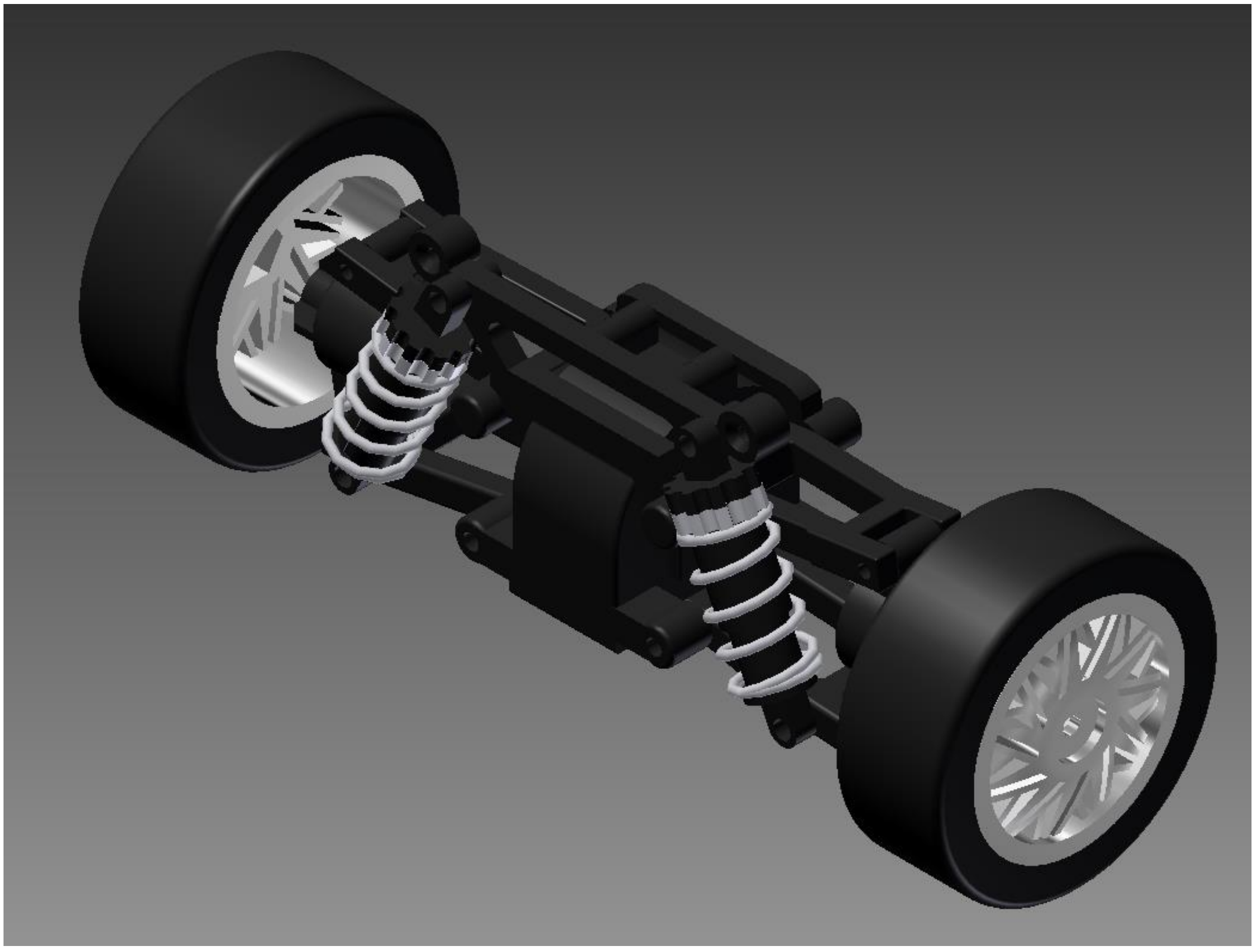
ME 4Z03
Final Project

Remote Control Car Rear Suspension



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Introduction

This final report for Mechanical Engineering 4Z03 will document the analysis of the stresses experienced in a dynamic motion simulation of a Tamiya TT-01 rear suspension. The scope of this report will be limited to the rear suspension and as a result, no other components will be analyzed.

I chose the Tamiya TT-01 for this project because I am currently using the chassis as a robotics platform for my Mechatronics Capstone Project. In this project we use the TT-01 as the base for a fully autonomous car system that can navigate a 3 lane, arbitrary track with randomly placed obstacles to avoid in any of the 3 lanes. I was also very interested in gas powered remote control cars when I was younger so I thought choosing this project would be a fun and interesting way to learn and practice some practical CAD skills.

Background

The Tamiya TT-01 is a very popular and inexpensive 1/10 scale remote control car that is raced extensively around the world in competitions and recreationally. The TT-01 comes in many different kit versions that are used for drifting and racing. Each version also comes in different upgrade levels that include aluminum parts, metal bearings, oil filled shocks etc. The version that I have decided to model and perform analysis on for this project is the lowest level model and thus, nearly all parts are made from plastic. Below you can see the car in its entirety as well as a close up of the rear suspension that will be modeled in this project.

Figure 1: TT-01 Chassis

Source: (http://upload.wikimedia.org/wikipedia/en/a/a8/Tamiya_TT-01D_Chassis.jpg)

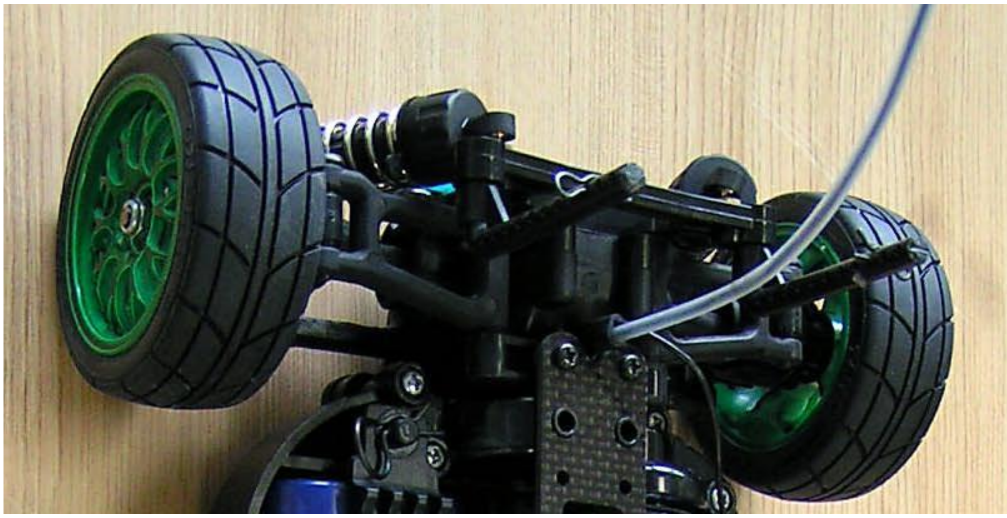

Figure 2: TT-01 Rear Suspension

Source: (http://oyajippa.up.seesaa.net/image/TT-01hatu.jpg)

Objective

The objective of this project is to determine where the greatest stress is experienced in the bottom back a-arm. This will allow me to determine if it is possible to increase the strength of this part without adding significant mass to the part. This analysis will be conducted by constructing the entire rear suspension system so that I can model the complex interactions between parts in the system. Once the rear suspension is modeled I will then analyze the forces experienced in an extreme but real life scenario. This scenario will be simulated using a cyclic load applied to both rear wheels of the car. Since I will be analyzing the basic geometry and "design style" for obvious optimization locations, the model will not reflect the real car's measurements exactly but will be as close as possible.

Parts

Bottom Back A-Arm

The bottom back A-Arm is made from ABS plastic and was created by extruding the a-arm shape and then extruding the posts and holes.

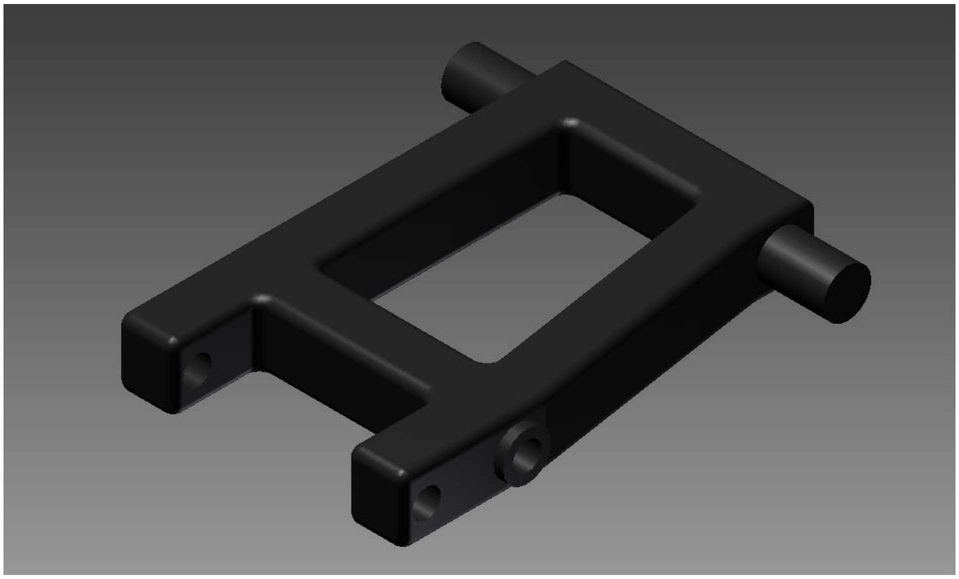

Figure 3: Bottom Back A-Arm

Top Back A-Arm

The top back A-Arm is made in exactly the same way as the bottom back a-arm, from ABS plastic and was created by extruding the a-arm shape and then extruding the posts and holes.

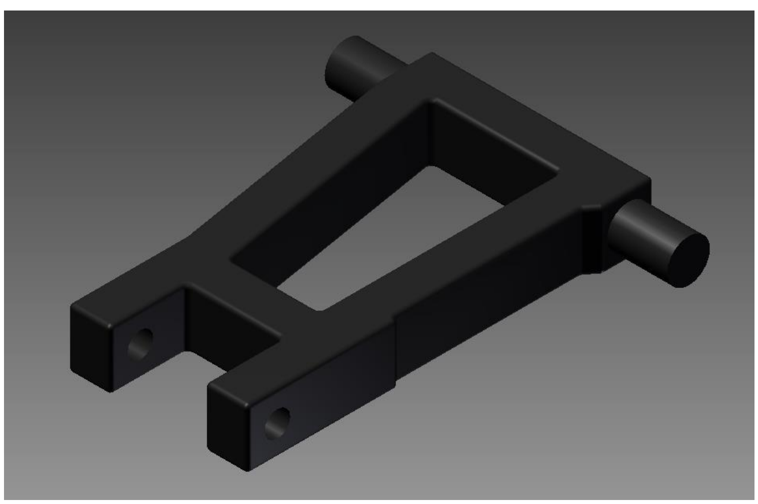

Figure 4: Top Back A-Arm

Rear Knuckle

The rear knuckle connects the top and bottom a-arms with the wheel while allowing for rotation of the wheel and suspension travel at the same time. This part was made using ABS plastic and was created using various extrusions and cutouts. These dimensions can be seen in Appendix A.

