Ed Green Engineering 315 Thorn St Sewickley PA 412-208-5884

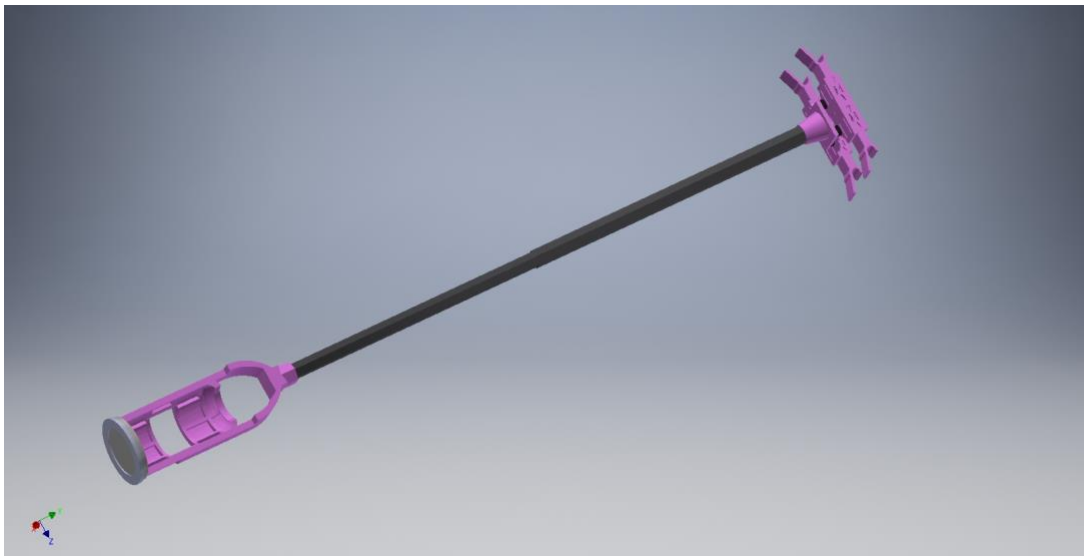
FEA Analysis of Reign Maker WSD

3/28/2021

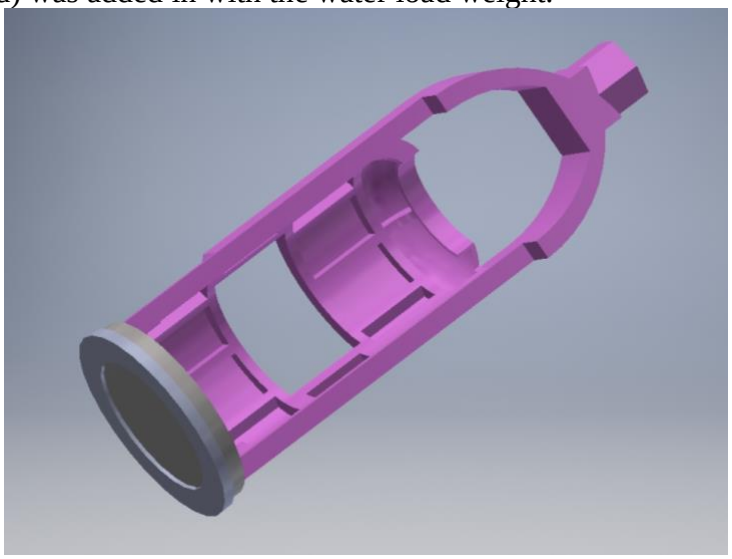
The Reign Maker Water Sampling Device Assembly was analyzed using Inventor 2014 Simulation. Geometry was generally stripped of holes and radii to reduce the mesh and solve time. It was reported the frame sections had been reduced so modeling concentrated on the frame stresses. The whole model was still used in order to apply the same loads as previously analyzed in August 2020. All items were bonded together using contact elements.

Geometry

An overall view of the stripped down geometry is shown below.



The stripped down water basket assembly is shown below. The bottle cage door was removed as it didn't seem to add structure using slip pin hinges and button closures, the weight of the door and the bottle (also not modeled) was added in with the water load weight.



