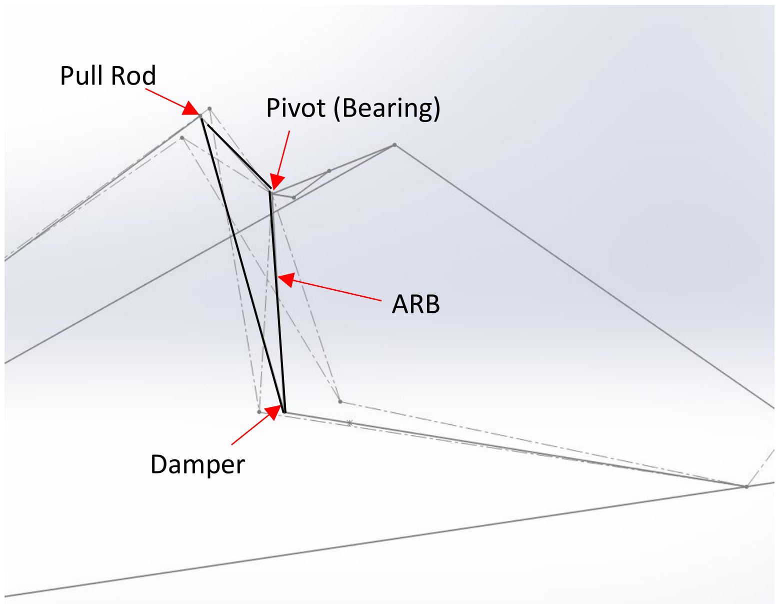
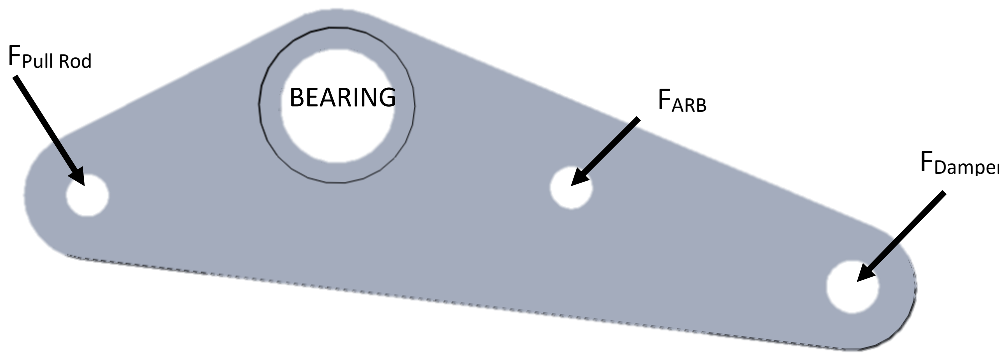
Rocker Optimization

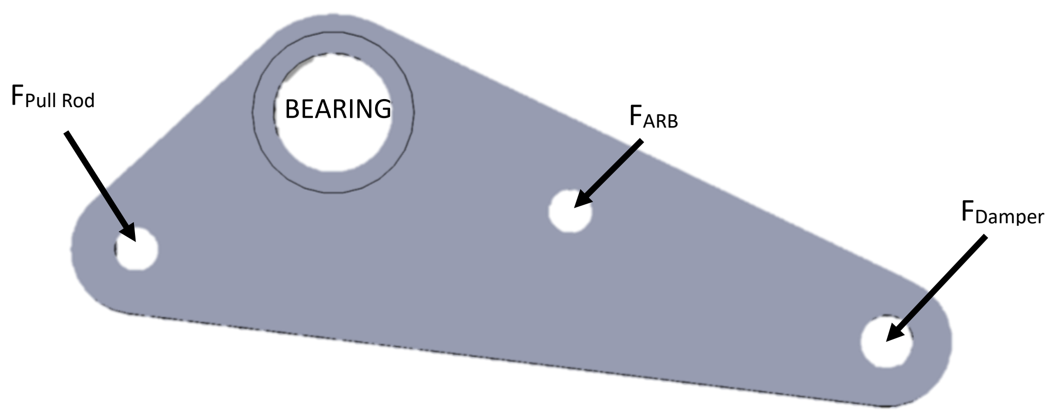
This report will break down the optimization process for the front and rear rocker. It will individually dive into suspension geometry, design goals, part optimization.

Predefined Geometry



Based on preexisting frame and suspension design choices the critical points for the rocker are predetermined in space. These critical points include where the center of the axis of rotation of the bearing is located. The mounting points of the pull rod, ARB, and damper. All of these mounting points are in a single plane and define the critical triangular aspect of the rocker. The mounting hardware the damper and rod ends define the height of the rocker. The bearing must also be a tall enough to accommodate the bearing. For the 2020 car we switched from dual opposing bearings to a single angular contact need bearing combination that is better suited for the loads this part sees, and is lower profile than the former years configurations, this allows the tabs to be moved in closer to each other. A flange is added to the bottom of the bearing mounting hole to help with location and retention. This defined the basic geometry pictured above.





Forces and Loads

The rocker sees loads applied from the pull rod, damper, and ARB, which are all in plane with the exception of the pull rod which sometimes is applying a force that is out of plane by a couple of degrees. These forces are modeled as their theoretical maximums during the simulation in order to create part that will be capable of withstanding worst case scenarios.