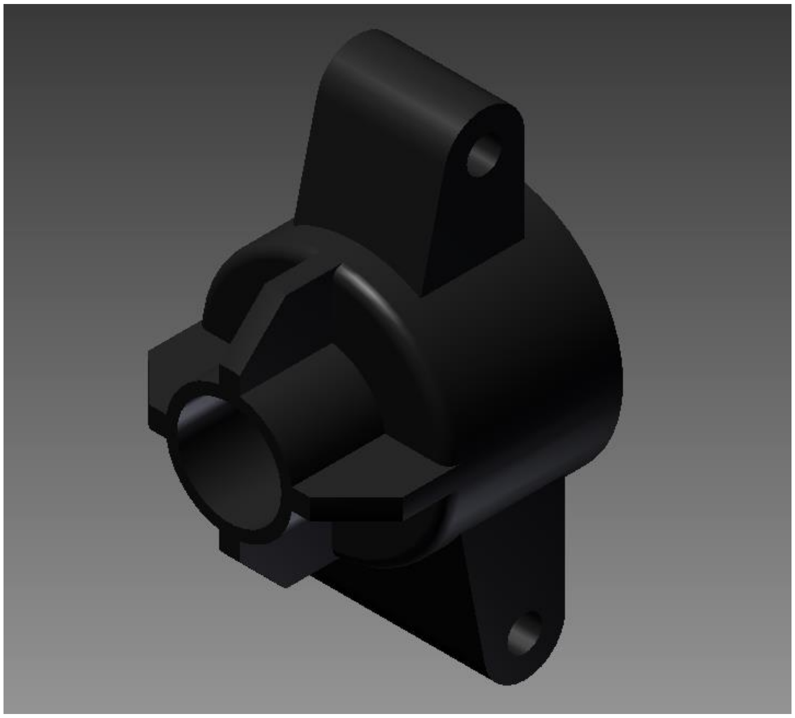

Figure 5: Knuckle

Tire

The tire was created from ABS plastic and a revolution was used to create the shape. These dimensions can be seen in Appendix A.

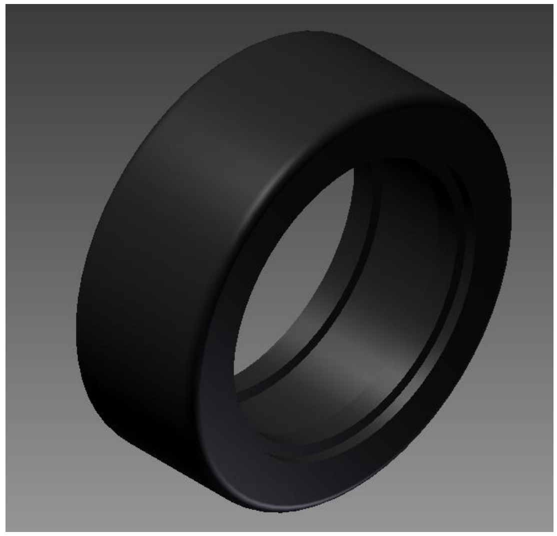

Figure 6: Tire

Rim

The rim was a very complicated part to make and was created using a revolution to make the actual rim profile and a patterned cutout to make the spokes. The rim was made from ABS plastic but was rendered with a chrome finish.

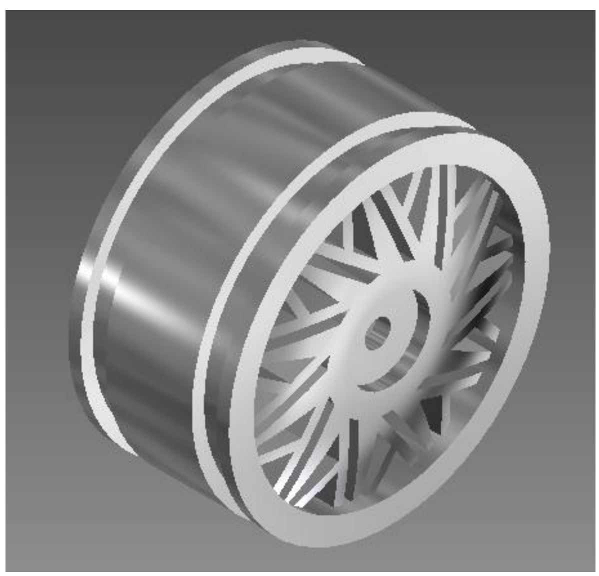

Figure 7: Rim

Shock Top Cap

The shock top cap allows for the shock assembly to mount to the top shock bracket and provides a flat surface for the top of the spring to press against when compressed. This part was made from ABS plastic and was created using multiple extrusions.

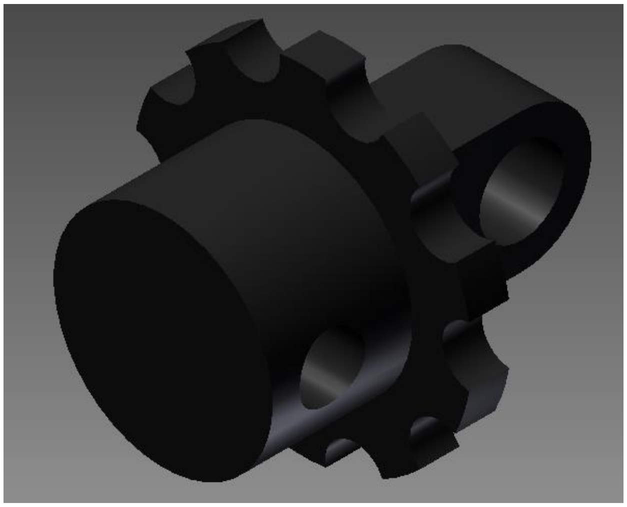

Figure 8: Shock Cap

Shock Middle

The middle piece of the shock is the female connection to the shock bottom. This cylinder is keyed as can be seen below; this prevents the shock from twisting during compression. This part is made from ABS plastic and created using a series of extrusions and cuts.

Figure 9: Shock Middle

Shock Bottom

The shock bottom is the male connection to the shock top. It slides within the shock top and has the opposite key feature that prevents twisting. The shock bottom also provides a connection to the bottom back a-arm and a flat surface for the spring to rest against while in compression. This part was made from ABS plastic and was created using a series of extrusions and cuts.

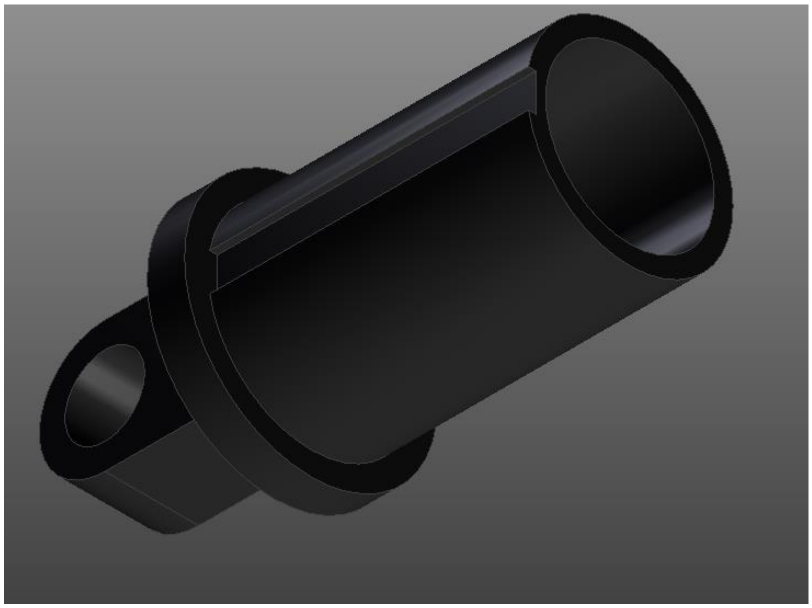

Figure 10: Shock Bottom

Rear Differential Box 1

The rear differential box 1 is a very complicated part because it connects with both top a-arms, both bottom a-arms as well as the 2 shocks. The differential box also connects to the body risers and houses the actual differential but these parts are not included in this report. This part was created using many extrudes and cuts from many different faces to create the part you see below. This part was made from ABS plastic.

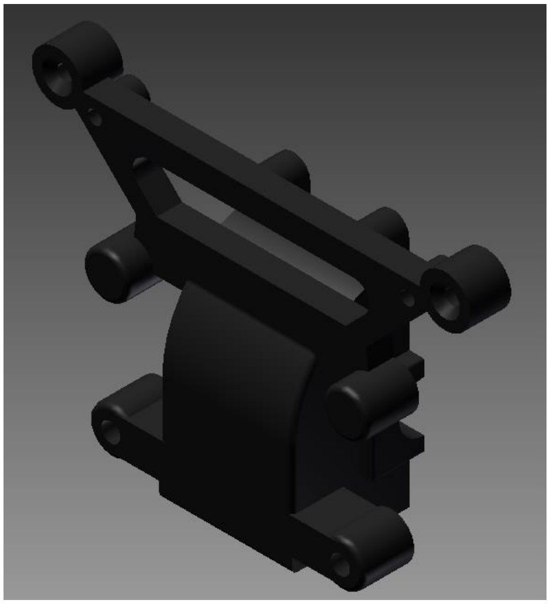

Figure 11: Rear Differential Box 1

Rear Differential Box 2

The rear differential box 2 is exactly the same as the rear differential box 1 but the shock risers are cut off. This was an easy way to make both sides of the part symmetrical without having to create an entirely new part from scratch. This part is made from ABS plastic.

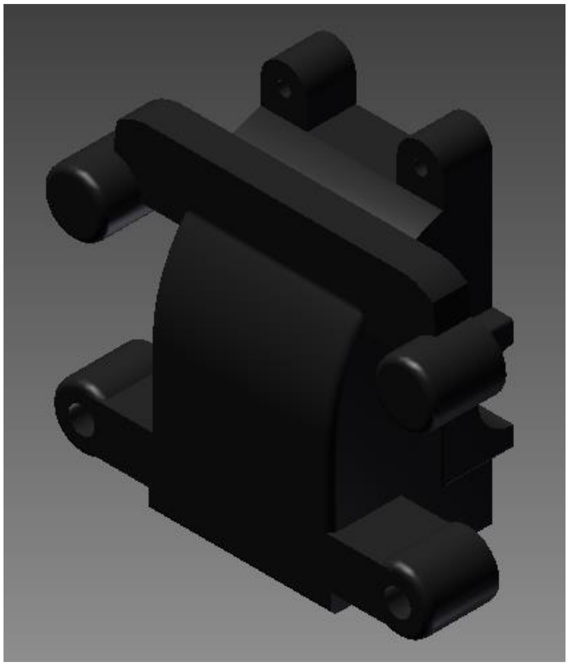

Figure 12: Rear Differential Box 2

Assembly

Shock Sub-Assembly

As you can see below the shock sub-assembly consists of the shock cap and the shock middle. The shock bottom is not included in this sub-assembly because it was easier to add it to the full assembly later as it made the joints easier to define in the dynamic simulation. The cap was connected using two mates between the face of the cap and the face of the middle piece and two edges between the cap and middle piece.

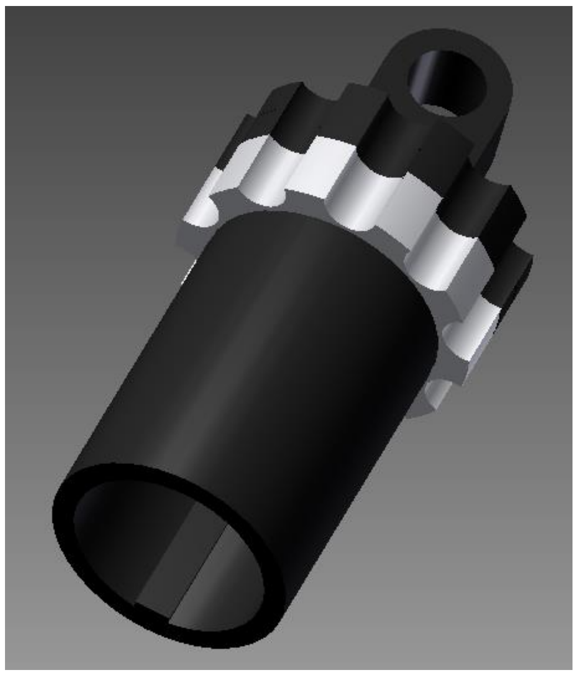

Figure 13: Shock Sub-Assembly

Rear Differential Box Sub-Assembly

The rear differential box sub-assembly was just the connection of the two parts using two mates.