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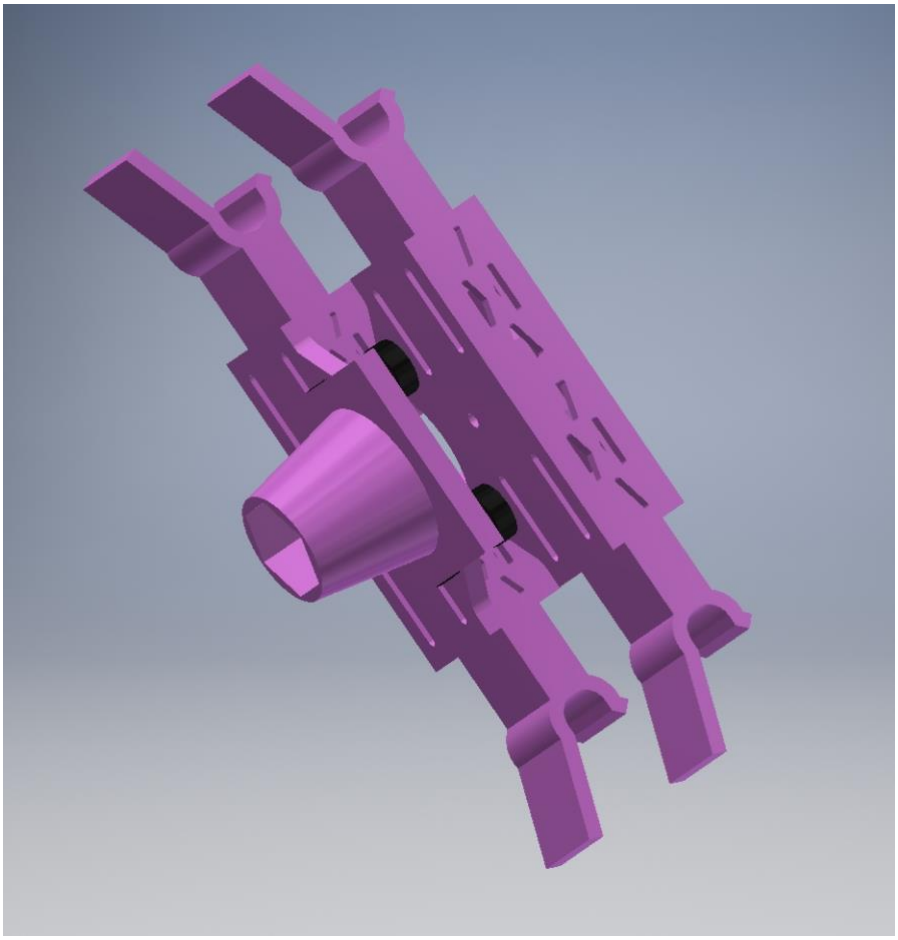
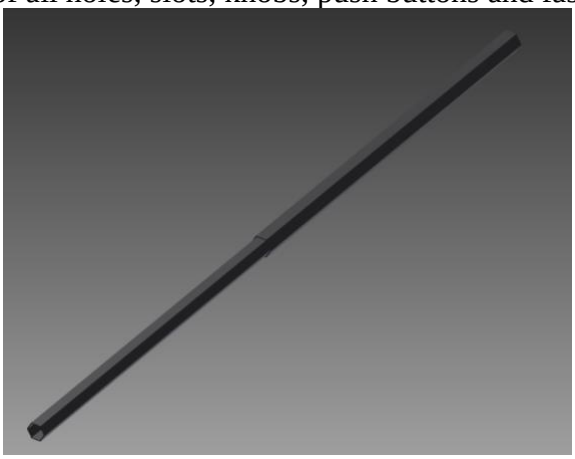
The water sampling assembly was stripped of pulleys, rope, pulley cover, springs, spring pins and fasteners. The claws were extended out as shown to be in the operating condition. The claw pin guides are a different configuration than was analyzed in August 2020.



The hex tubes were stripped of all holes, slots, knobs, push buttons and fasteners.



Materials

The same material properties were assigned per the August 2020 analysis

Nylon

Bottle Cage
Base Spring Plunger
Pole Adaptor
Frame Clamps
Top Frame

Mechanical Properties

Density	.0408 lbmass/in^3
Yield Strength	6100 psi
Ultimate Tensile Strength	12000 psi
Young's Modulus	.288e6 psi
Poisson's Ratio	.35
Shear Modulus	.1e6 psi

Stainless steel

Metal Base Plate

Mechanical Properties

Density	.291 lbmass/in^3
Yield Strength	36260 psi
Ultimate Tensile Strength	78320 psi
Young's Modulus	28e6 psi
Poisson's Ratio	.3
Shear Modulus	10.7e6 psi

ABS Plastic – this was used in place of rubber to simplify the model. The fasteners were removed and the rubber had too much elasticity to hold the assemlby in tension.