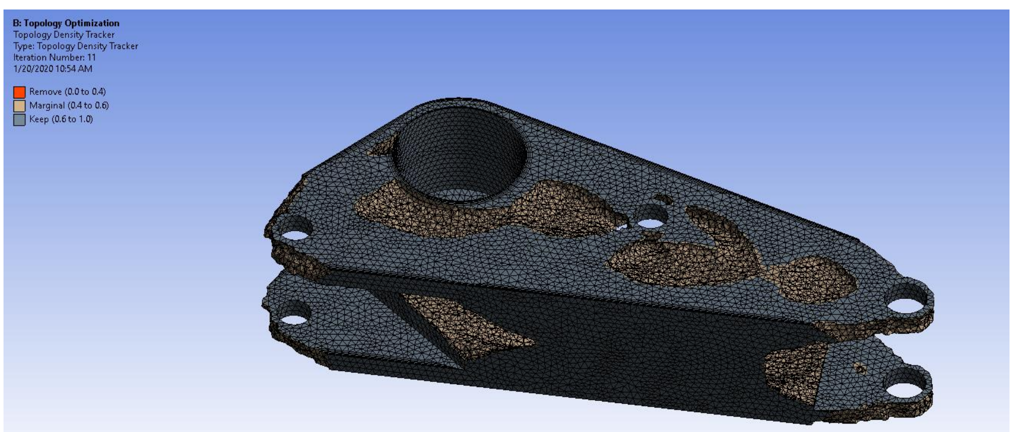
Modeling

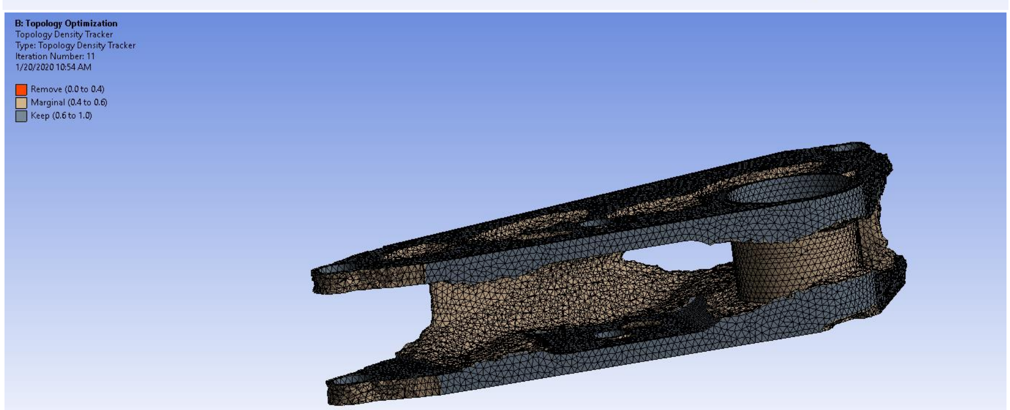
The static simulation of the loads on this part was created and solved in ANSYS 19 R2. An assembly was pulled from SOLIDWORKS with the rocker and parts to mimic the bolts where the rod ends and damper would normally mount. Having these mock bolts makes it much easier to apply loads in the same way as they would be on the real car. Bonded connections are specified between all faces of the bolt and the rocker that contact, starting with these as bonded makes running this much simpler and helps to avoid RBM. The mesh for these parts was tinkered with throughout running. Originally I started with a quad/hex type that prioritized tetrahedrons. I did eventually shift to an automatic mesh so that I could easily implement inflation around parts of the rocker that have a finer gradient of change. To do this I simply used ANSYS's built in inflation feature. I did also create multiple coordinate systems based around an origin at the center of the bore for the bearing and with a primary axis parallel to one side of the rocker. In my spreadsheet these are noted as “bearing origin 1” and “bearing origin 2” and it is specified for what items each one is used.

Topology

A topology optimization was first run on a simplified solid rocker, this made the initial decisions of where to take away material much easier and considerably cut down on the number of iterations needed create a sufficiently optimized. Further these initial decisions of where to make changes to tend to propagate though the whole project and thus having a validated starting point is critical. The amount of material to retain was exaggerated to be lower than it really should be to see more of the areas material would be removed some. Also because all the forces in this model are in plane the solver really wants to take material out of the middle area. However because on the actual car the forces are not always perfectly in plane this must be looked at more carefully. This is accounted for in a later static structural case where the pull rod force is out of plane as we would expect it to be during suspension travel.

The gray surface are those that are unchanged from the original model. The brown denotes faces that have had material adjacent to them removed. This helps to visualize the trends the topology is taking in material removal location.

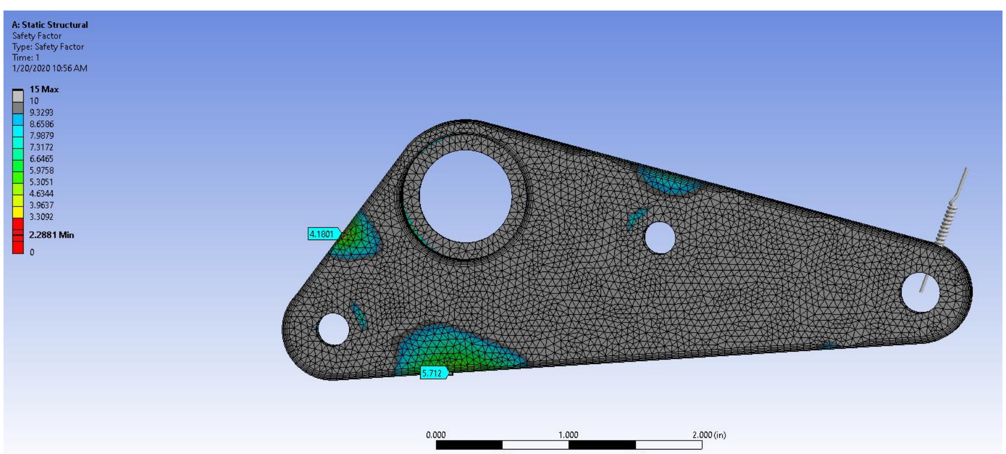


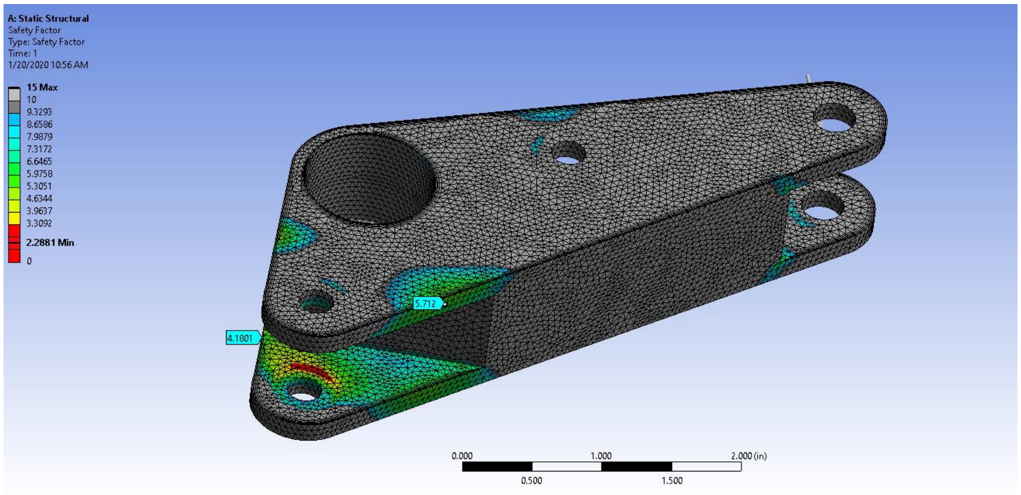


The optimizations above are created from a solid rocker and most of the mass is pulled from the middle before going to the top and bottom planes. Below are cases where a very aggressive optimization is run on a rocker with some material already removed? Again these are far more aggressive cases than you would actually want however they do make it easier it see where the best places are to remove material. Later on as the iterations are being done the topology is rerun to see where it would continue to remove material.

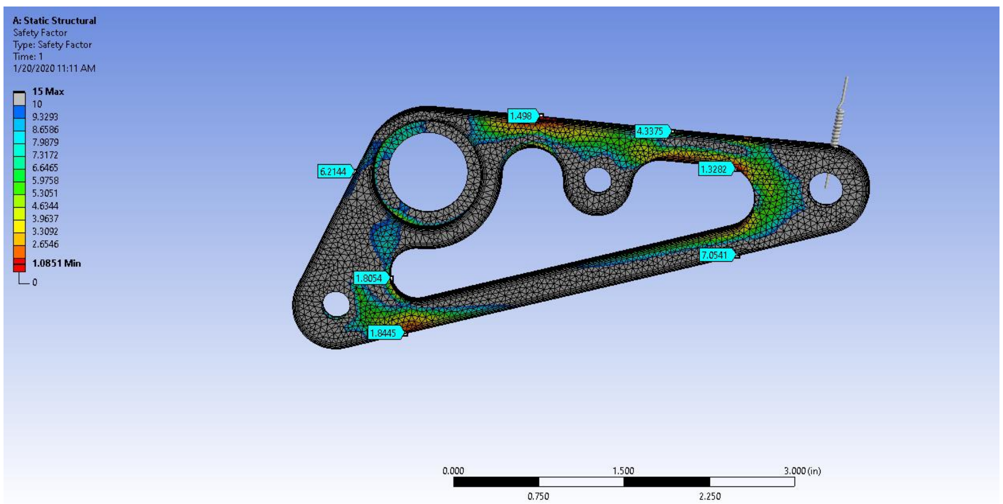
Iterations

After viewing the way material is removed via the topology optimization decisions driving where to remove material from the SOLIDWORKS model are made. These changes are then pushed back into the ANSYS static structural simulation top provide validation that the rocker is still meeting minimum requirements and driving the next steps in the process. The things that are payed particular attention to are stress, strain, deformation, and especially safety factor. The goal minimum factor of safety across the part was an absolute minimum of 2, and a significantly higher factor of safety across most of the part. To begin a lightening series of pockets was applied from a top down perspective of the part. Below the process is described along images.