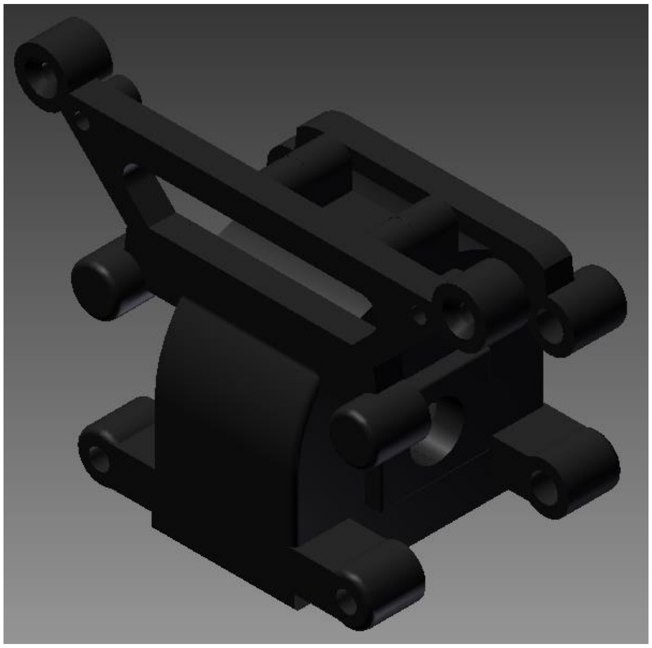

Figure 14: Rear Differential Box Sub-Assembly

Wheel Assembly

The wheel sub-assembly was just the connection of the tire and rim.

Figure 15: Wheel Sub-Assembly

Total Assembly

As you can see below the total assembly was a very complicated endeavor involving many parts. Most of these parts were connected as hinges using a surface mate between the pin and sockets. Another mate was added between the two faces of the side of the pivots to constrain the movement axially. There is no spring component because these were simulated in the dynamic simulation environment using a spring/damper joint on the axis of motion of the shocks.

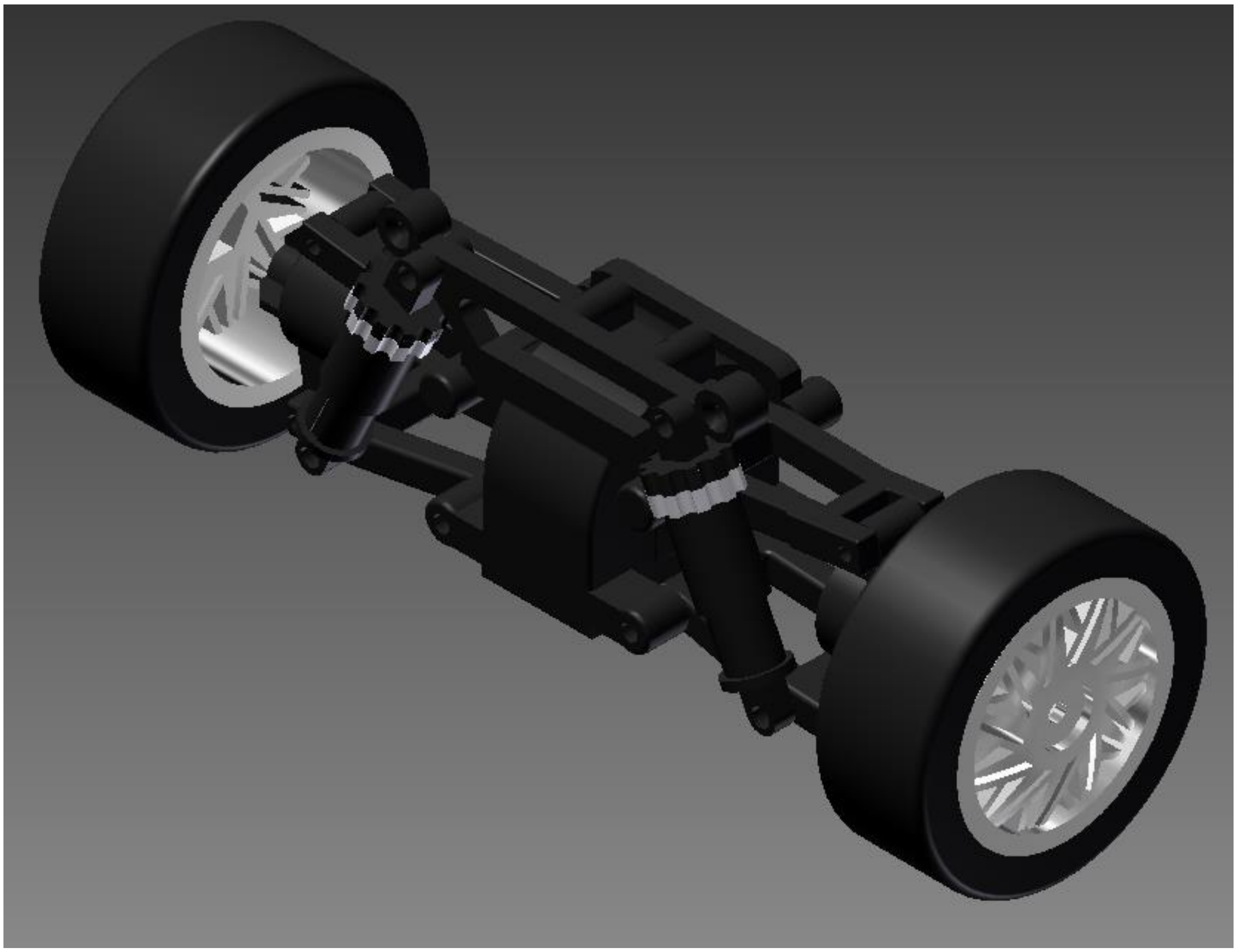

Figure 16: Total Assembly

Animations

Exploded View Animation

An animation of the assembly process is contained in the project folder and is named “exploded.avi”

Dynamic Simulation

A video of the dynamic simulation taking place over 2 seconds is contained in the project folder and is named “dynamic.avi”

Dynamic Simulation

I performed a dynamic simulation by applying a sine wave force of amplitude 50 Newtons and a frequency of 20Hz to the bottom of both wheel assemblies in the positive Y direction (UP). These simulations allowed me to trace the motion of the shocks to determine if they would collide with the shock head. As shown below, the total displacement of ~4mm is less than the allowed travel of ~8mm, thus the middle piece did not collide with the shock head.

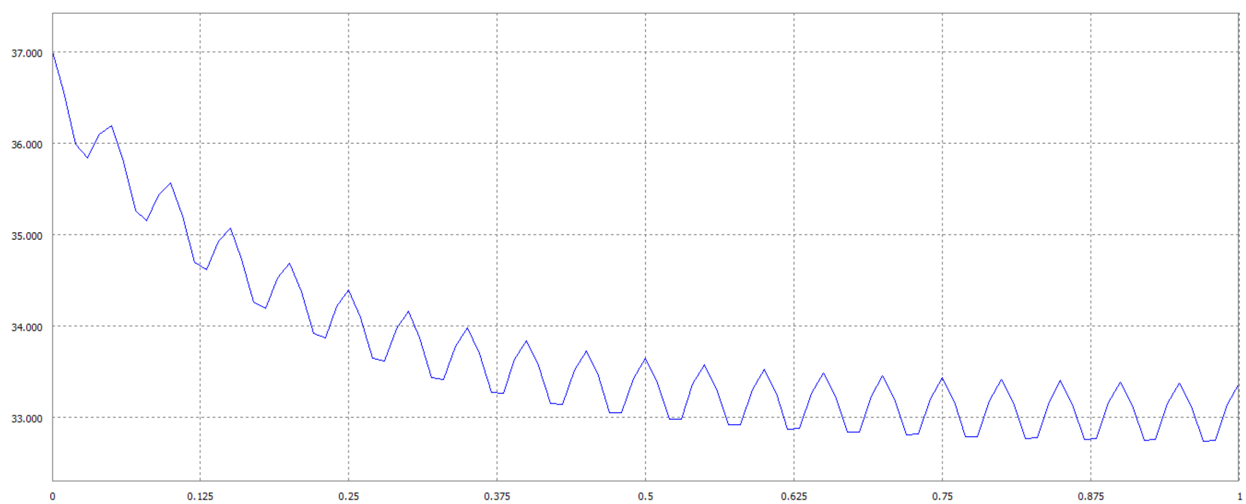

Figure 17: Shock Travel

As you can see above I started the simulation with a preload on the suspension, the system reaches steady state by around .75s this is why I decided to use 10 points from 0.90s to 1.00s for my FEA analysis.

FEA Analysis

FEA analysis was performed by exporting 10 points from the dynamic simulation from .90s to 1.00s. This resulted in the loss of point .96 because the inclusion of .96s would result in 11 points. I have no idea why inventor decided to remove point .96s. Below you can see the results of the FEA with the max and minimum stresses and safety factors and their locations shown on the picture. The displacement of the part can also be seen by comparing the colored area to the wireframe drawing overlaid. At 0.91s, 0.94s, 0.96s and 0.99s all have factors of safety of less than 1. This means the part will fail in these circumstances, this finding will be analyzed in the conclusion of this report.

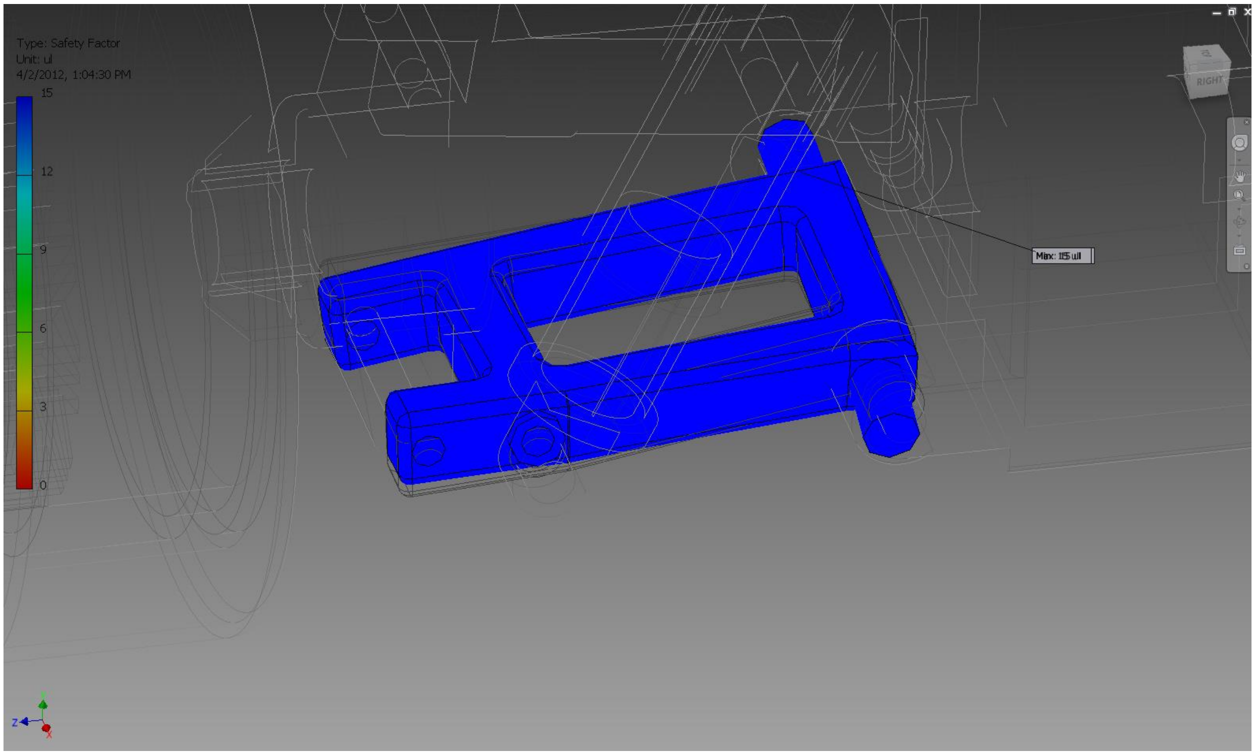

Figure 18: FEA at .90s (Safety Factor)