Rubber bumper

Mechanical Properties

Density	.038 lbmass/in^3
Yield Strength	2900 psi
Ultimate Tensile Strength	4293 psi
Young's Modulus	.3e6 psi
Poisson's Ratio	.38
Shear Modulus	.117e6 psi

Titanium – this was used for simplification, as the carbon graphite properties are orthotropic

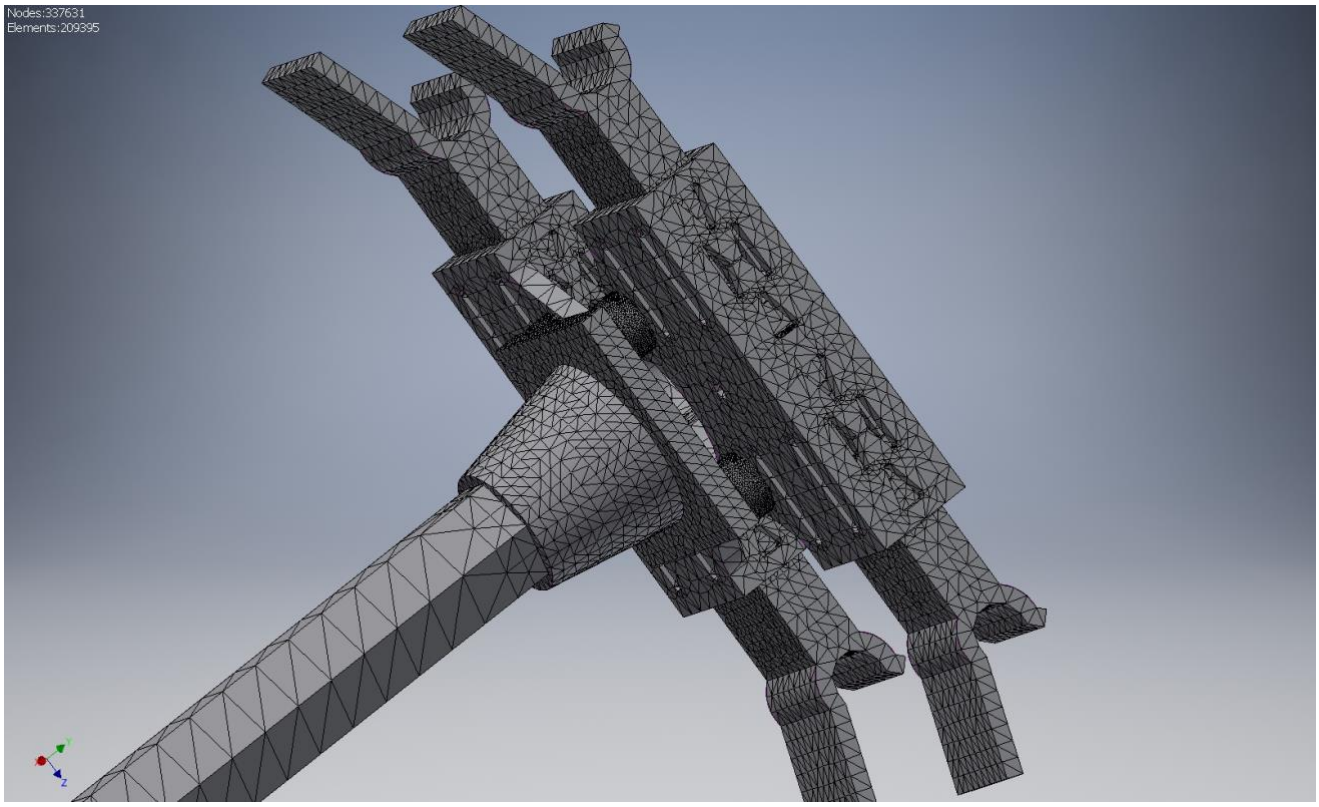
Carbon Fiber Hex Tube

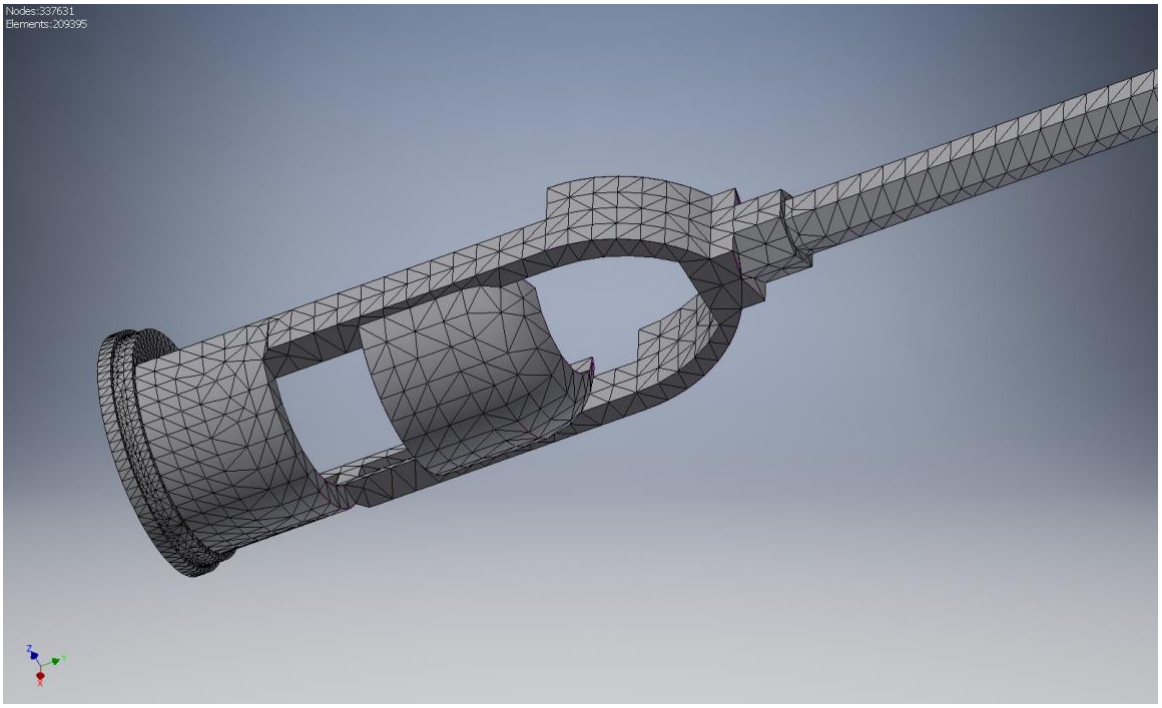
Mechanical Properties

Density	.16 lbmass/in^3
Yield Strength	39972 psi
Ultimate Tensile Strength	49965 psi
Young's Modulus	15e6 psi
Poisson's Ratio	.36
Shear Modulus	5.4e6 psi

Mesh

The automatic mesher was used. Average element size was .05 fraction of the model diameter and minimum element size was .2 as a fraction of average size. The grading factor was 1.5 at maximum turn angle 60 degrees. The mesh contained 337631 tetrahedron elements and 209395 nodes,





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Constraints

In all load cases all 4 claws were constrained with a pin constraint as if they were attached to the drone. The pin constraints were fixed in the radial and axial directions and allowed to rotate freely.