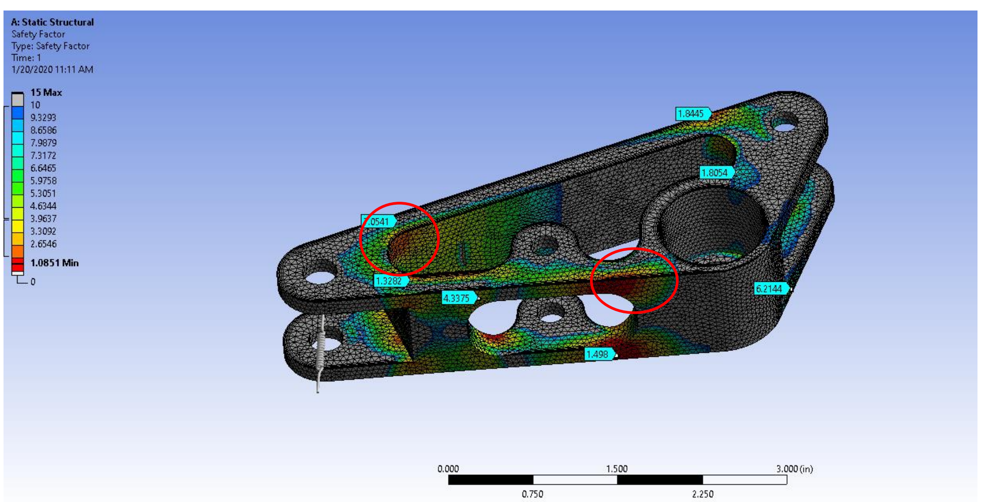




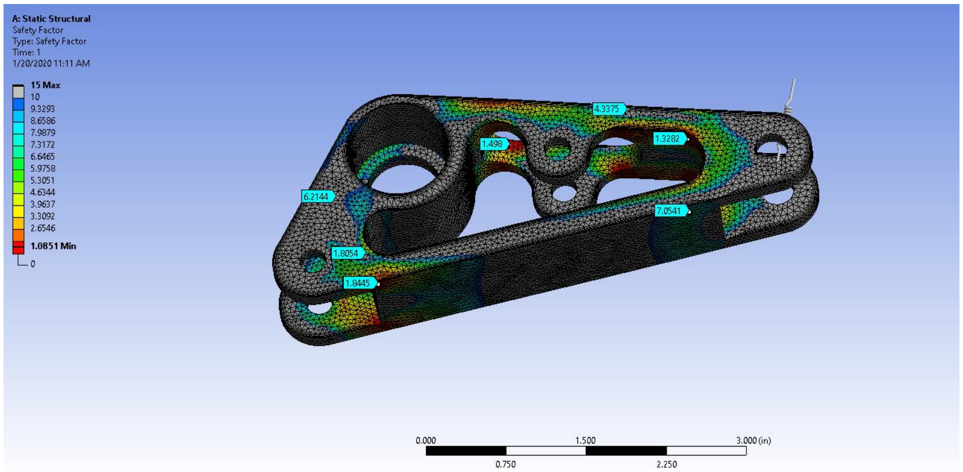
To begin a solid rocker is solved for in Ansys as a baseline. This allows for getting the simulations setup as desired with the proper mater and coordinate systems.

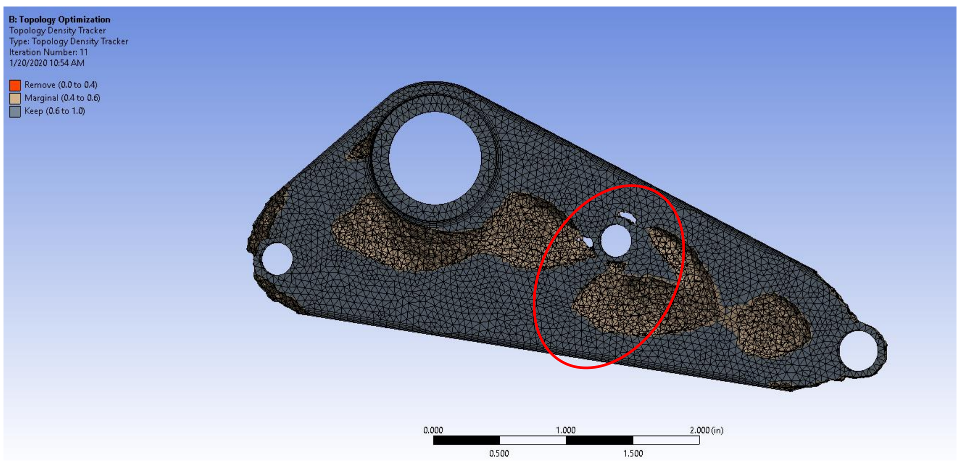


The whole middle section of the rocker is removed to see where failure modes and stress concentrations start to appear on the perimeter of the part. Knowing where the initial failure points are can then inform decisions about where to add material.



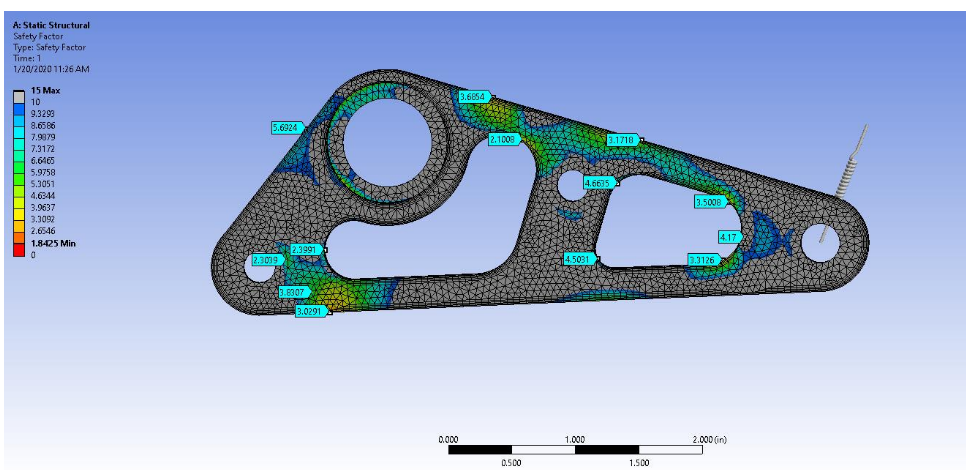
Here we see the weakest points around the ARB mounting point and bottom half of the rocker of both ends where it bows slightly.



