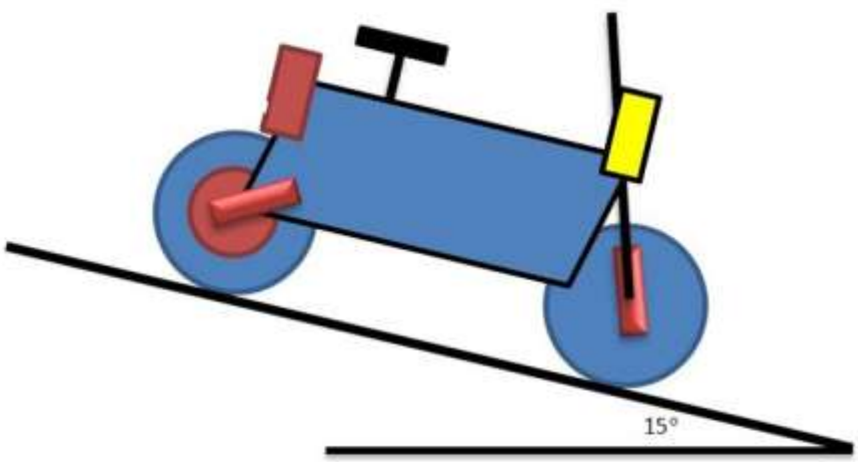
Finite Element Method (FEM) Analysis Report



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Objective

In this lab we used Finite Element Method (FEM) to test the L-Channel, U-Channel, and bicycle frame based on assumed loads with static boundary conditions. In doing so we will create illustrative plots of Von Mises stress contours, Displacement contours, and Factor of Safety contours. By completing this analysis we will become knowledgeable in static solid and shell elements analysis using Solidworks.

L-Channel

In this Finite Element Analysis (FEA) we are going to be using the Solidworks model as illustrated below to perform the analysis. This L-Channel is part of the DANI Robot originally used during our previous labs. In this lab we assumed certain restraints and loads conditions.

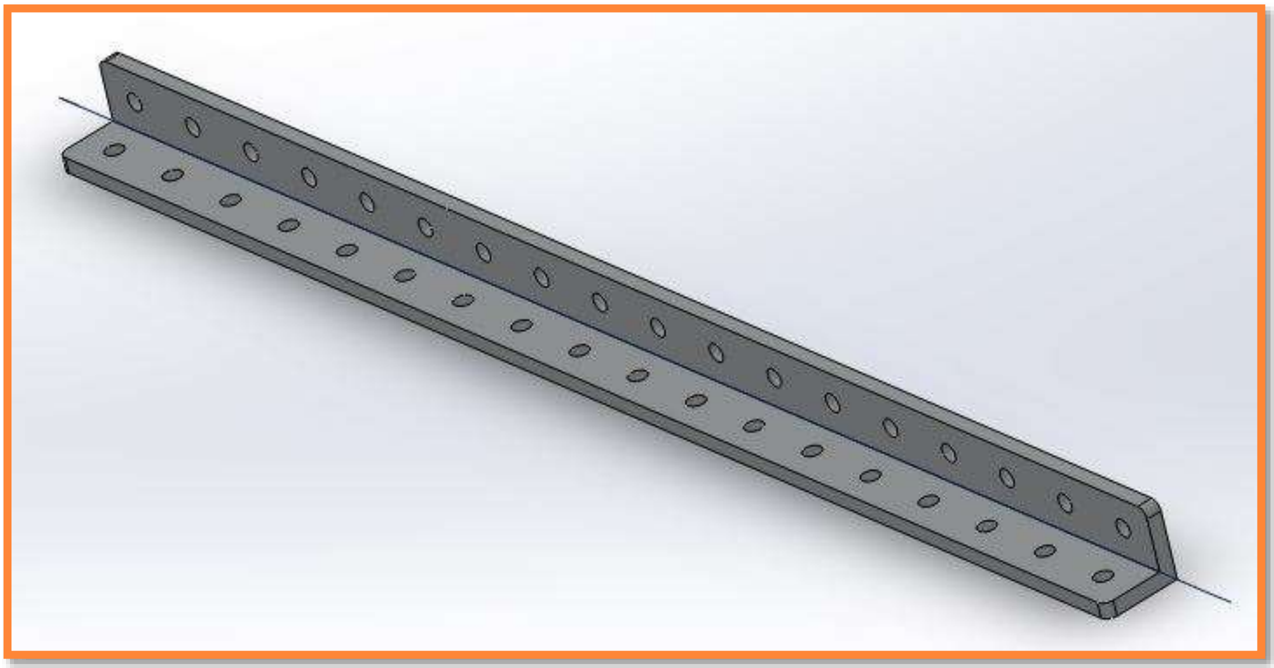


Figure 1: 288mm long Solidworks L-Channel Model used in FEM analysis.