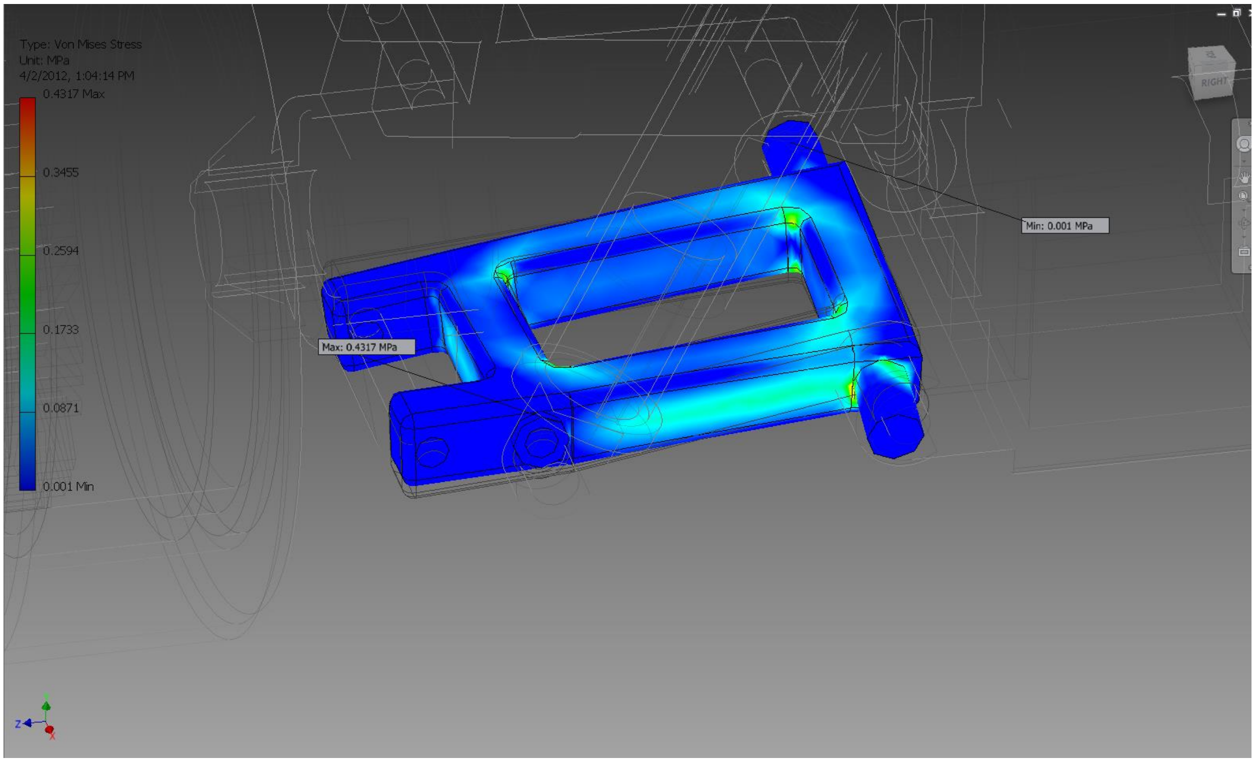

Figure 19: FEA at .90s (Von Mises Stress)

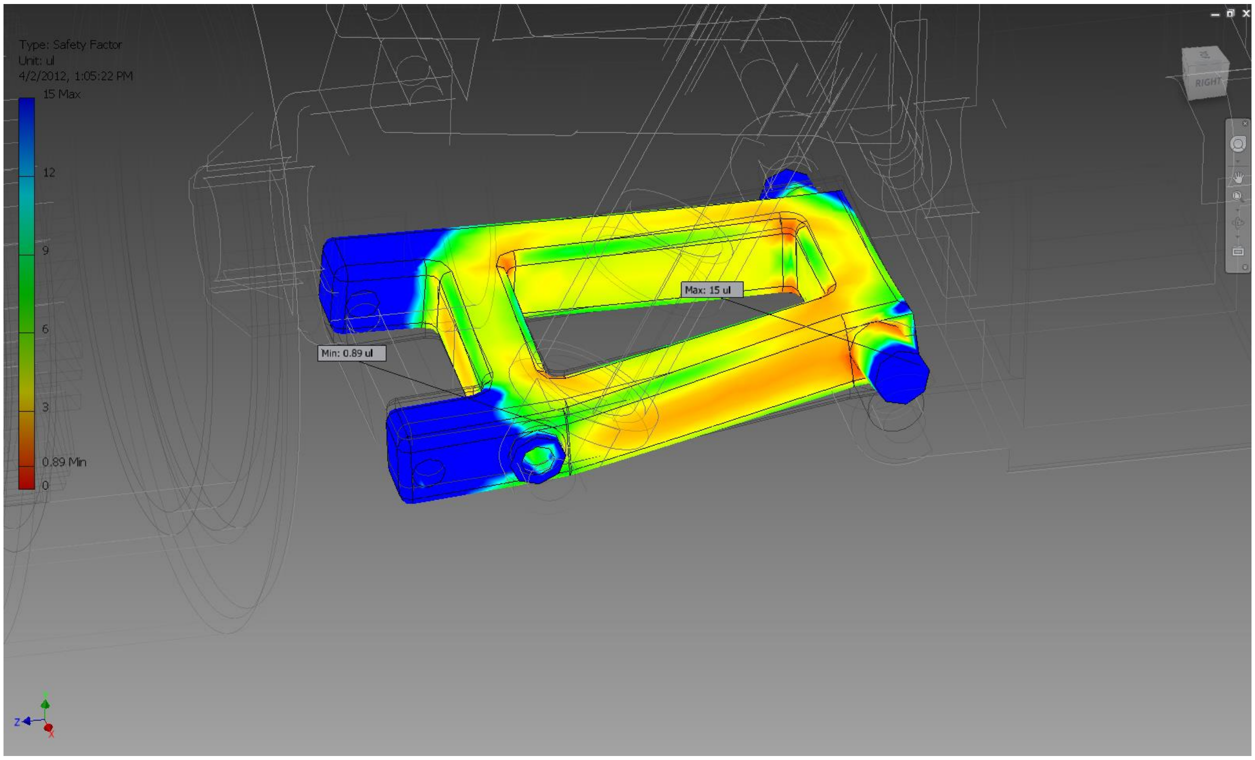

Figure 20: FEA at .91s (Safety Factor)

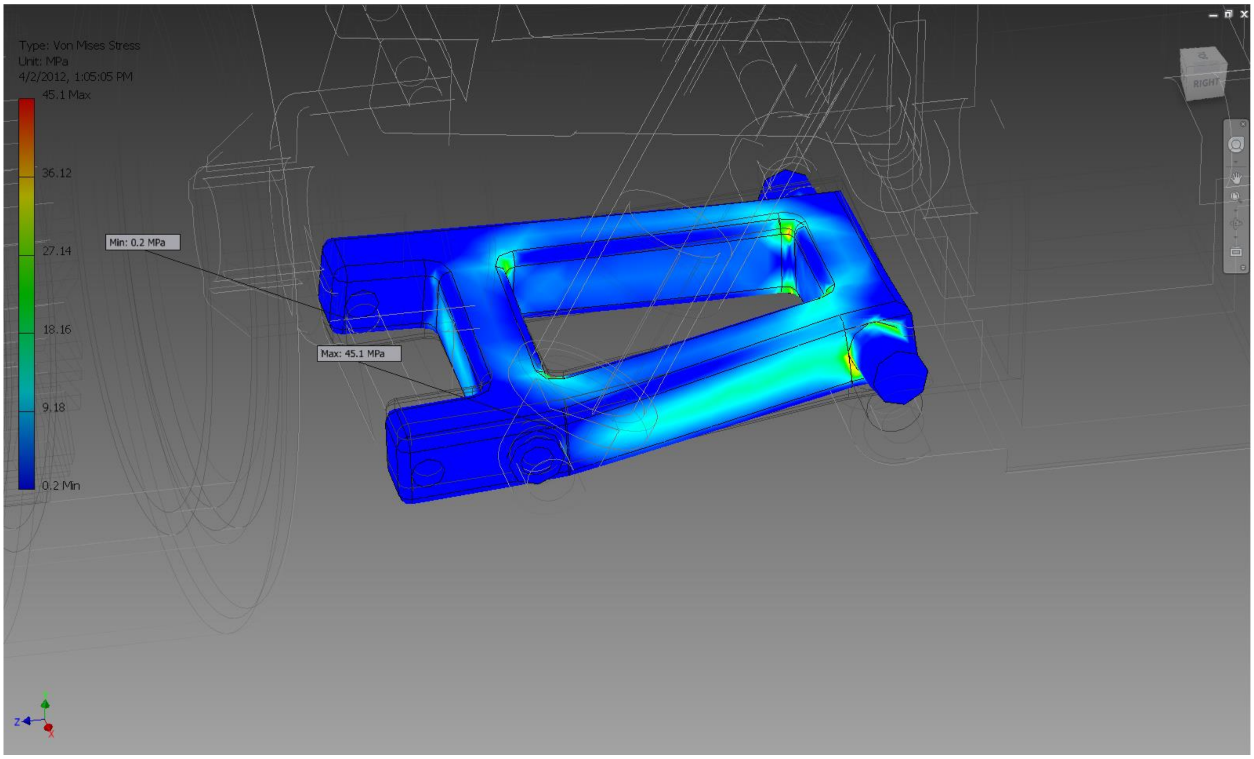

Figure 21: FEA at .91s (Von Mises Stress)

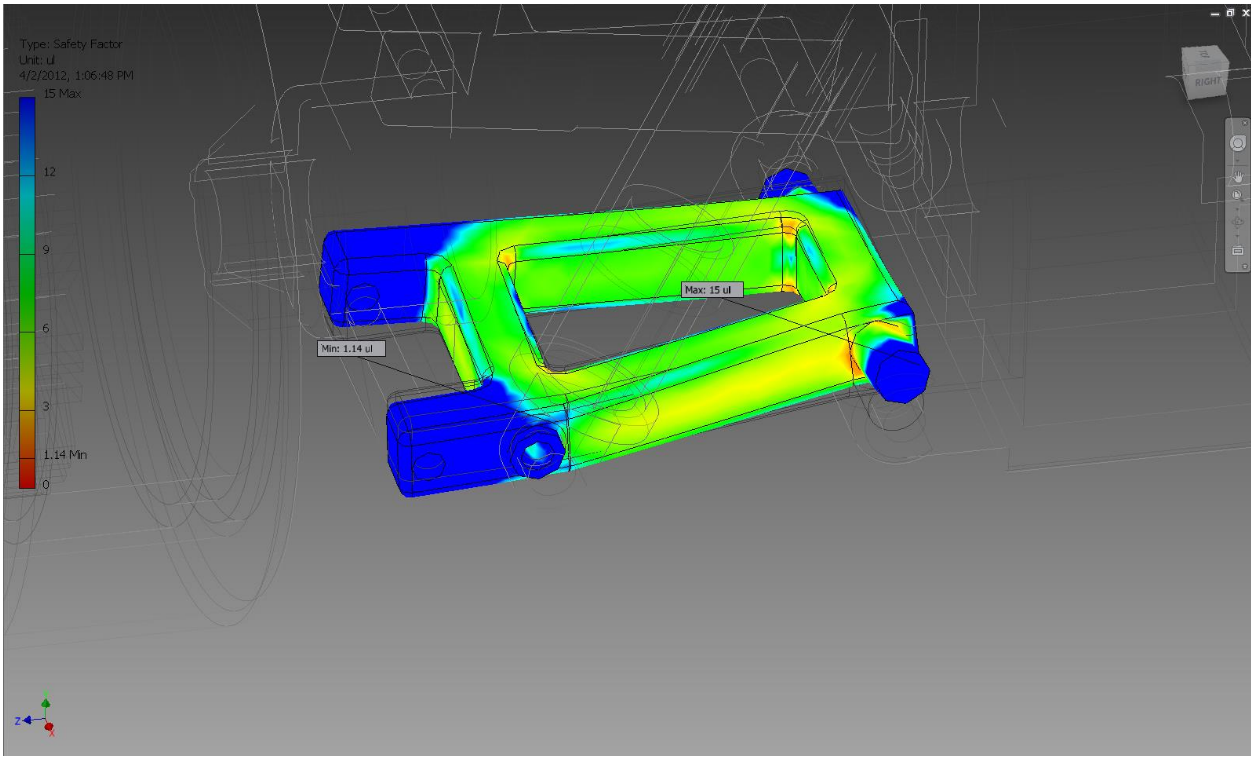

Figure 22: FEA at .92s (Safety Factor)