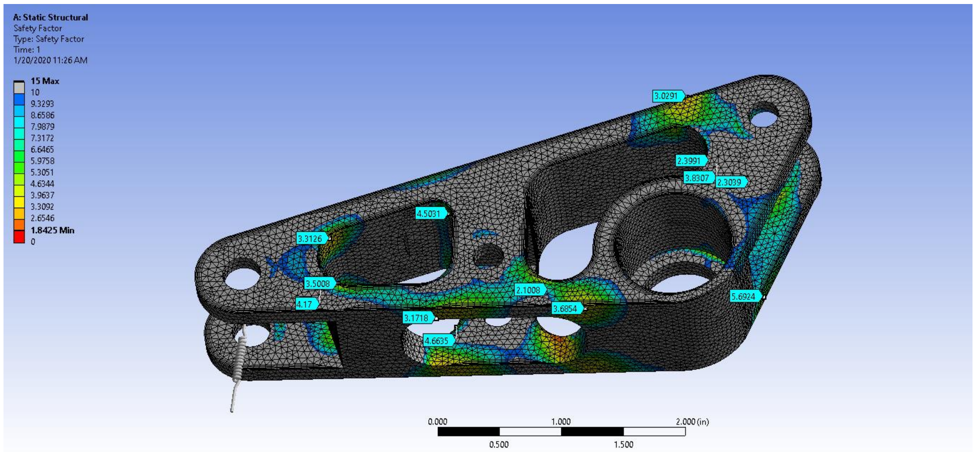


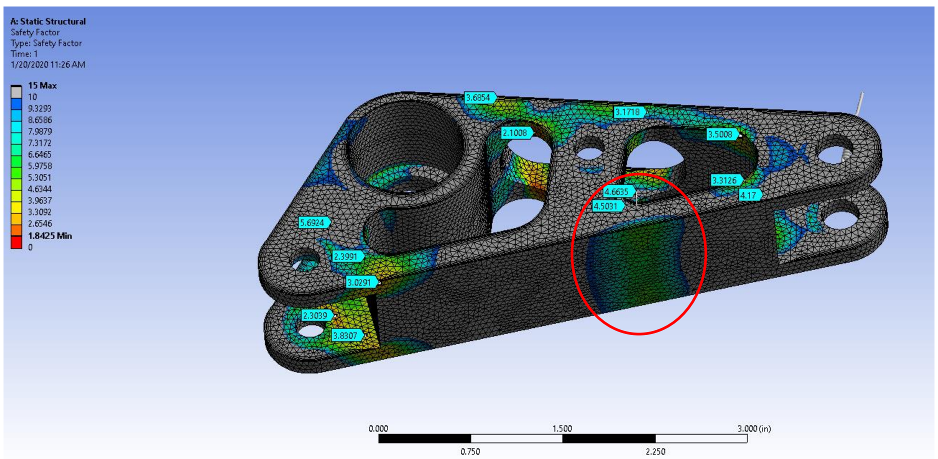
In this topology material was not removed from the full height of the part because a certain amount of mass had to be retained by the analysis. In the future this could be resolved by an adaptive analysis.

Here I can see where the topology wants to keep material across the ARB mount point.



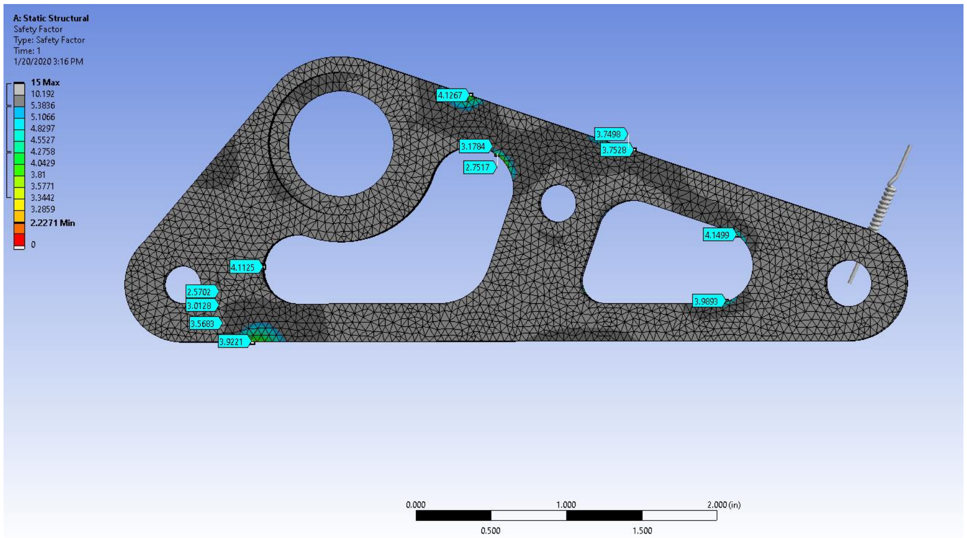
Here a bridge was added across from the ARB to the main body to make the part more ridged and relive weak sections at the extremes of the cutout as was as around the ARB near the bearing mount.



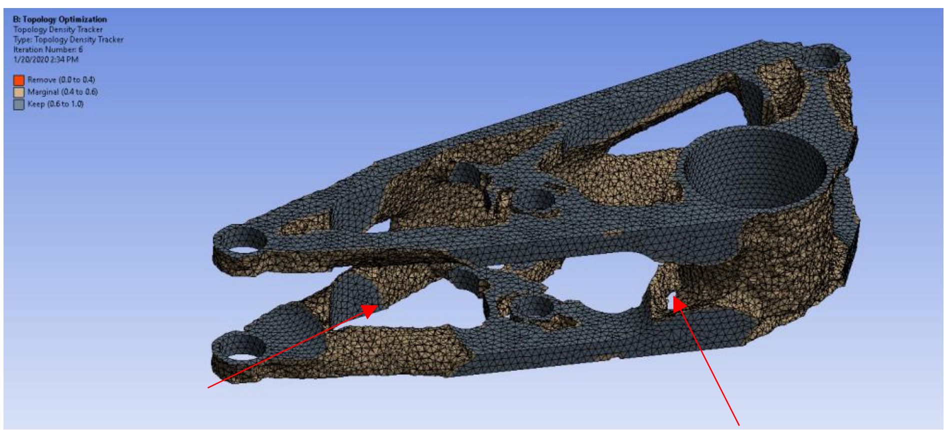


This did reduce the factor of safety where the section added meets the long side of the part. This is because as the rocker flexes this section pushes into that face.

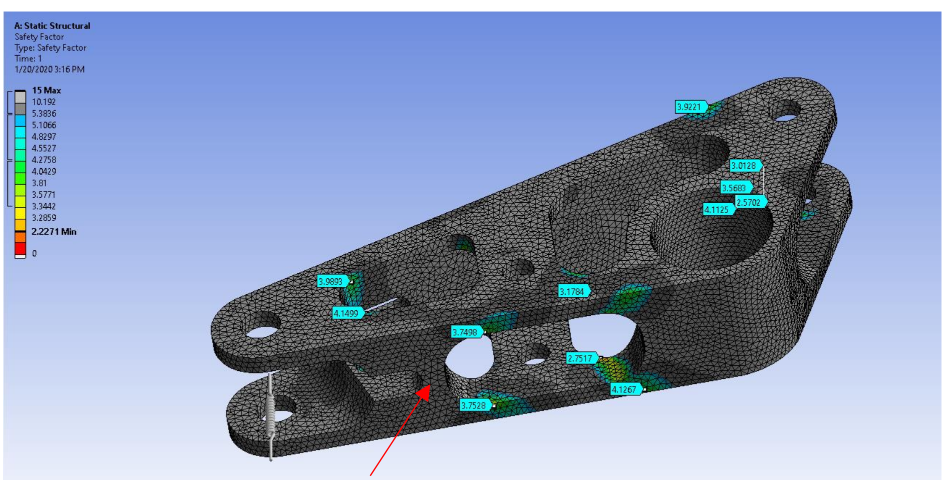
This topology was run after the material removal in the previous steps. Seeing that it wants to make minimal changes to this profile gives some level of confirmation that the decisions made were sensible.