Assumptions

To begin the FEA we first have to make certain assumptions about the type of fixtures, loads, and element analysis type. We assume the restraints are screws around the 4 outer holes and load of 750N to one of the inner surface. (Note: Apparently we were having extreme difficulties performing the analysis of 2 or more solid mesh layer analysis due to computer capabilities so we used only one layer.) By performing only one layer meshed analysis our results will be much more inaccurate than the three layer meshed analysis so that should be taken into account when presenting the FEA results.

Table 1: L-Channel assumptions for FEA

Analysis type	Static
Mesh type	Solid Mesh
Solver type	FFEPlus
Incompatible bonding options	Automatic
Fixtures	Four outer holes (green)
Loading	750 N on one inside surface (orange arrows)

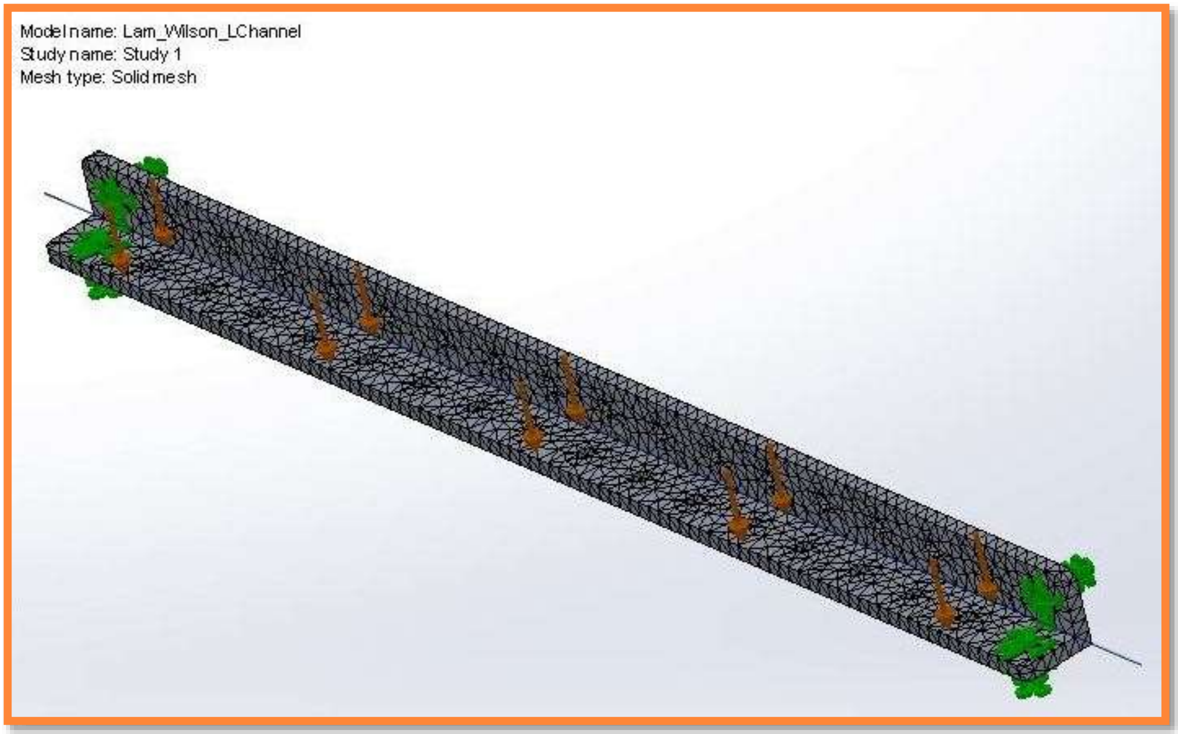
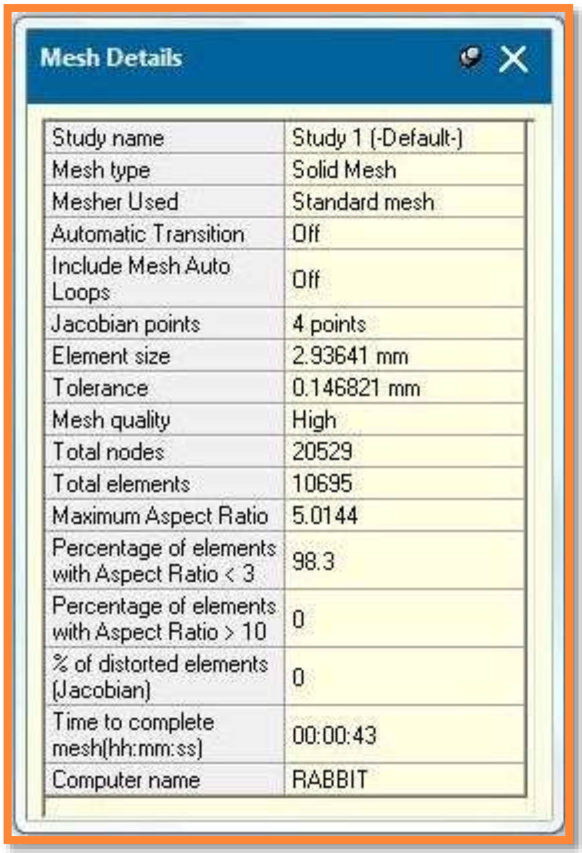