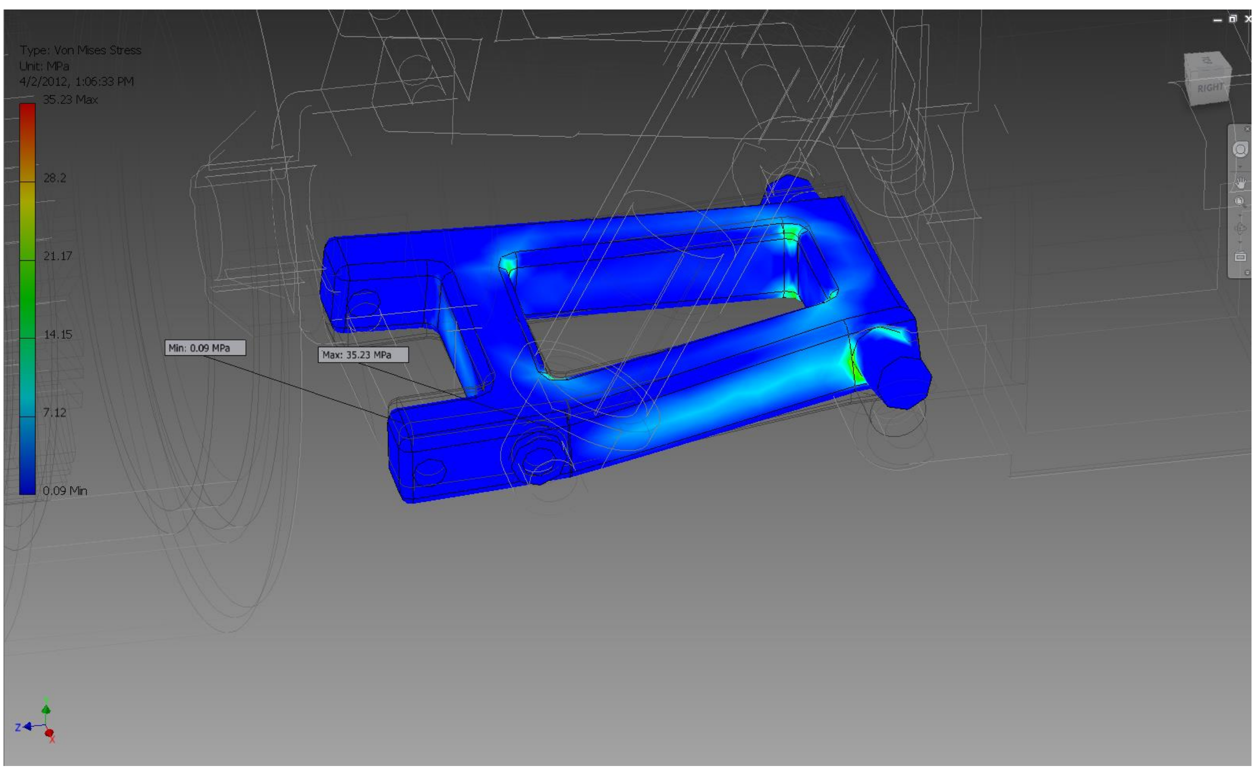

Figure 23 : FEA at .92s (Von Mises Stress)

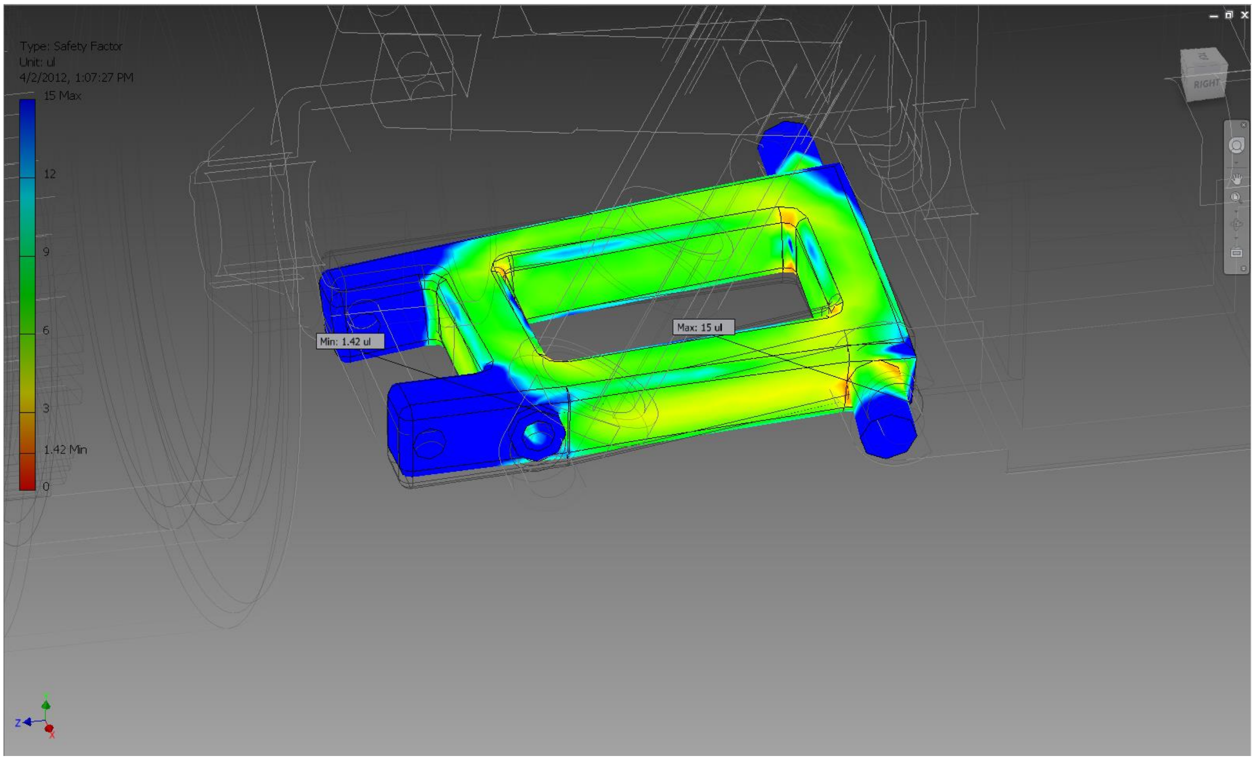

Figure 24: FEA at .93s (Safety Factor)

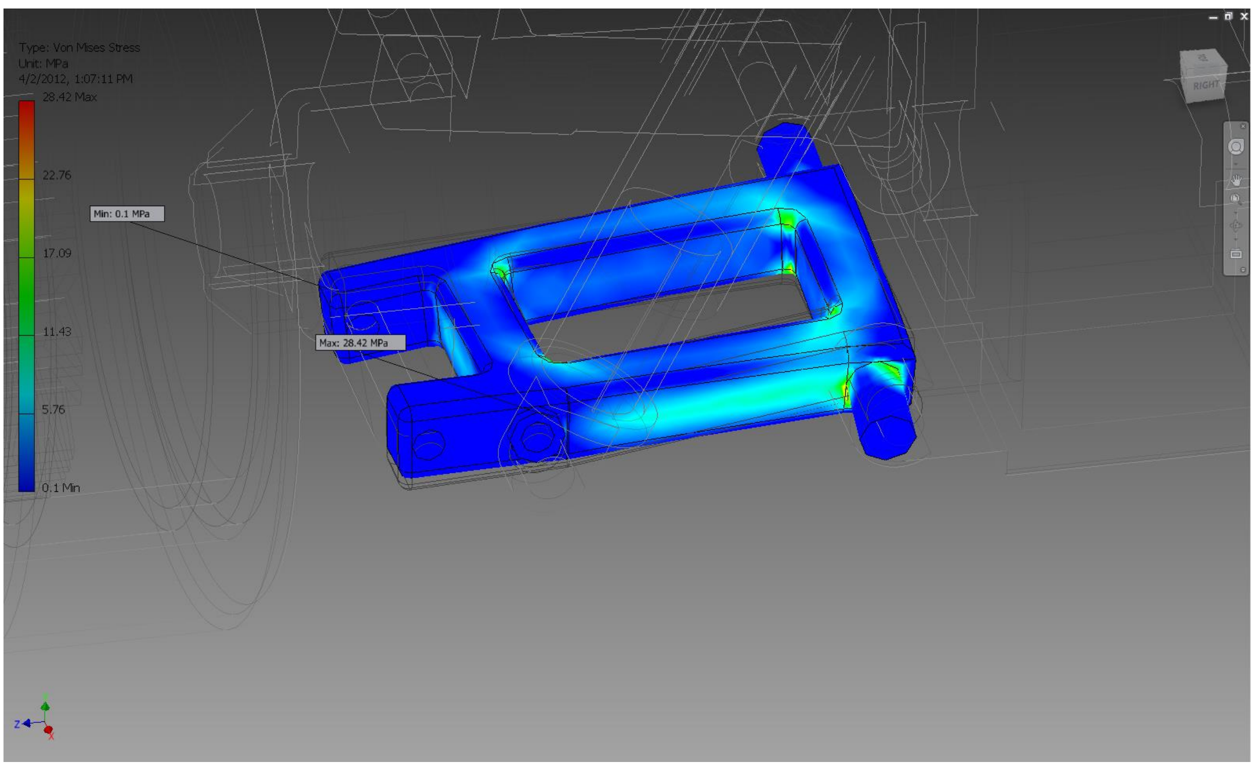

Figure 25: FEA at .93s (Von Mises Stress)

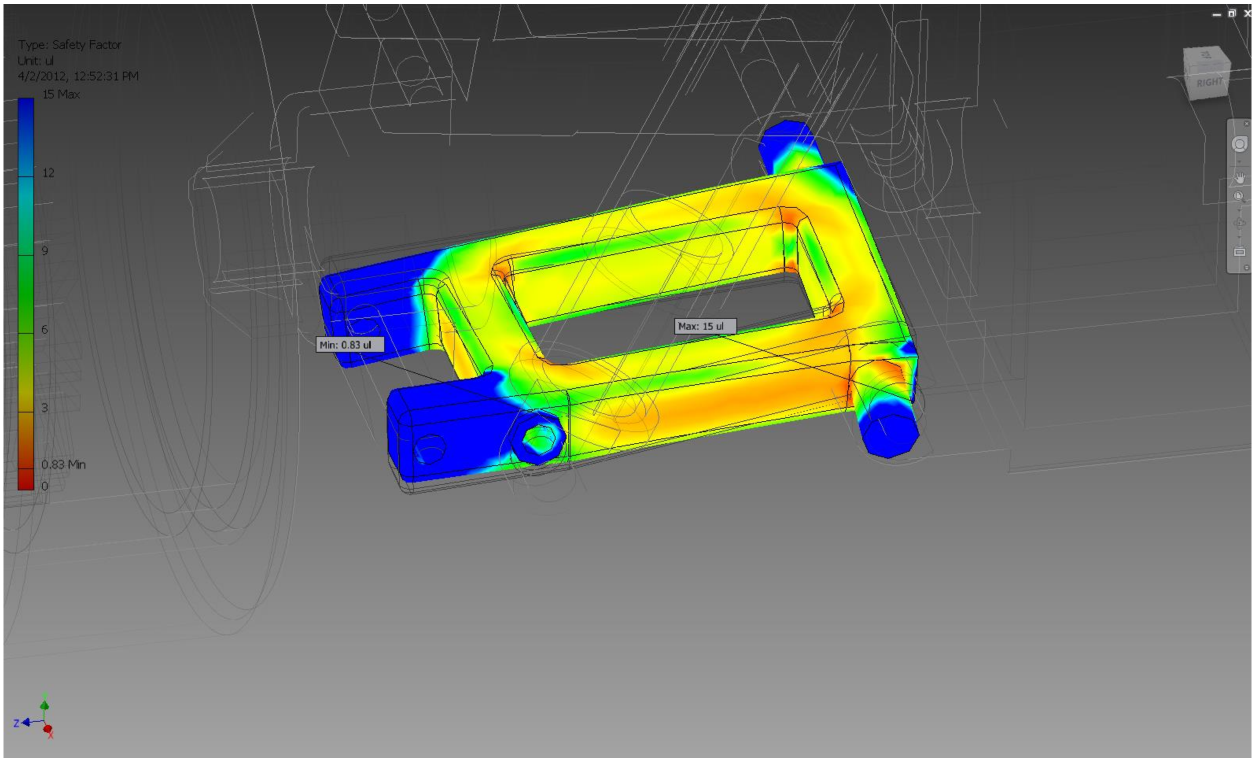

Figure 26: FEA at .94s (Safety Factor)

