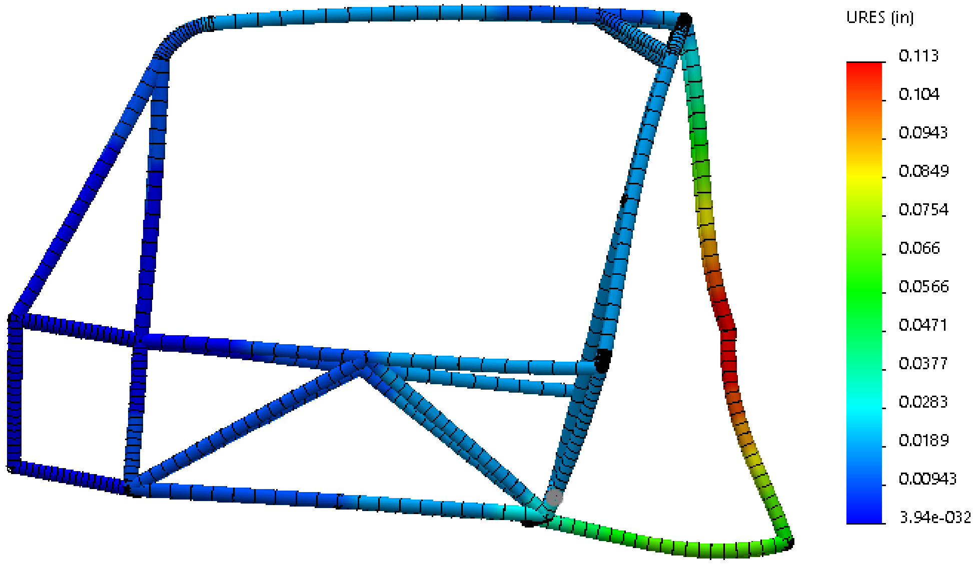

Figure 12: Front Supporting Deformation Simulation Results from Rear Impact Test.

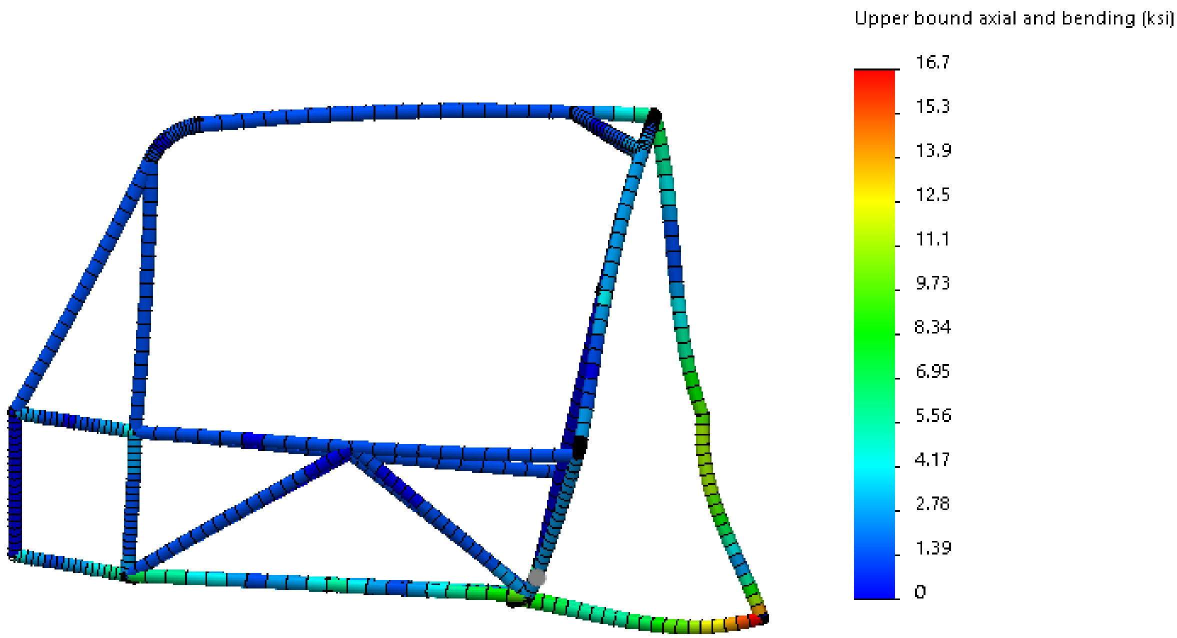

Figure 13: Front Supporting Stress Simulation Results from Rear Impact Test.