Figure 2: One layer Meshed Model with applied loads (orange) and restraints (green).



Mesh Details

Study name	Study 1 (-Default-)
Mesh type	Solid Mesh
Mesher Used	Standard mesh
Automatic Transition	Off
Include Mesh Auto Loops	Off
Jacobian points	4 points
Element size	2.93641 mm
Tolerance	0.146821 mm
Mesh quality	High
Total nodes	20529
Total elements	10695
Maximum Aspect Ratio	5.0144
Percentage of elements with Aspect Ratio < 3	98.3
Percentage of elements with Aspect Ratio > 10	0
% of distorted elements (Jacobian)	0
Time to complete mesh(hh:mm:ss)	00:00:43
Computer name	RABBIT

Figure 3: Mesh Elements and Nodes Details (One layer Meshed Model).

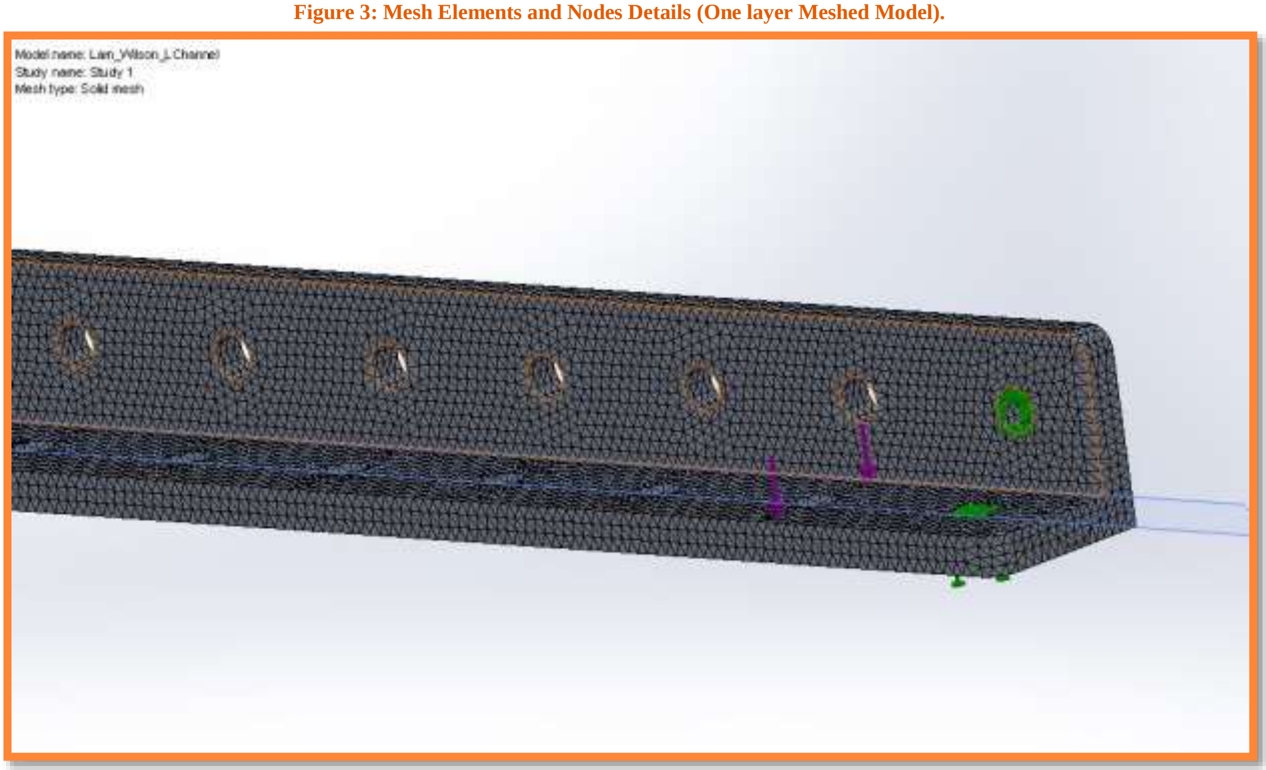


Figure 4: Three layer solid mesh model (apparently during the analysis PC crashed).