Load Case 1 Gravity Only with 300 g Water Load

Gravity was applied in the vertical down direction. The weight of the missing door and bottle were added to the water load for a total of 1.0 lbs. The load was attached to the side walls of the 3 bolt holes in the bottom of the bottle cage.

The total reaction load in the Y direction for this case was 4 lbs. Claw inward reaction forces (compressing the spring) are 1.5 lbs each claw equal and opposite across the Top Frame. Each claw also has axial reaction forces of 1.3 lbs in opposing directions.

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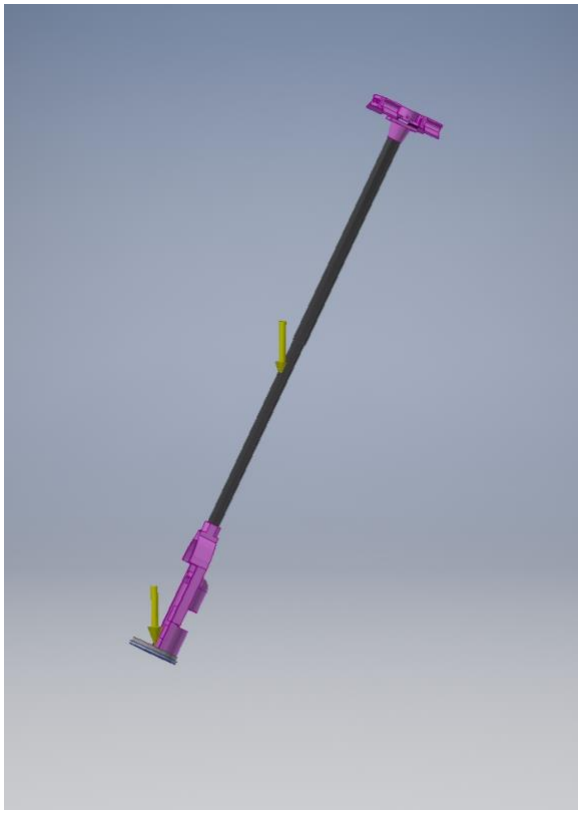
Load Case 2 Gravity and Water Load at a 25 degree angle Pitch

The gravity and the 1 lb water + door load was changed to a 25 degree angle to simulate the maximum pitch of the drone.



For this case the claws had up and down reaction forces as expected with a magnitude of 2.5 lbs up and .25 lbs down. The inward force against the springs increased to 3.6 lbs at the higher loaded end and .9 lbs at the other end. Axial forces were unbalanced with 1.0 lbs on the loaded end and .6 lbs on the other.