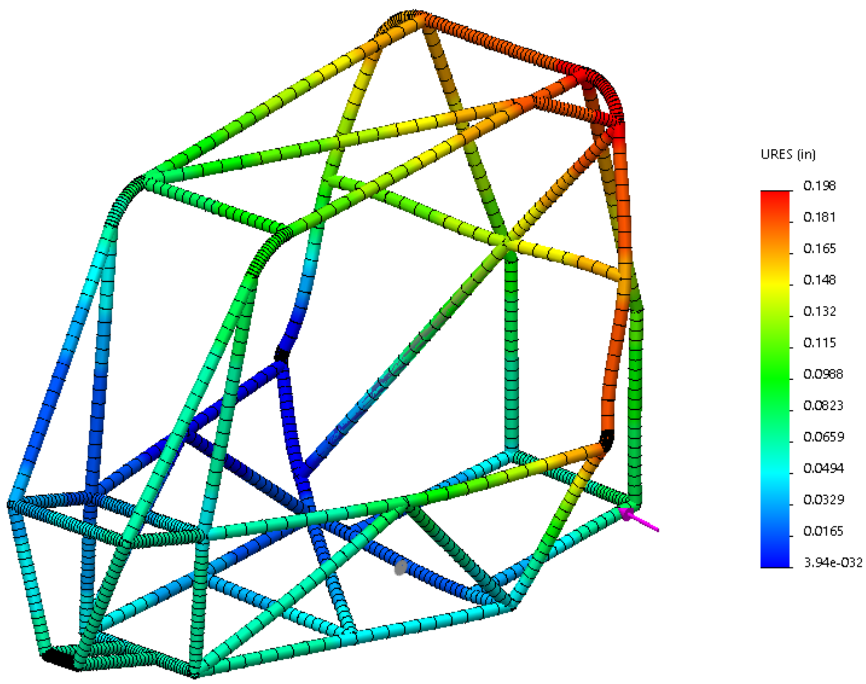

Figure 14: Front Supporting Deformation Simulation Results from Side Impacting Test.

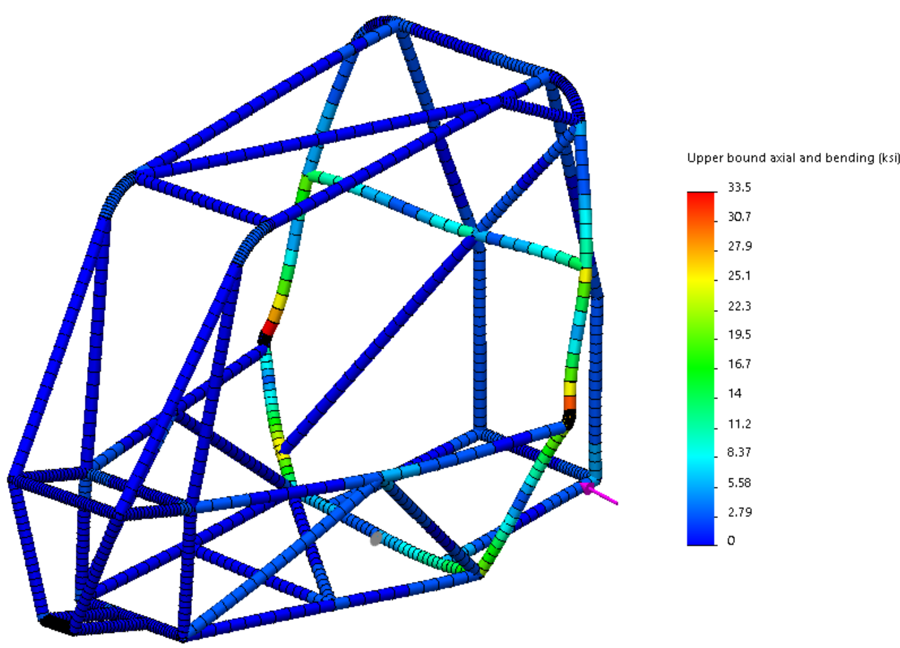

Figure 15: Front Supporting Deformation Simulation Results from Side Impacting Test.