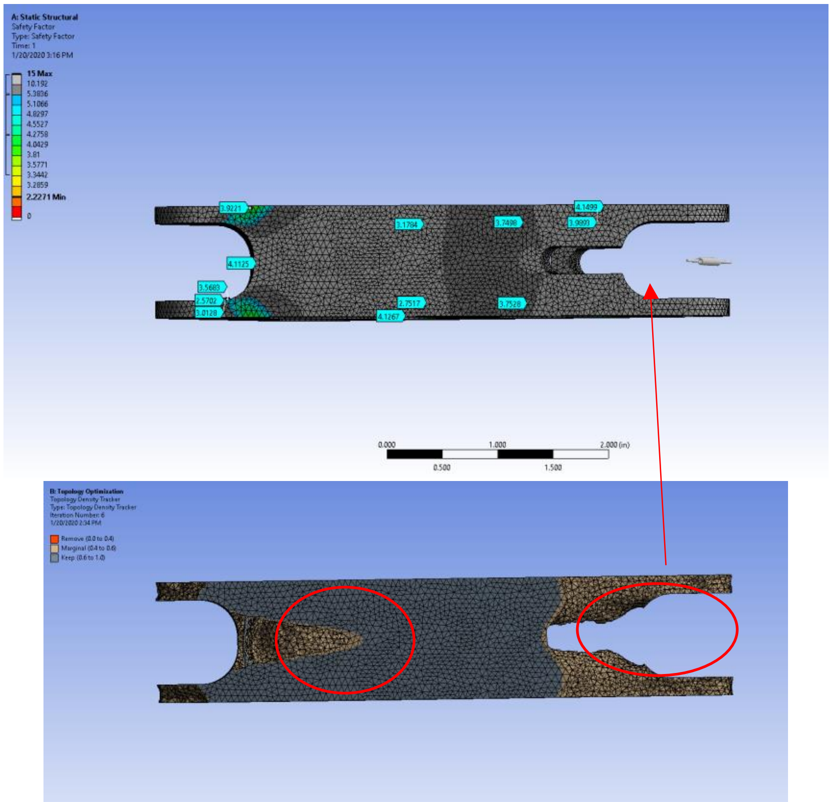
Here is the final view from the top, a large amount of material was able to be removed. Further these cutouts are easy to machine with their easy access and large radii.

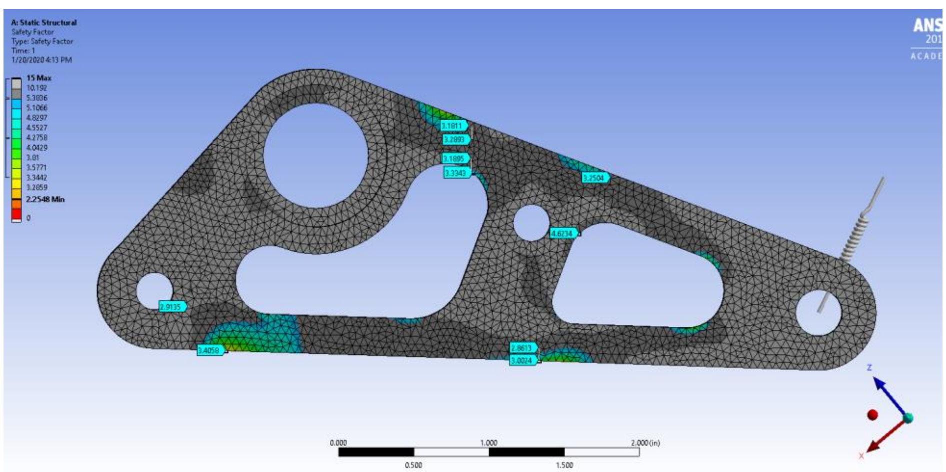


The next process is to remove material from the center section of the rocker, this started with simple slots cut from the openings of the damper and pull rod.

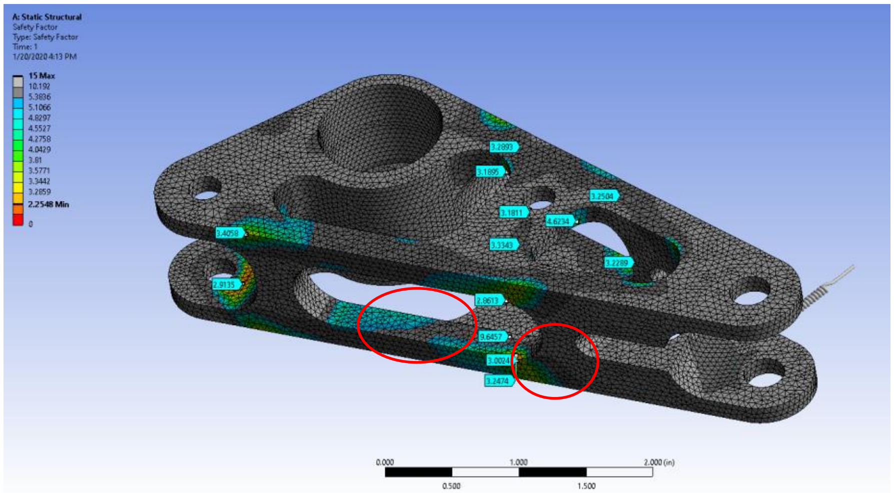


The slot added is very similar to those from last year’s rockers wherein it is open on one side. One benefit of this is that it makes it easier to position spacers between the rod ends and rocker faces. This is also a very simple feature to machine.