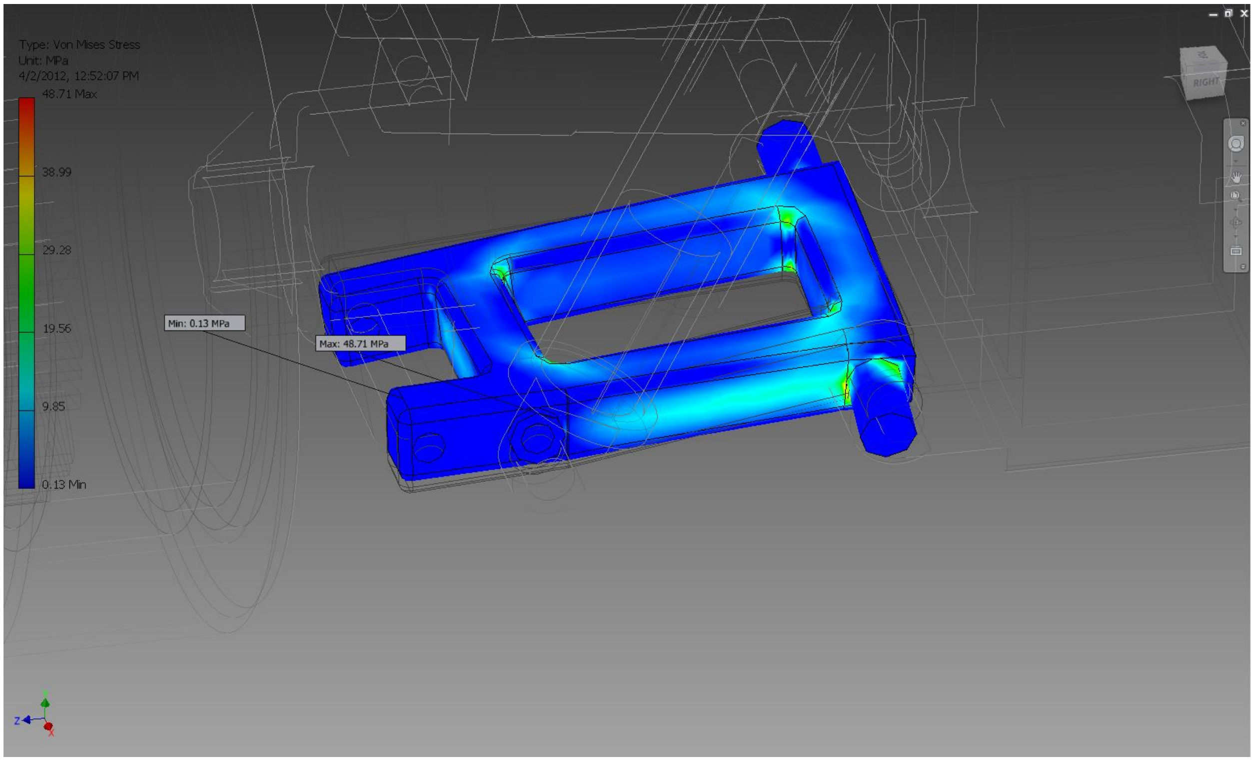

Figure 27: FEA at .94s (Von Mises Stress)

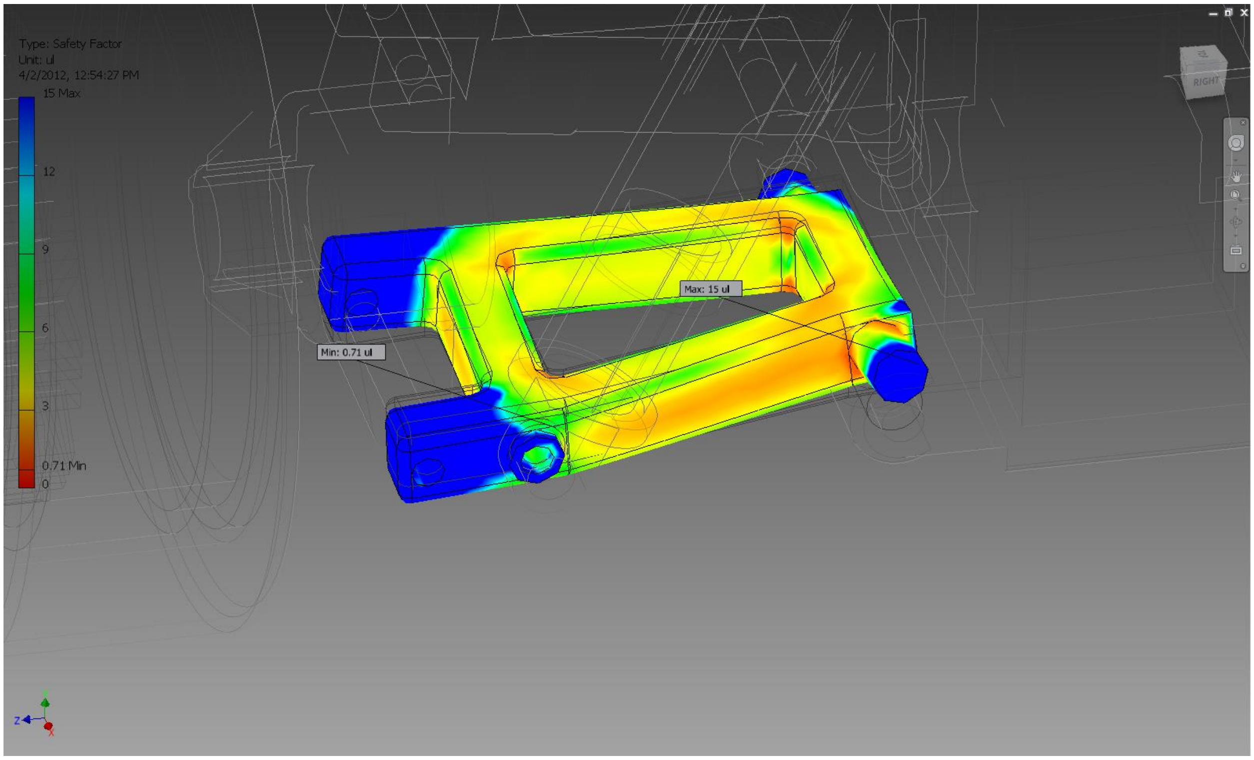

Figure 28: FEA at .96s (Safety Factor)

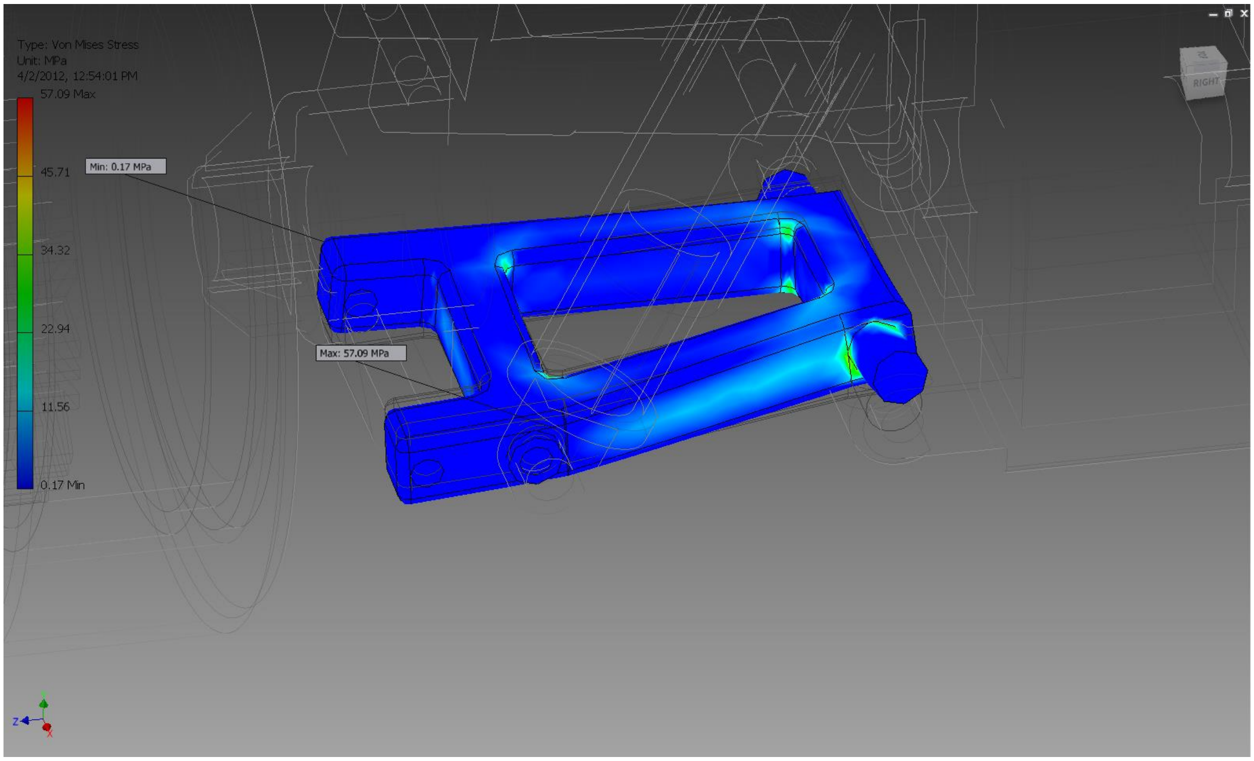

Figure 29: FEA at .96s (Von Mises Stress)

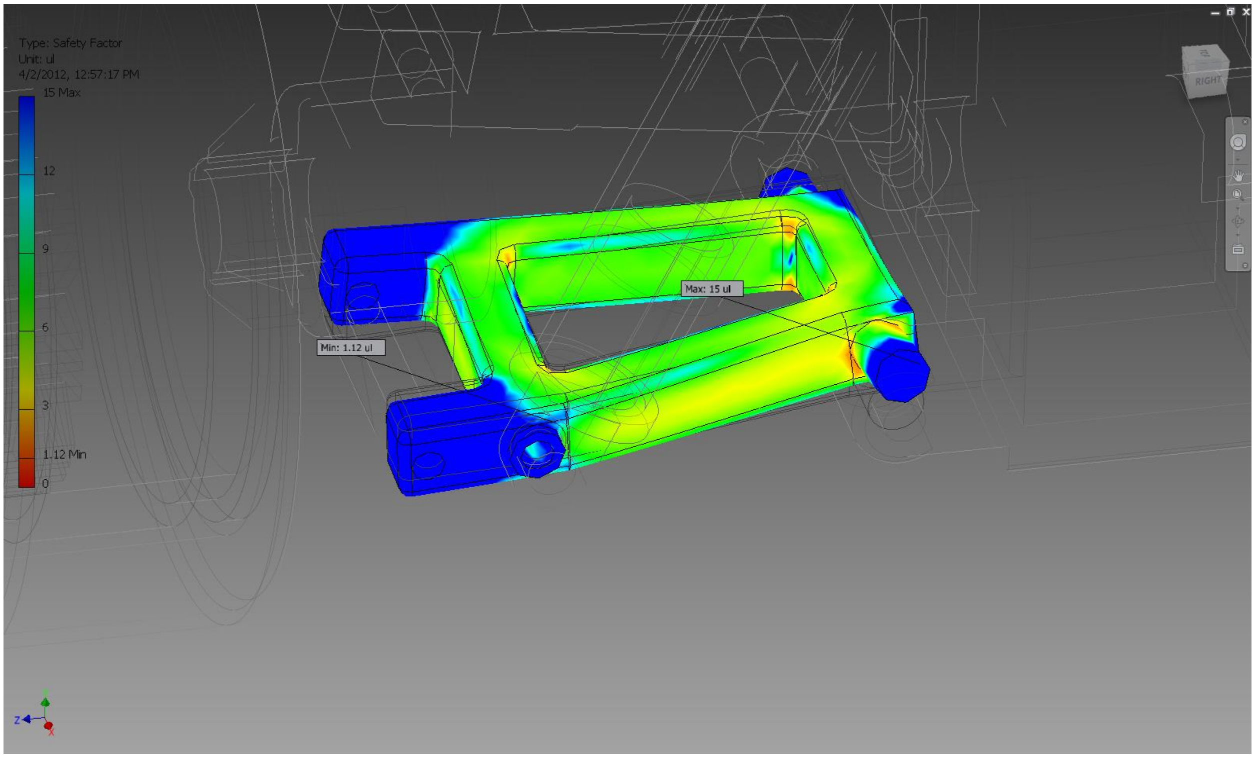

Figure 30: FEA at .97s (Safety Factor)