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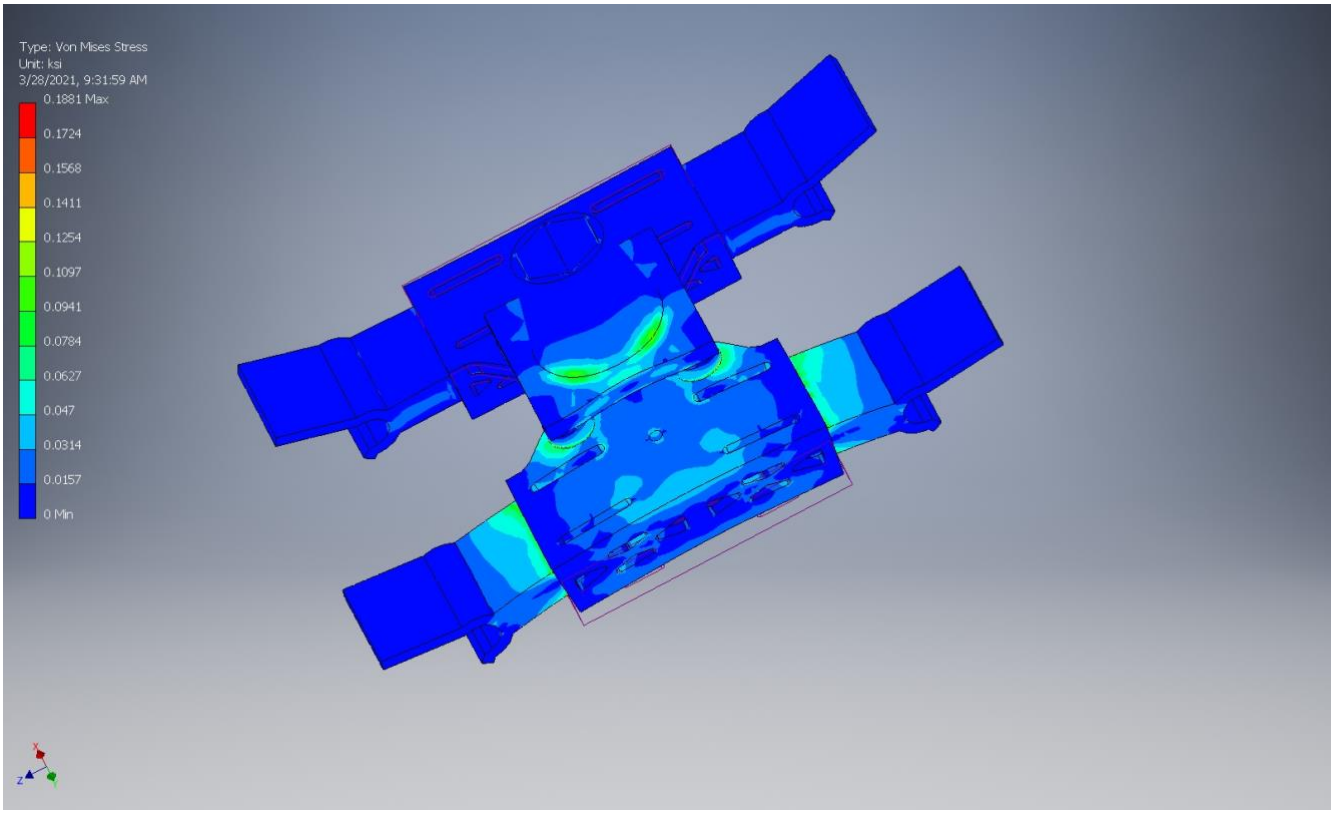

The stresses on the frame, claws and pole attachment are peak of 188 psi providing a safety factor greater than 30.