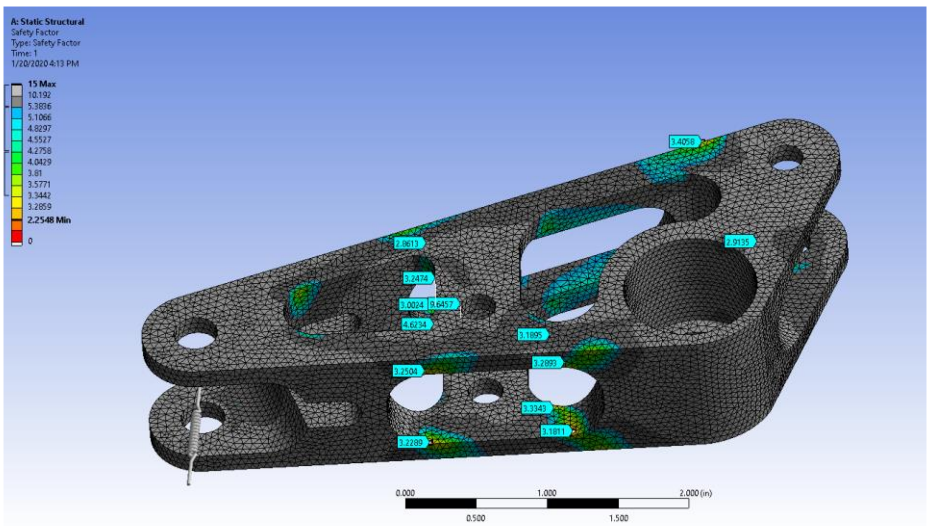


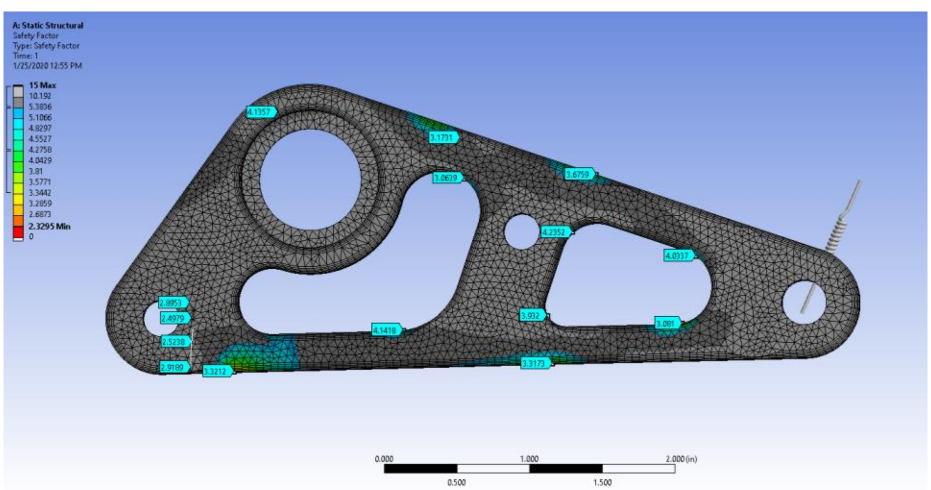


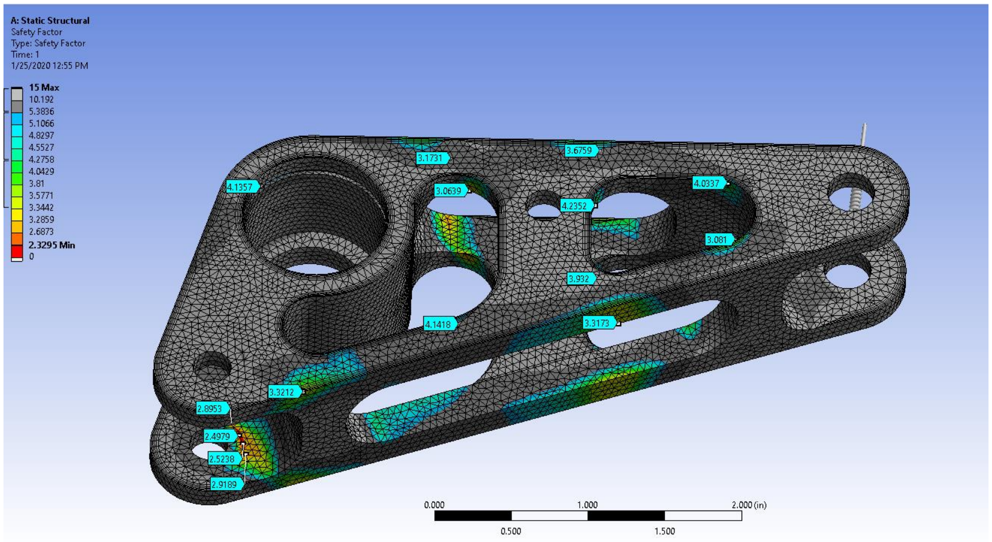
Though this feature maintains a very high factor of safety across the part it also reduces the weight very little. This initially seemed like the correct approach given the initial FEA, however after some consideration this seemed to be more a product of how the analysis was run and not that it was the best decision given the loading cases.



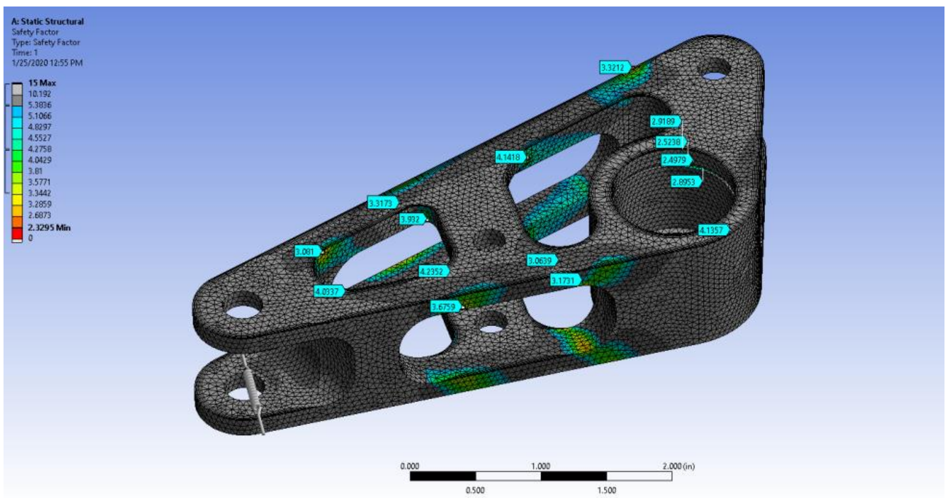
An additional isolated slot was added in addition to the slot that is open. Because this slot is not affected by the clamping forces from the hardware for the damper and pull rod it can be much wider. This slot does introduce a weak point as circled.

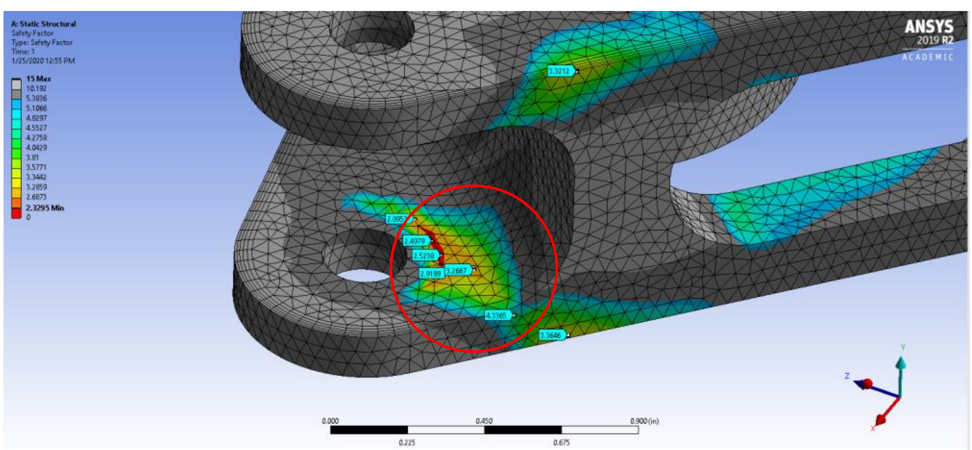






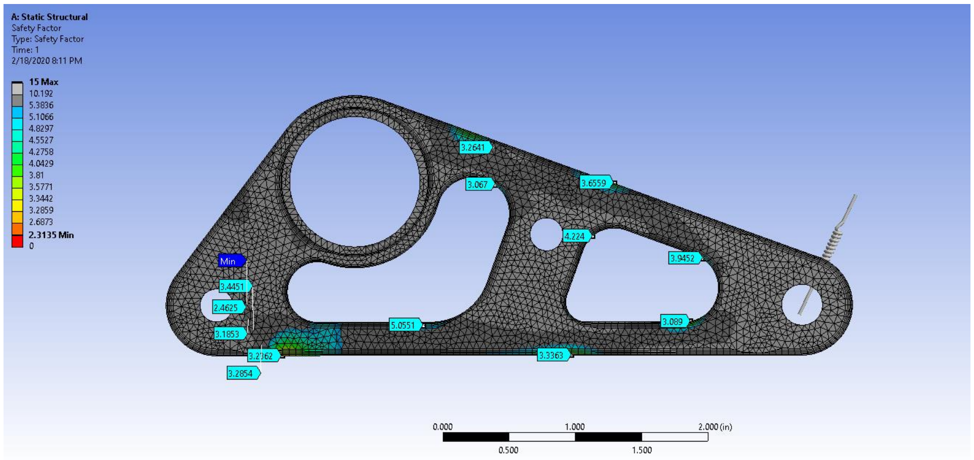
The open end slot was removed and the full width slot was removed, this configuration is significantly lighter and has a similar factor of safety across the part.