FEA Results

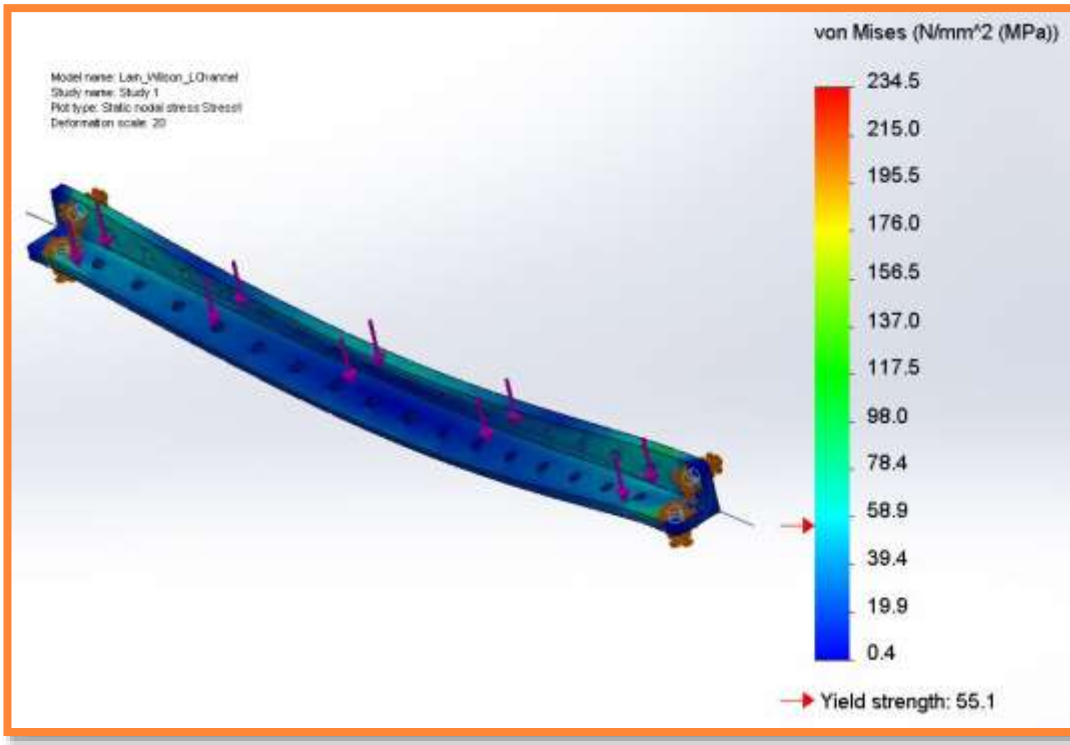


Figure 5: L-Channel Von Mises Stress for Static FEA

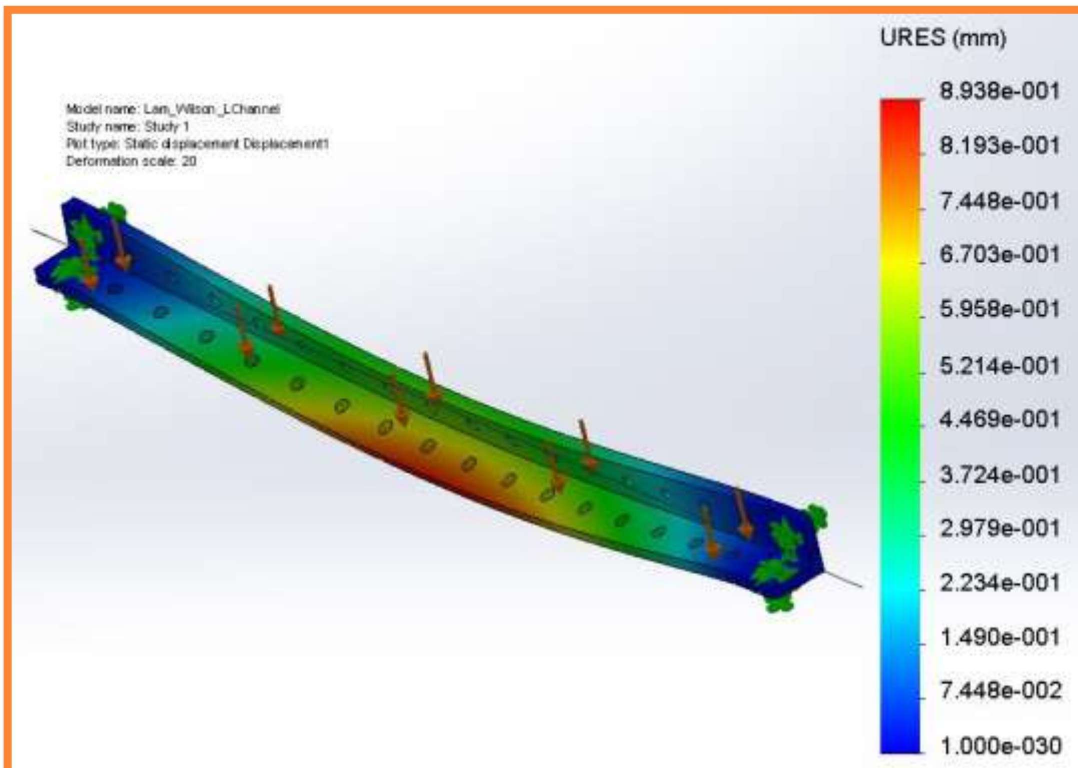