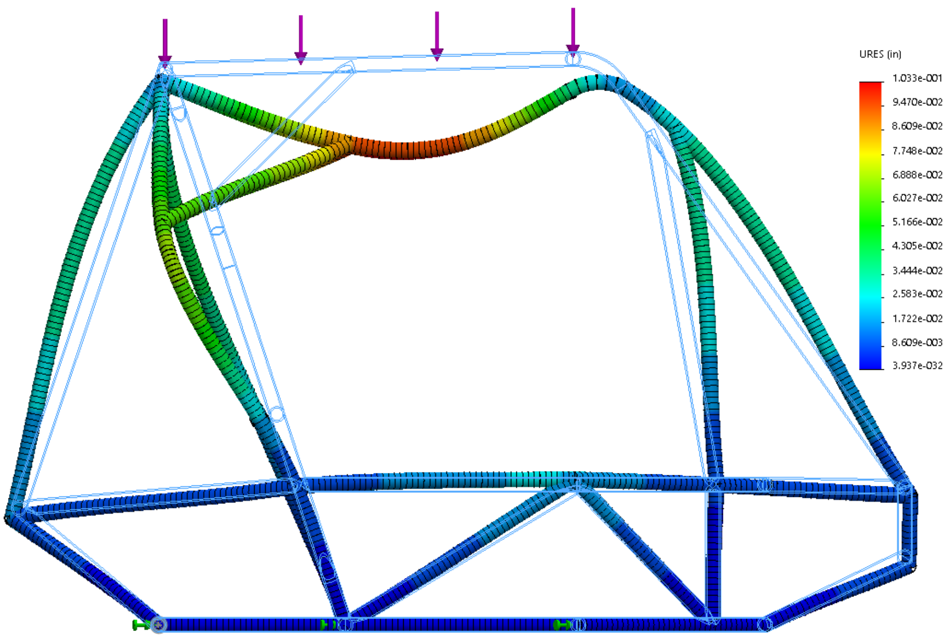

Figure 16: Front Bracing Deformation Simulation Results from Drop Test.

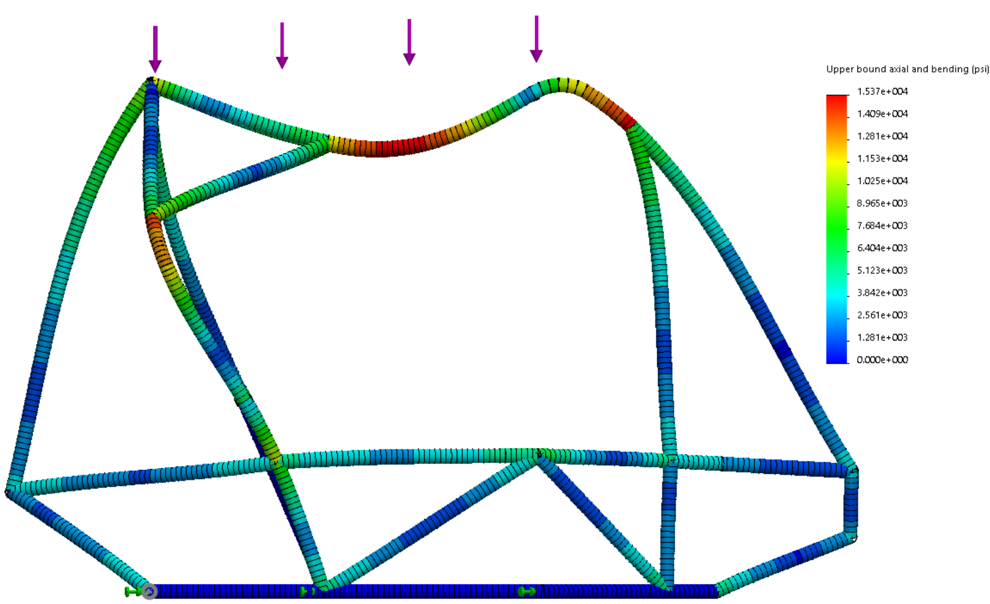

Figure 17: Front Bracing Stress Simulation Results from Drop Test.