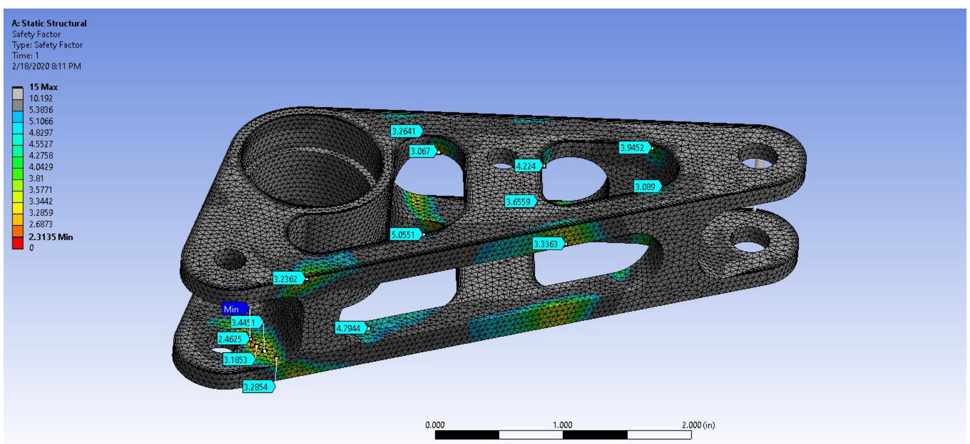


This point has consistently been the peak minimum for the factor of safety, this is because of how the mesh is defined in this region and the large force applied by the bolt. Knowing that this geometry is exactly the same as prior years we know this is not an actual failure mode.

Rear Rocker Final (Bonded)

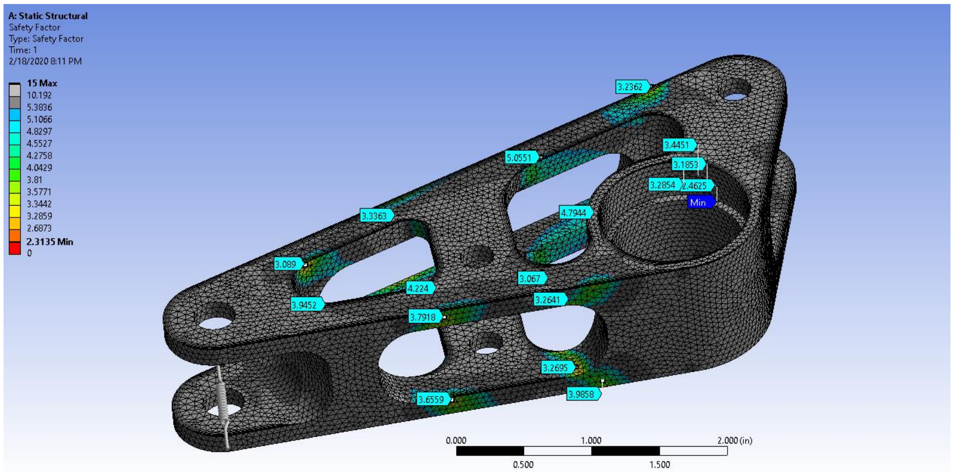


Mass	.21 lb
Min Factor Safety	2.31
Max (von-Mises) Stress	31835 psi
Max Elastic Strain	0.00233
Max Deformation	0.0044 in



The minimum safety factor still exists where the pull rod shoulder bolt interfaces with the part.

In the middle of the time frame the bearing about which the rocker pivots had to be changed due to supply constraints. However, it was managed to minimize the impact to the part. Maintaining a large safety factor.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Safety Factor
Type: Safety Factor
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2/18/2020 8:11 PM
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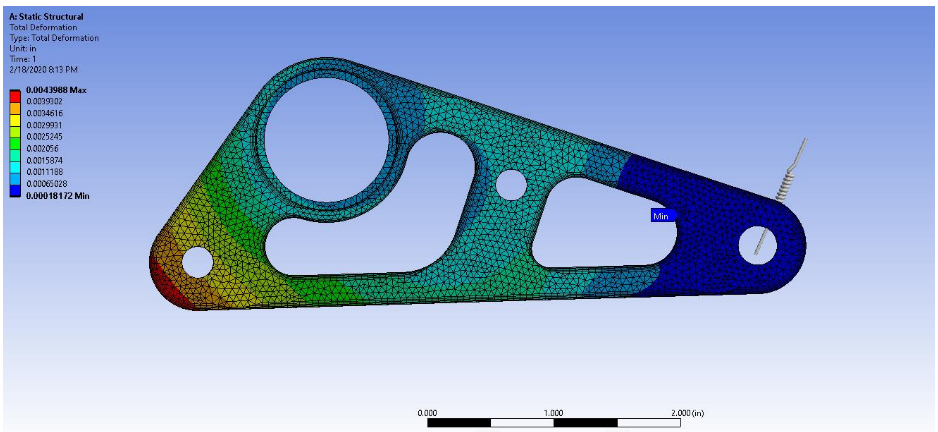
5.1066
4.8297
4.5527
4.2758
4.0429
3.81
3.5771
3.3442
3.2859
2.6873
2.3135 Min
0
3.2362
3.4451
3.1853
3.2854
2.4625
Min
5.0551
4.7944
3.3363
3.089
4.224
3.067
3.9452
3.2641
3.7918
3.2695
3.6559
3.9858
0.000
1.000
2.000 (in)
0.500
1.500


A: Static Structural
Total Deformation
Type: Total Deformation
Unit: in
Time: 1
2/18/2020 8:13 PM
0.0043988 Max
0.0039302
0.0034616
0.0029931
0.0025245
0.002056
0.0015874
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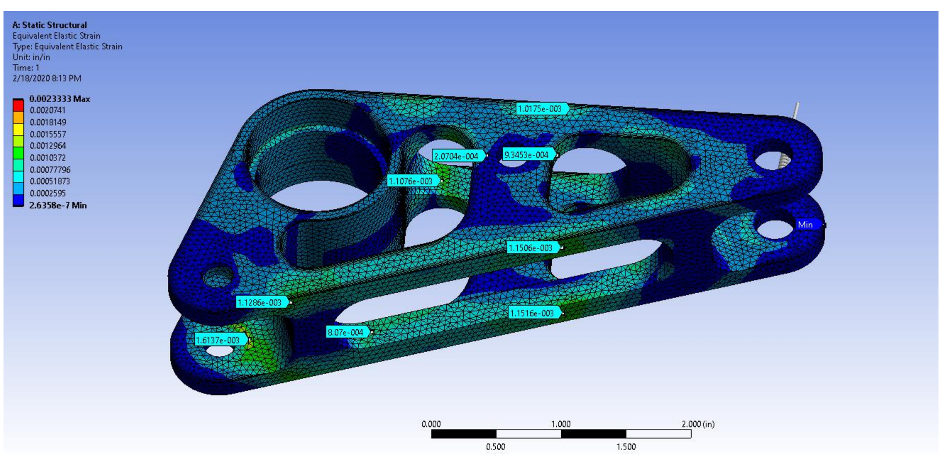
0.00065028
0.00018172 Min
Min
0.000
1.000
2.000 (in)
0.500
1.500