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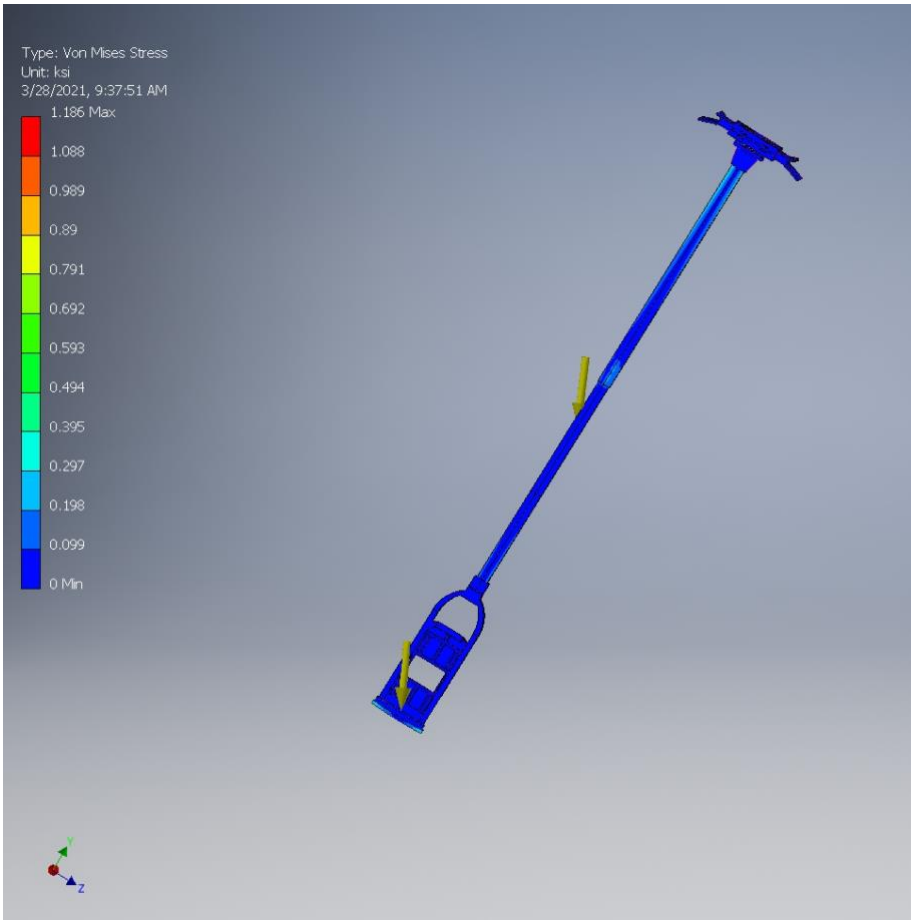
Load Case 3 Gravity and Water Load at a 25 degree angle Roll

The gravity and the 1 lb water + door load was changed to a 25 degree angle to simulate the maximum roll of the drone, the maximum roll is not listed in the manual but it was assumed to be equal to the pitch.



The reaction forces for this case are 2.3 lbs up on one side and 1.1 lbs down in the vertical direction. The inward forces are 1.6 lbs inward and 1.1 lbs outward. Axial forces are 1.6 and .1 lbs.

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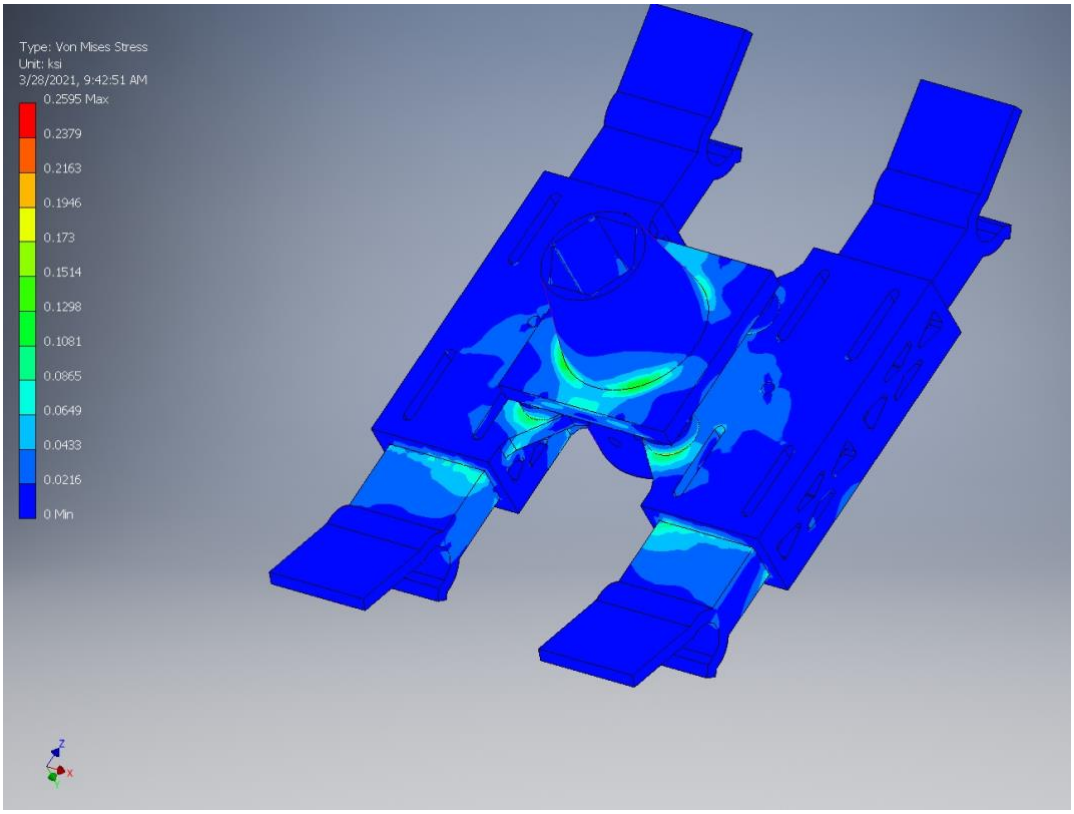