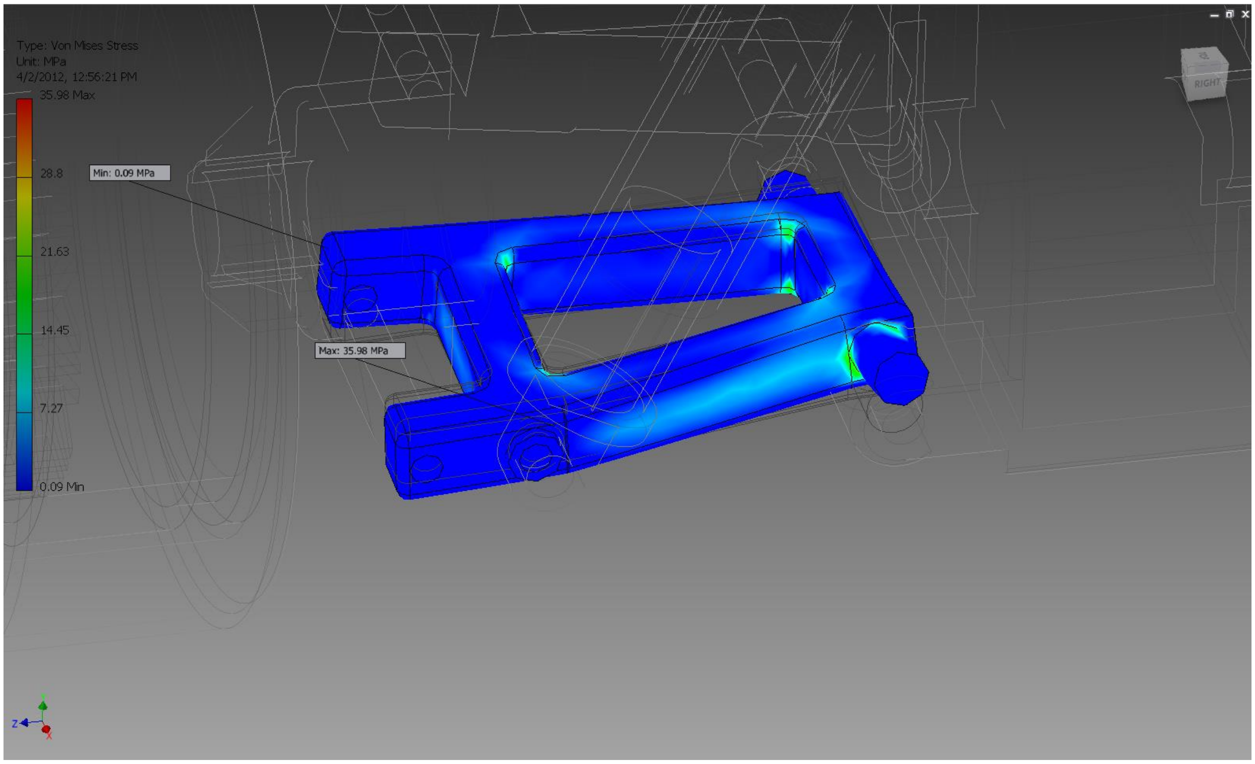

Figure 31: FEA at .97s (Von Mises Stress)

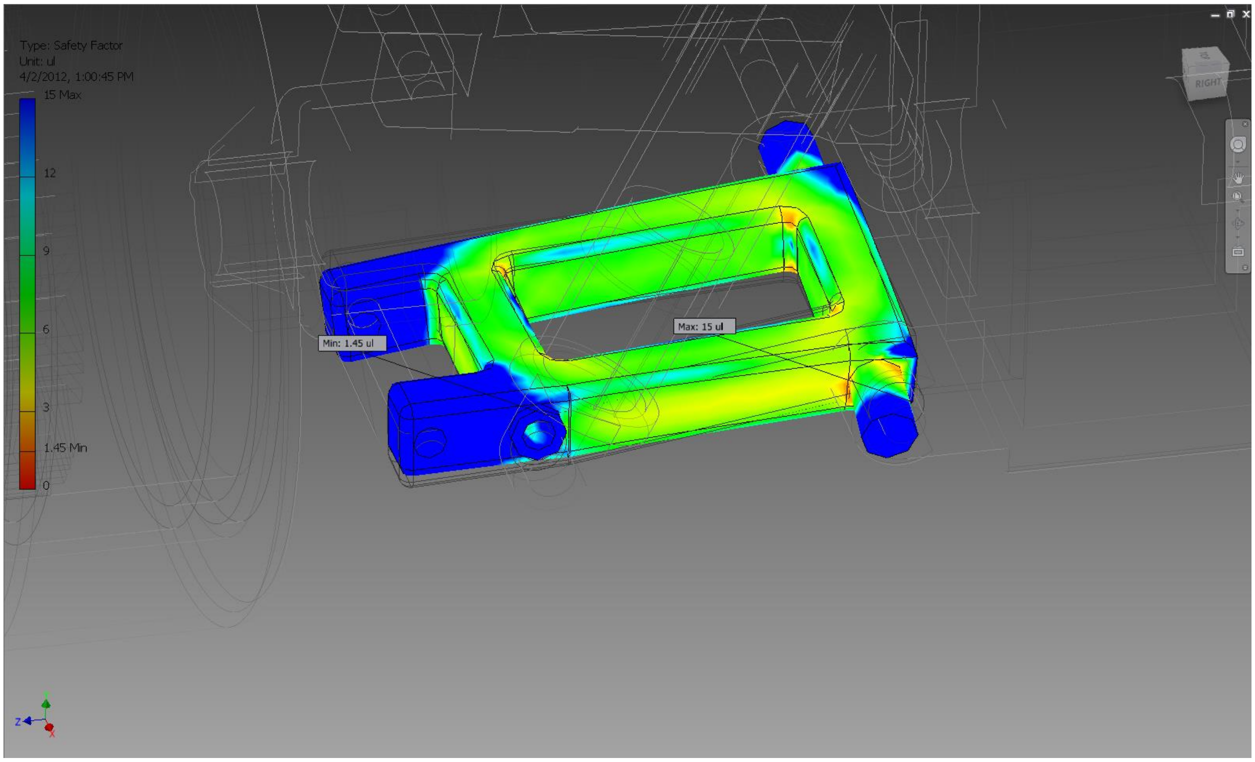

Figure 32: FEA at .98s (Safety Factor)

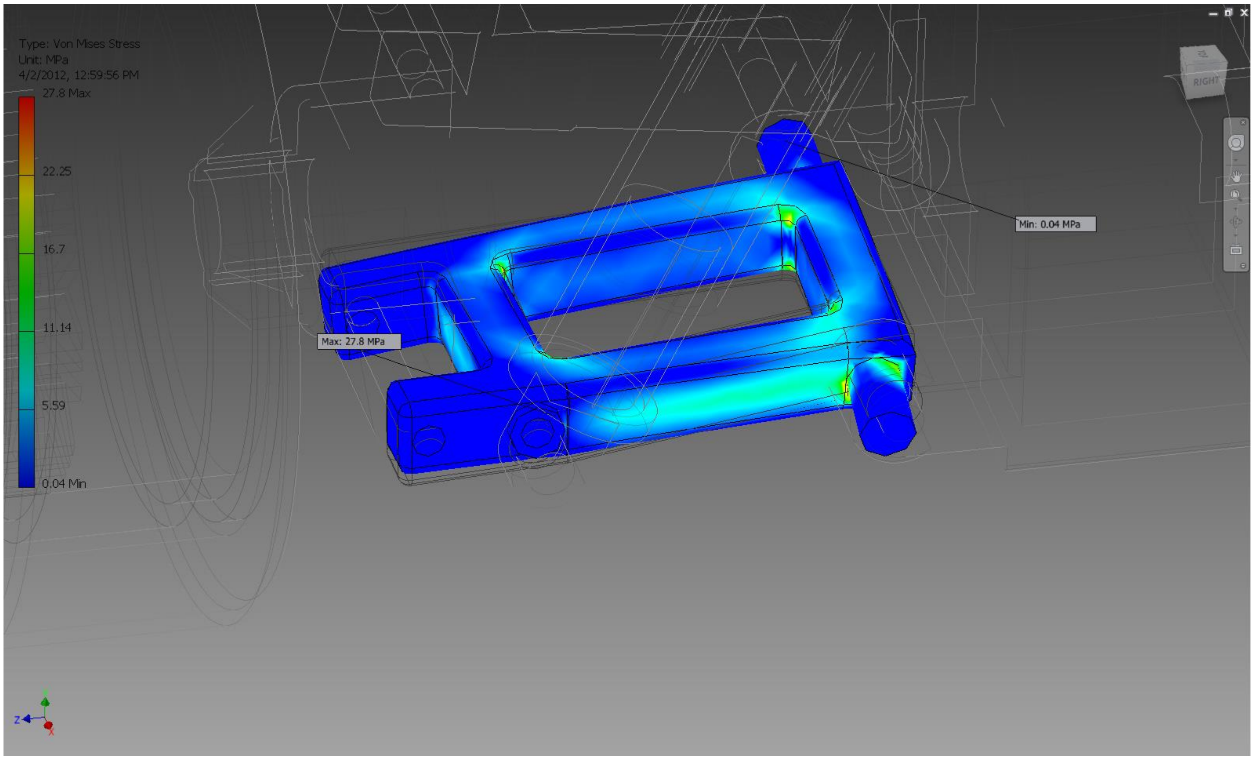

Figure 33: FEA at .98s (Von Mises Stress)