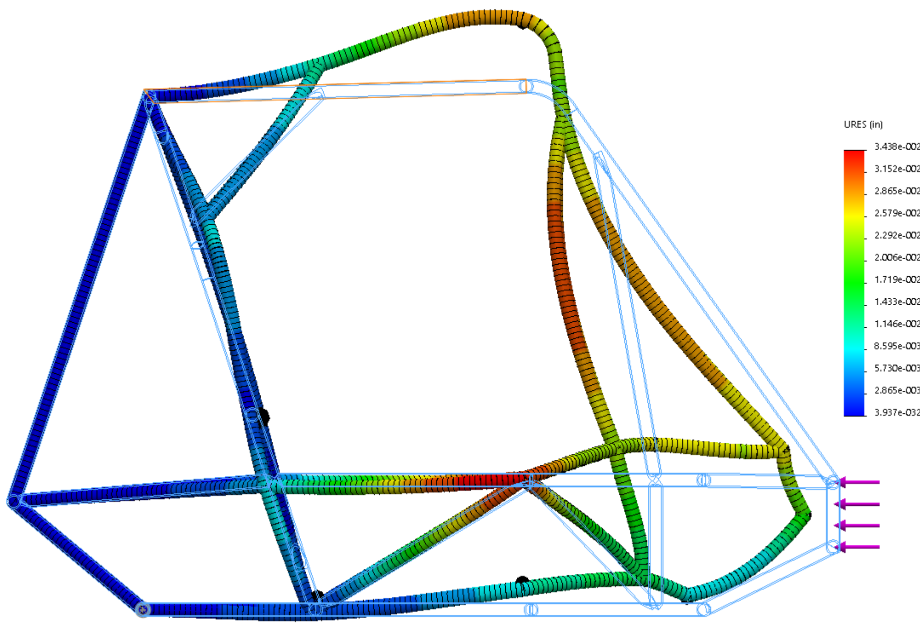

Figure 18: Front Bracing Deformation Simulation Results from Front Impact Test.

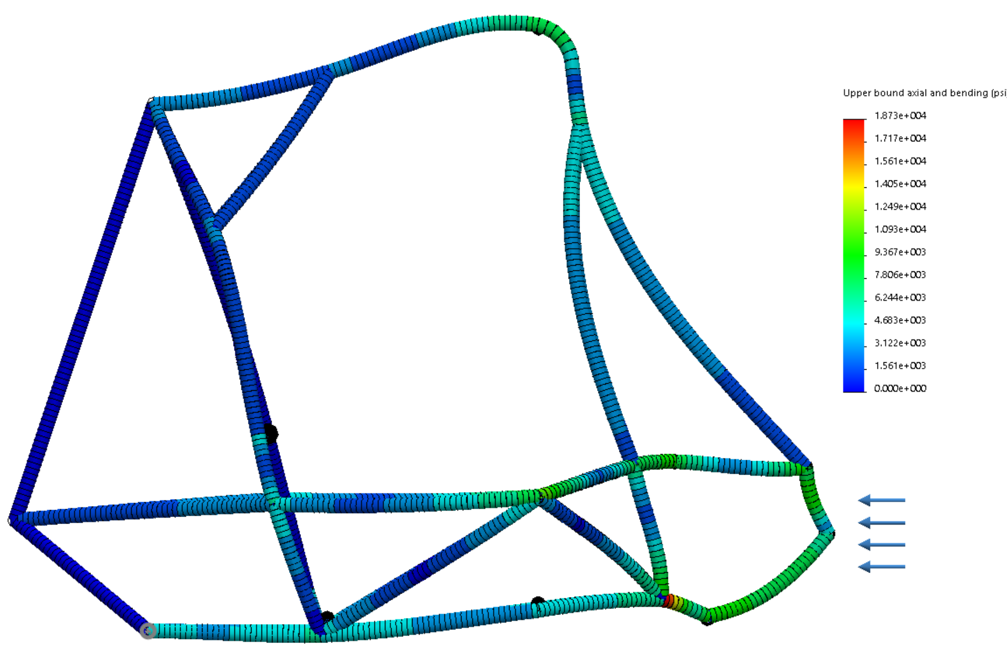

Figure 19: Front Bracing Stress Simulation Results from Front Impact Test.