The frame, claws and pole attachment peak stresses are all under 300 psi which provides a safety factor of 20.

Load Case 4 River Current Against Pitch Direction

The 1 lb water + door load was removed for this case as bouyancy would remove the weight load on the assembly. Gravity was left at 25 degrees. A river current of 5 knots was assumed for this case and applied to the bottle cage, metal plate and the lower portion of the hex tube. The river current at 5 knots was calculated at approximately .5 psi pressure. An area of the assembly up to 1" above the red knobs was calculated and combined with the river current pressure for a total load of 18.4 lbs in the pitch direction. For comparison, the manual lists maximum wind resistance at 8 m/s. The pressure generated by this equals .0055 psi creating a 1.7 lb load against the drone. It is believed the 18.4 lbs of river current will move the drone through the air and the river current load will not exceed 1.7 so the river current load is conservatively very high. The claws were held in place as if the drone could hold the load without drifting.

Reaction loads at the claws increased greatly for this case but are not realistic as the drone will not be able to hold its position and forces will be limited.

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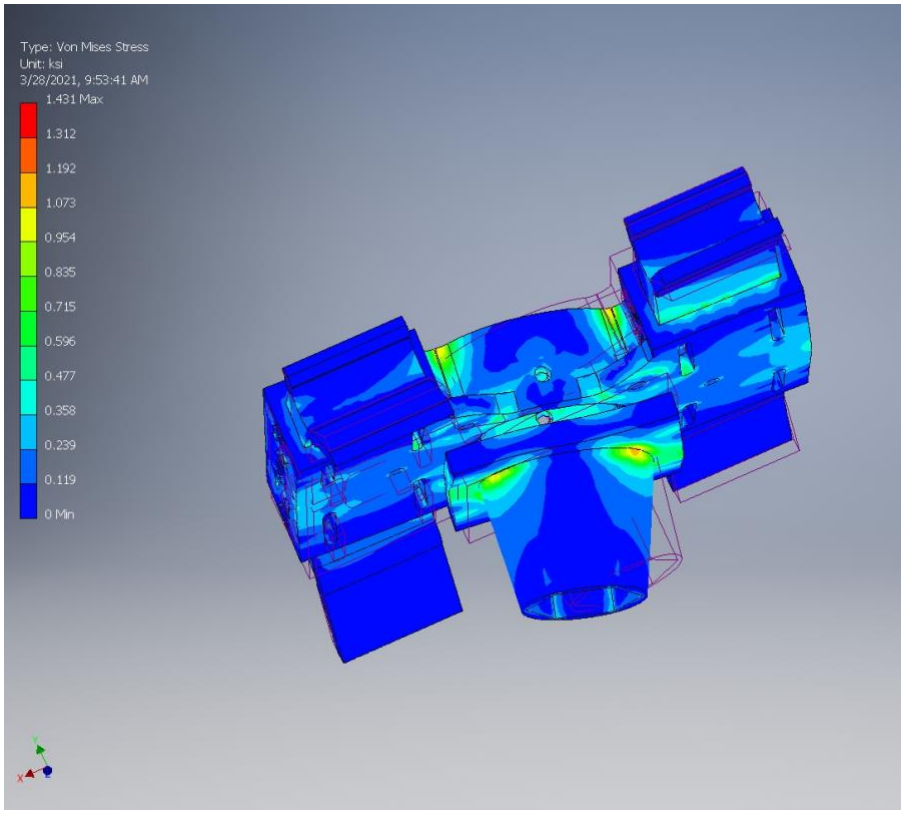

The stress on the frame, claws and pole attachment are modeled conservatively high. The peak maximum stress for this case is 1,400 psi which still provides a safety factor of 4.