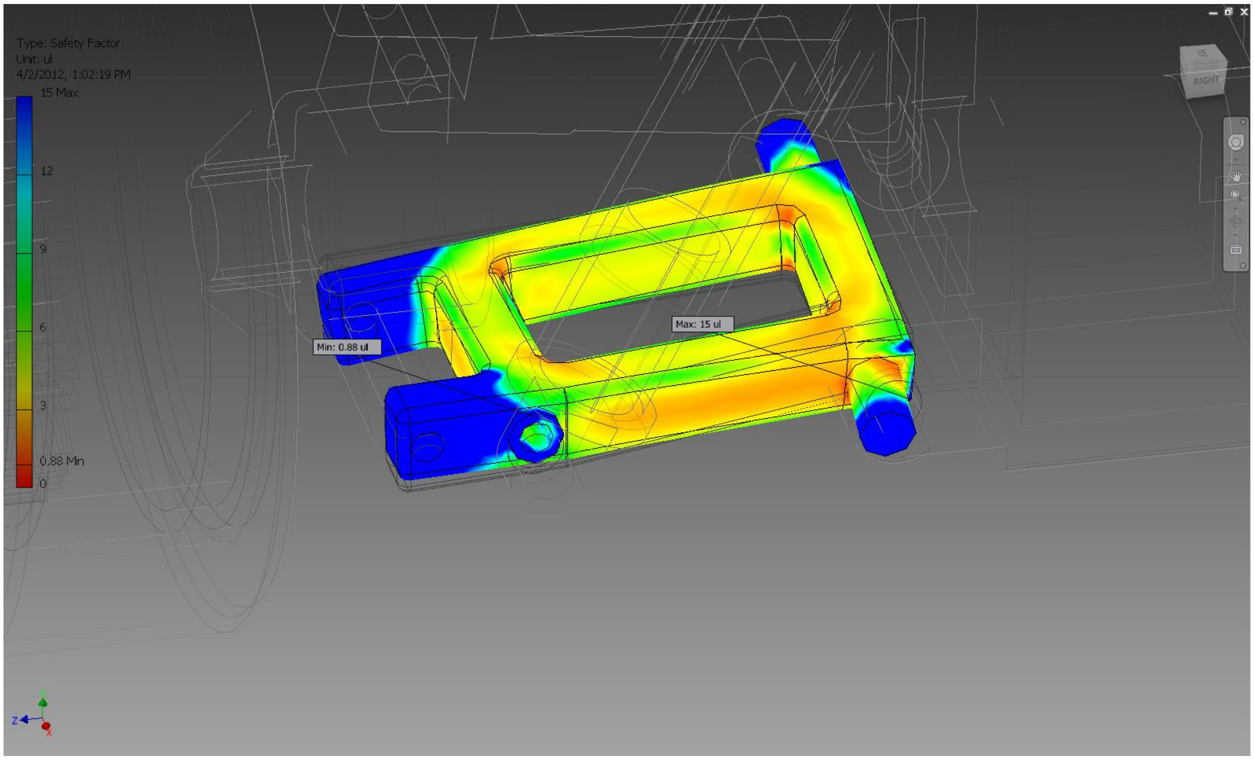

Figure 34: FEA at .99s (Safety Factor)

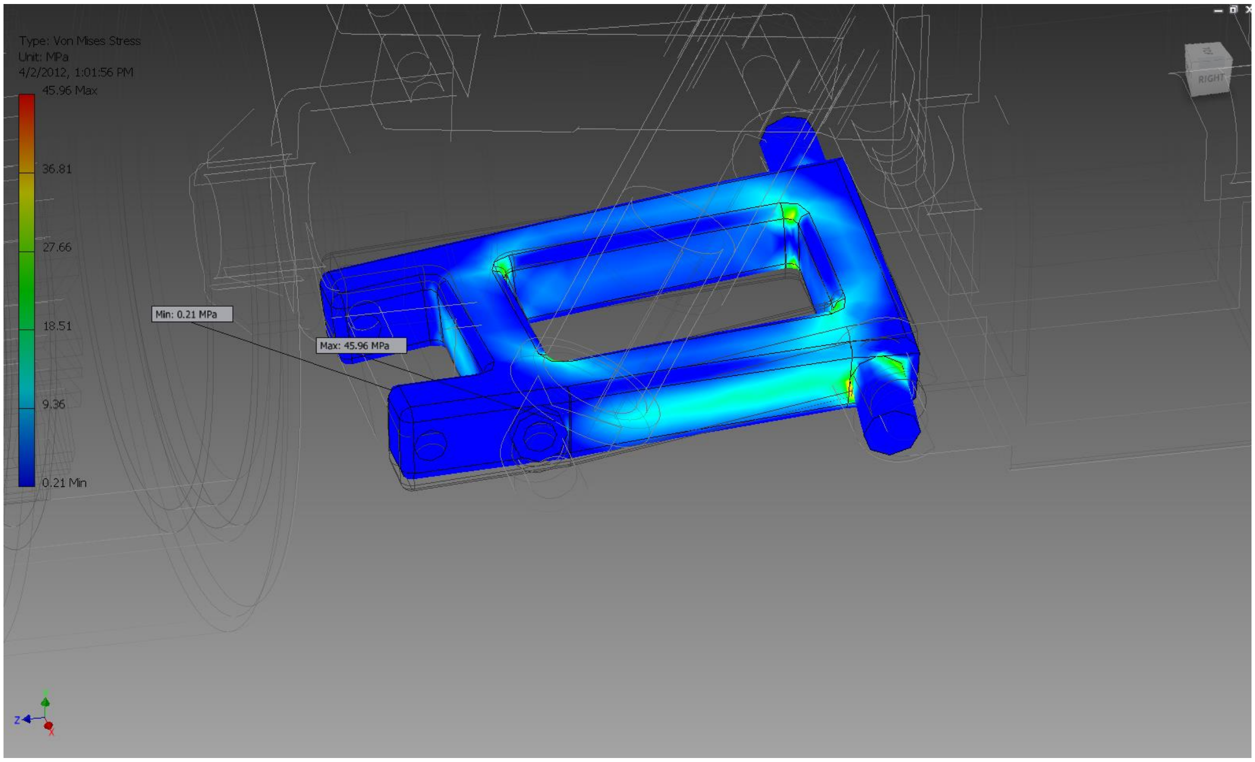

Figure 35: FEA at .99s (Von Mises Stress)

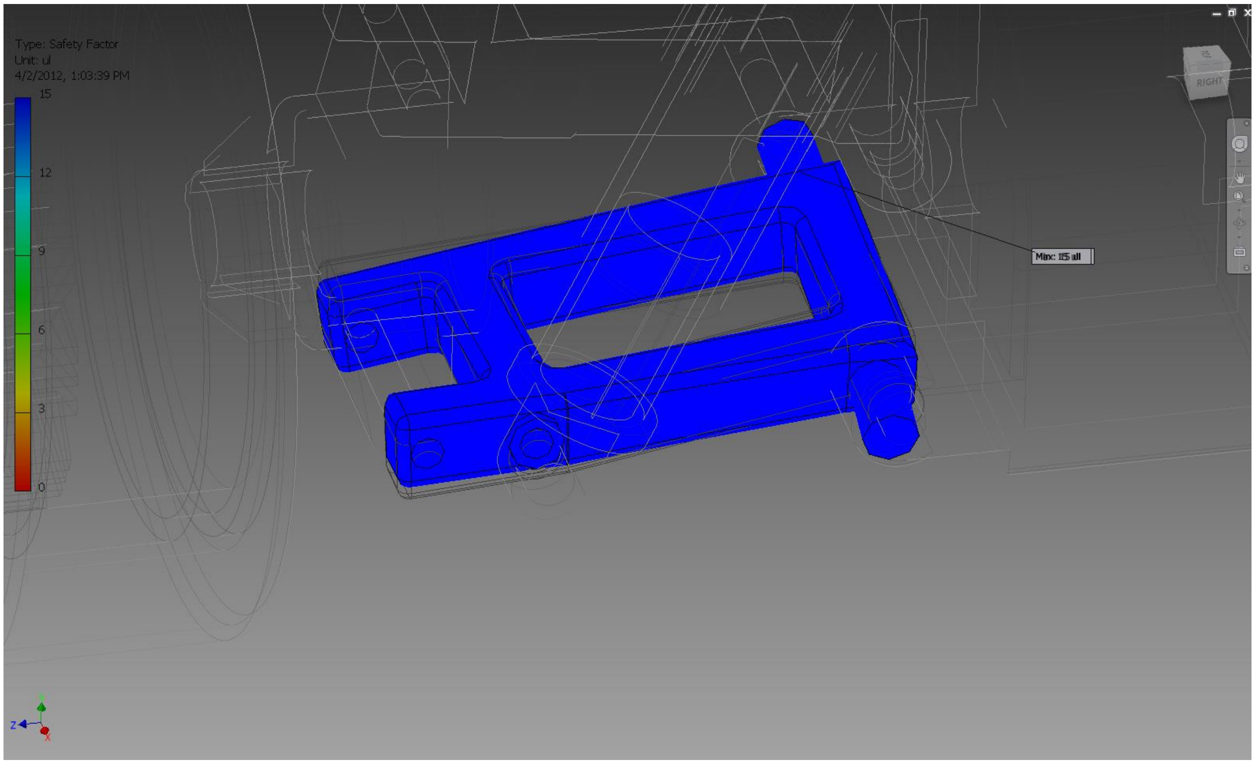

Figure 36: FEA at 1.00s (Safety Factor)

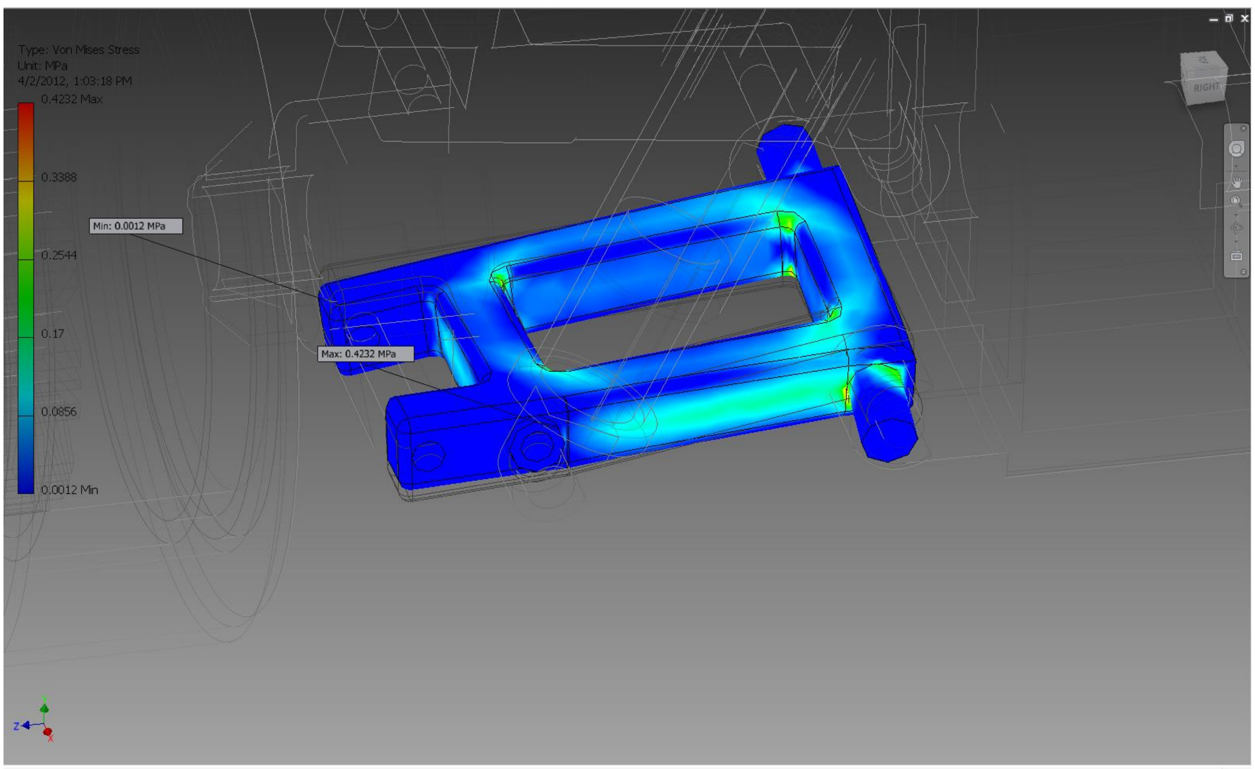

Figure 37: FEA at 1.00s (Von Mises Stress)

Conclusion

I have concluded that the stresses at all time intervals in the sine wave dynamic simulation result in maximum stresses at the same location. This location is the connection between the bottom shock piece and the bottom a-arm. This result is to be expected because the force of the entire shock is passed through that connection. I have also found that this part would not be able to survive a 20Hz sine wave of amplitude 50 Newtons, this corresponds to approximately 5.1kg or 11.2lbs so it is not an unreasonable amount of force. I expect that the fasteners used in the real car would provide added strength because they are made of steel and would fill the void of the hinge hole. If I were redesigning this part I would remove some material from the hinge pins and reallocate to the shock connection. Since there is very little stress on the hinge pins the safety factor would still be quite large and the safety factor of the shock mount location would be increased while keeping the same current weight. This modification would be very useful in race conditions where a strong, lightweight car can mean the difference between a win and a loss.