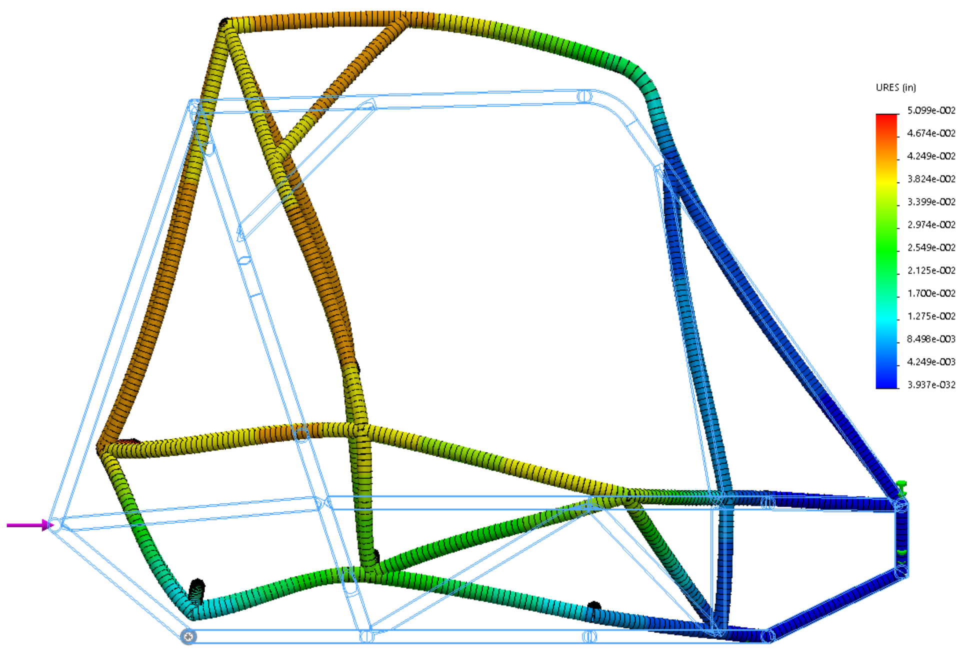

Figure 20: Front Bracing Deformation Simulation Results from Rear Impact Test.

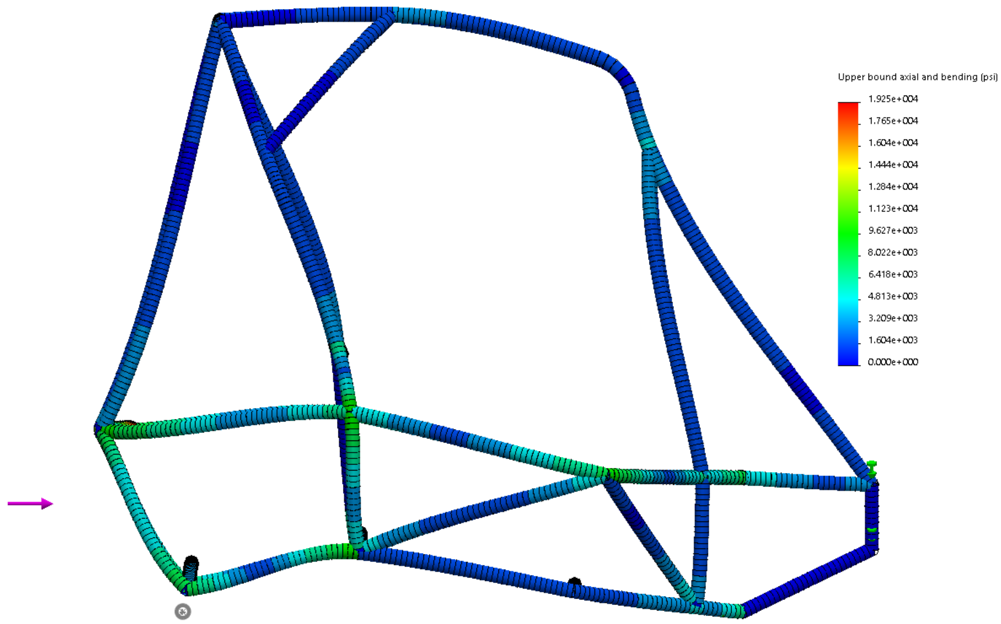

Figure 21: Front Bracing Stress Simulation from Rear Impact Test.