A: Static Structural
Equivalent Elastic Strain
Type: Equivalent Elastic Strain
Unit: in/in
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2/18/2020 8:13 PM
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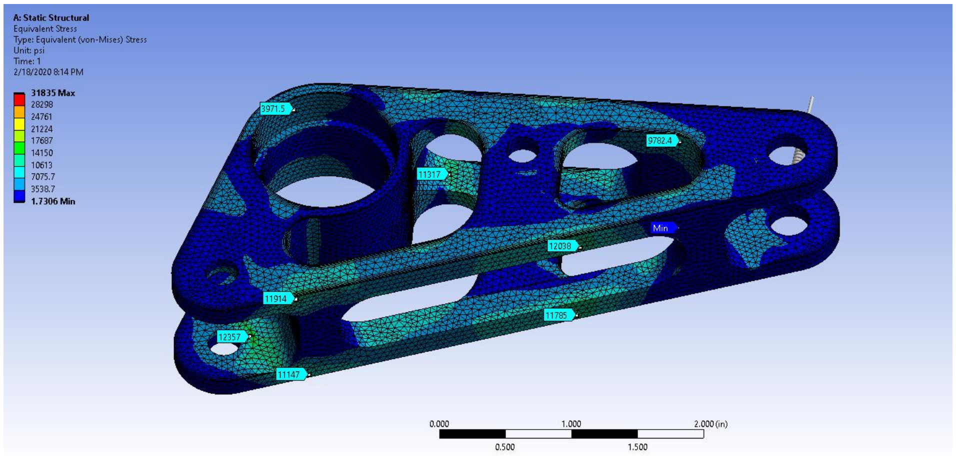
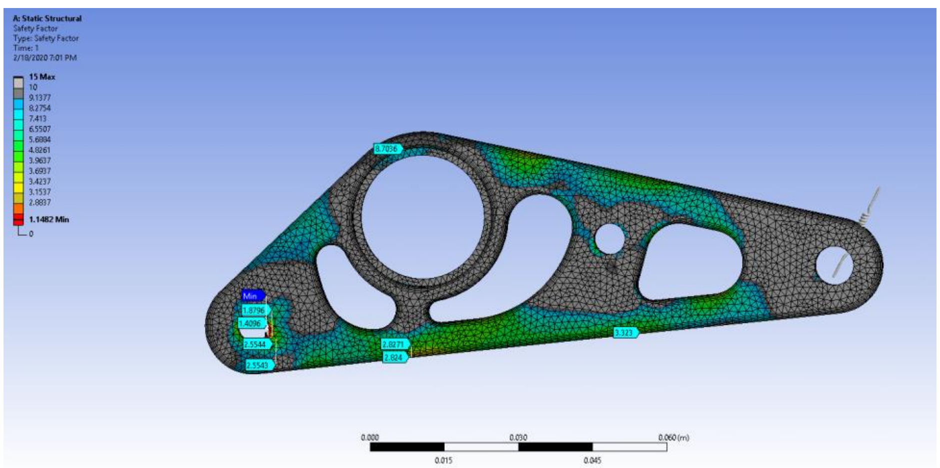
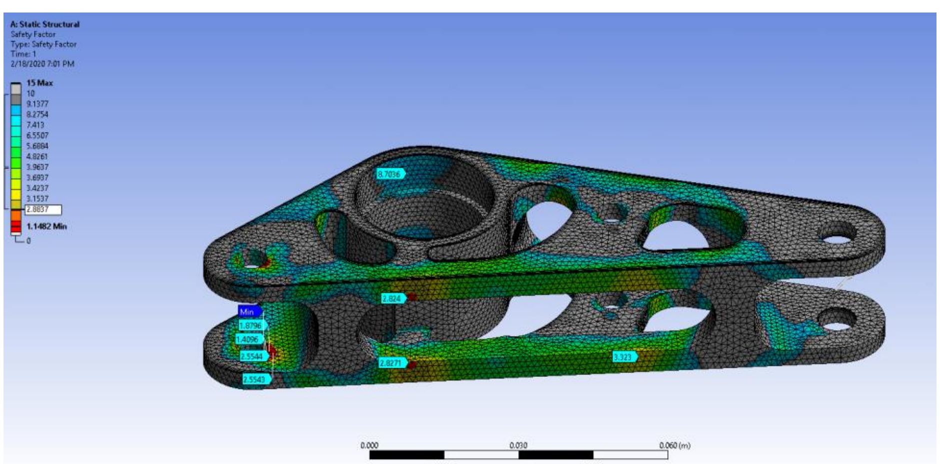
0.0018149
0.0015557
0.0012964
0.0010372
0.00077796
0.00051873
0.0002595
2.6358e-7 Min
1.0175e-003
2.0704e-004
9.3453e-004
1.1076e-003
Min
1.1506e-003
1.1286e-003
1.1516e-003
1.6137e-003
8.07e-004
0.000
1.000
2.000 (in)
0.500
1.500

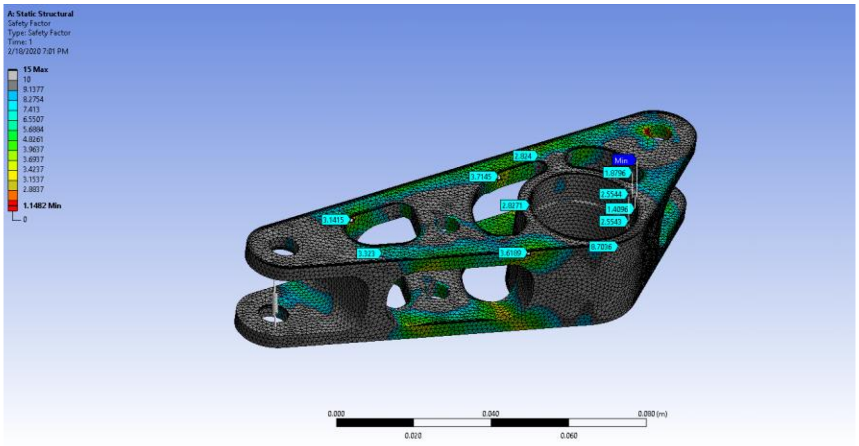


Front Rocker Final (Frictionless)

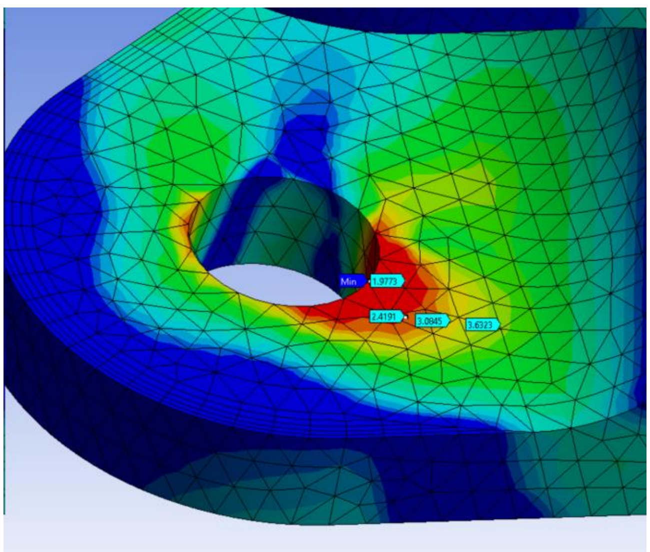


Mass	.22 lb
Min Factor Safety	2.7
Max (von-Mises) Stress	31764
Max Elastic Strain	.00312
Max Deformation	.0064





Abnormal Minimum FOS



Actual Minimum FOS