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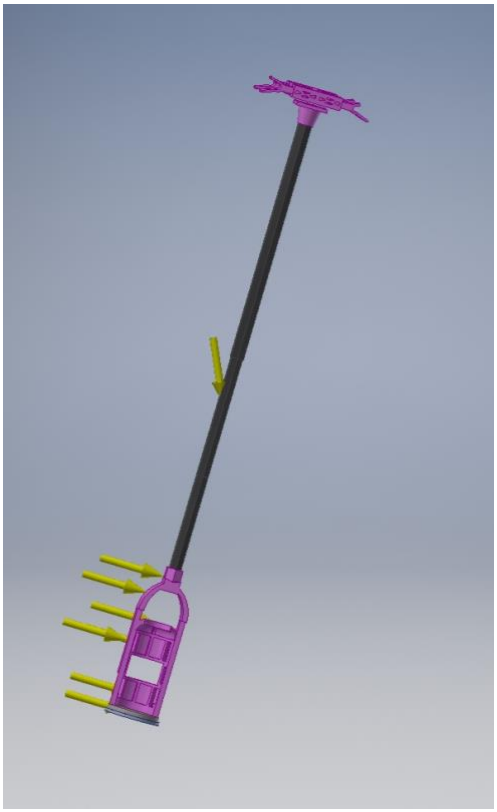
Load Case 5 River Current at a 25 degree angle Roll

The 1 lb water + door load was removed for this case as bouyancy would remove the weight load on the assembly. Gravity was left on at an angle. A river current of 5 knots was assumed for this case and applied to the bottle cage, metal plate and the lower portion of the hex tube. The river current at 5 knots was calculated at approximately .5 psi pressure. An area of the assembly up to 1" above the red knobs was calculated and combined with the river current pressure for a toal load of 21.5 lbs in the pitch direction. For comparison, the manual lists maximum wind resistance at 8 m/s. The pressure generated by this equals .0055 psi creating a 1.7 lb load against the drone. It is believed the 21.5 lbs of river current will move the drone through the air and the river current load will not exceed 1.7 so the river current load is conservatively very high. The claws were held in place as if the drone could hold the load without drifting.



Reaction loads at the claws increased greatly for this case but are not realistic as the drone will not be able to hold its position and forces will be limited.

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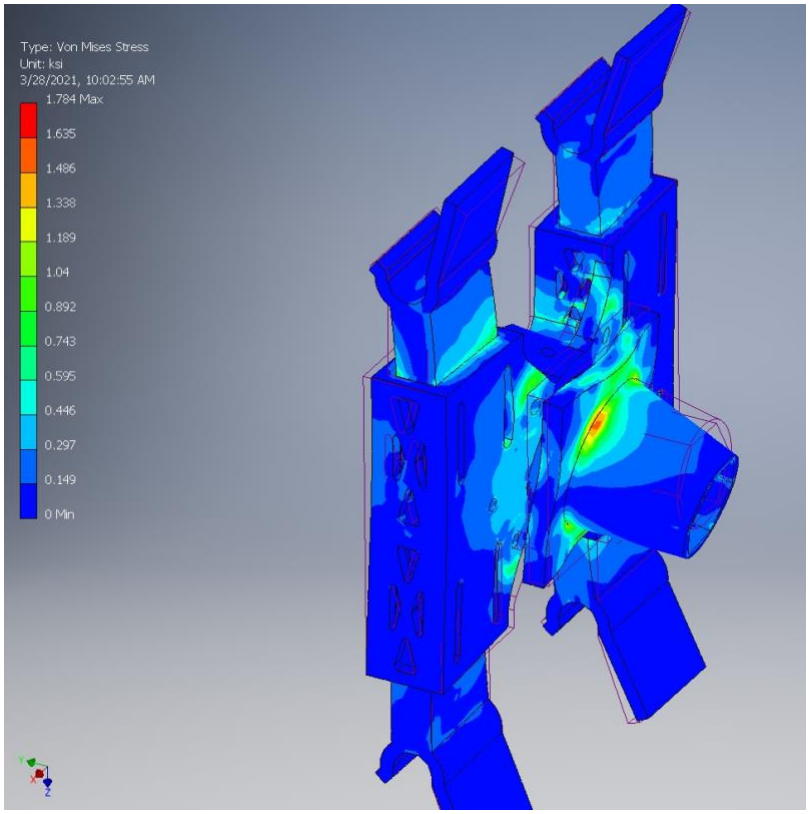

The stress on the frame, claws and pole attachment are modeled conservatively high. The peak maximum stress for this case is 1,800 psi which still provides a safety factor greater than 3.

Results Discussion

This report was tailored to checking the stresses in the redesigned frame. Frame stresses are low and have significant safety margin. The cases for river current forces against the drone were considered as if the drone was held steady in one spot. This case is over conservative as the drone cannot hold against the river current and net forces on the drone are limited below the fully held drone case. Even those cases have a safety factor greater than 3 to yield.

The frame and claw changes that have been made to lighten them up provide adequate strength against the expected forces.