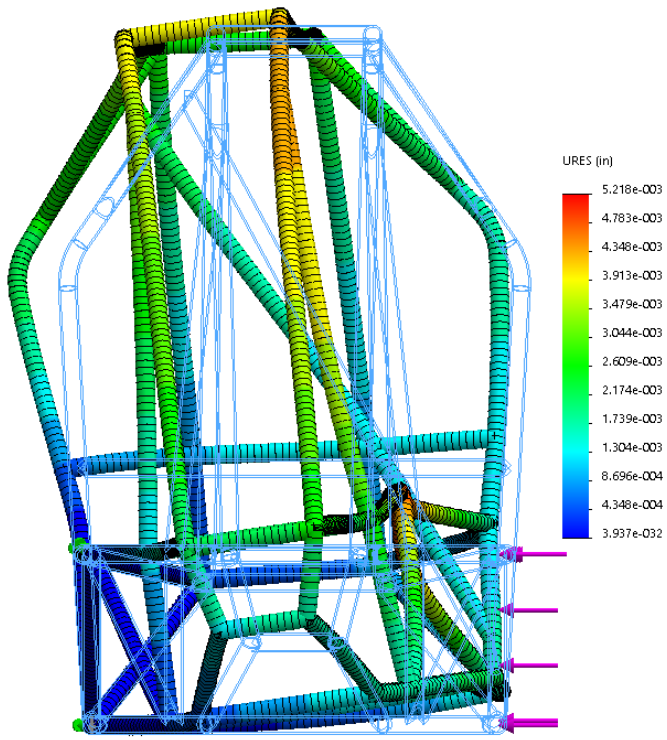

Figure 22: Front Bracing Deformation Simulation Results from Side Impact Test.

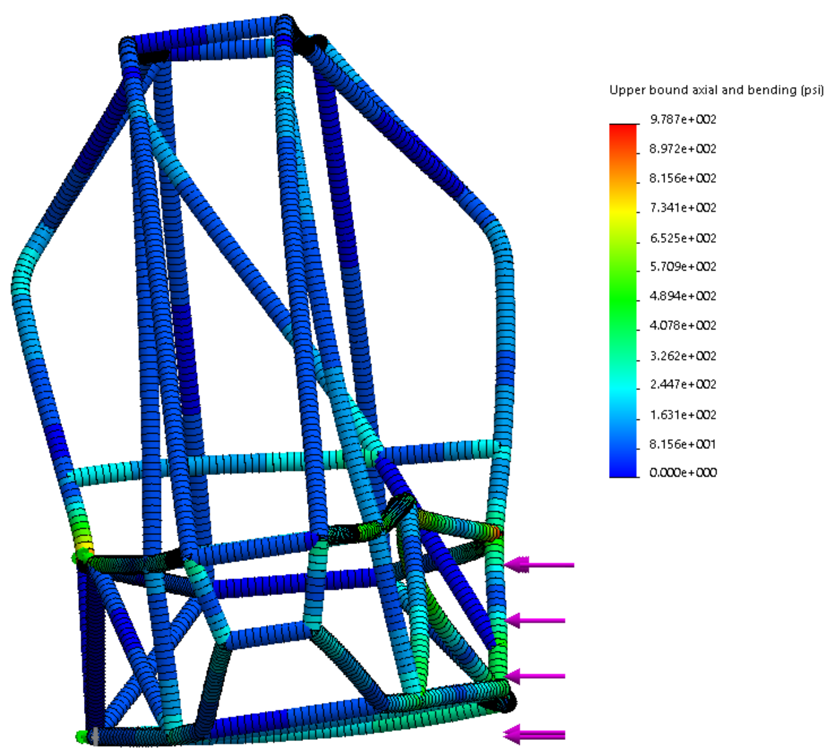

Figure 23: Front Bracing Stress Simulation Results form Side Impact Test.