Figure 6: L-Channel Loading Displacement for Static FEA

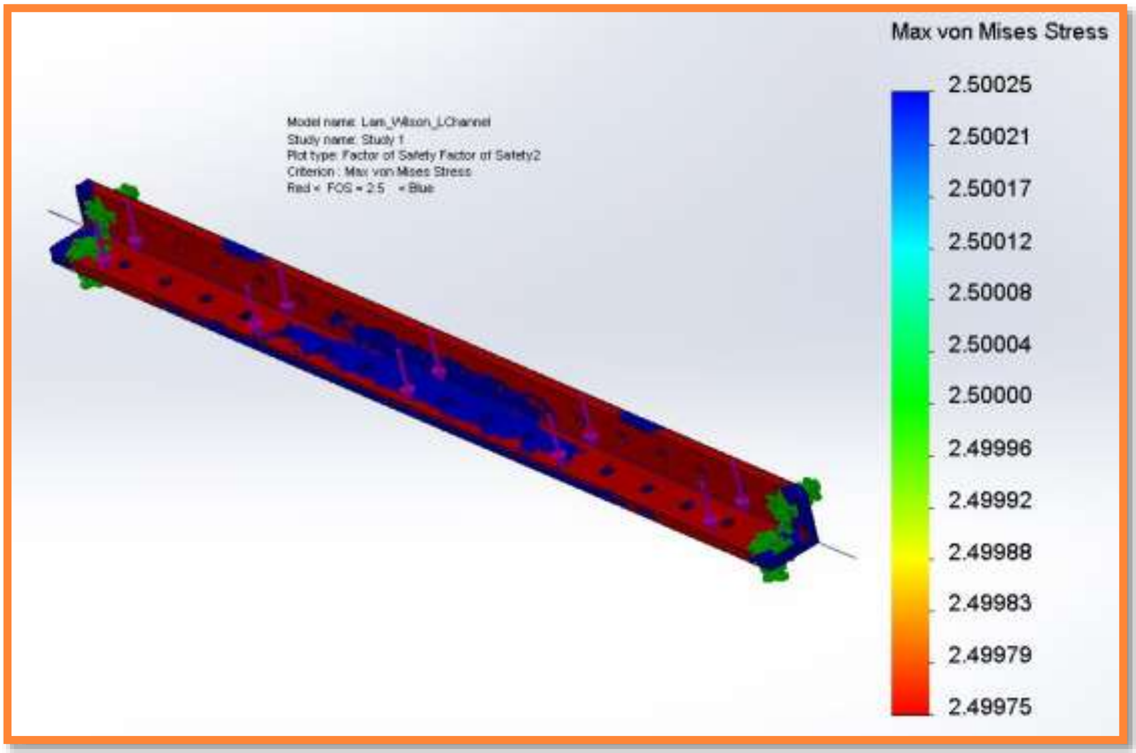


Figure 7: L-Channel Factor of Safety around 2.5 for Static FEA

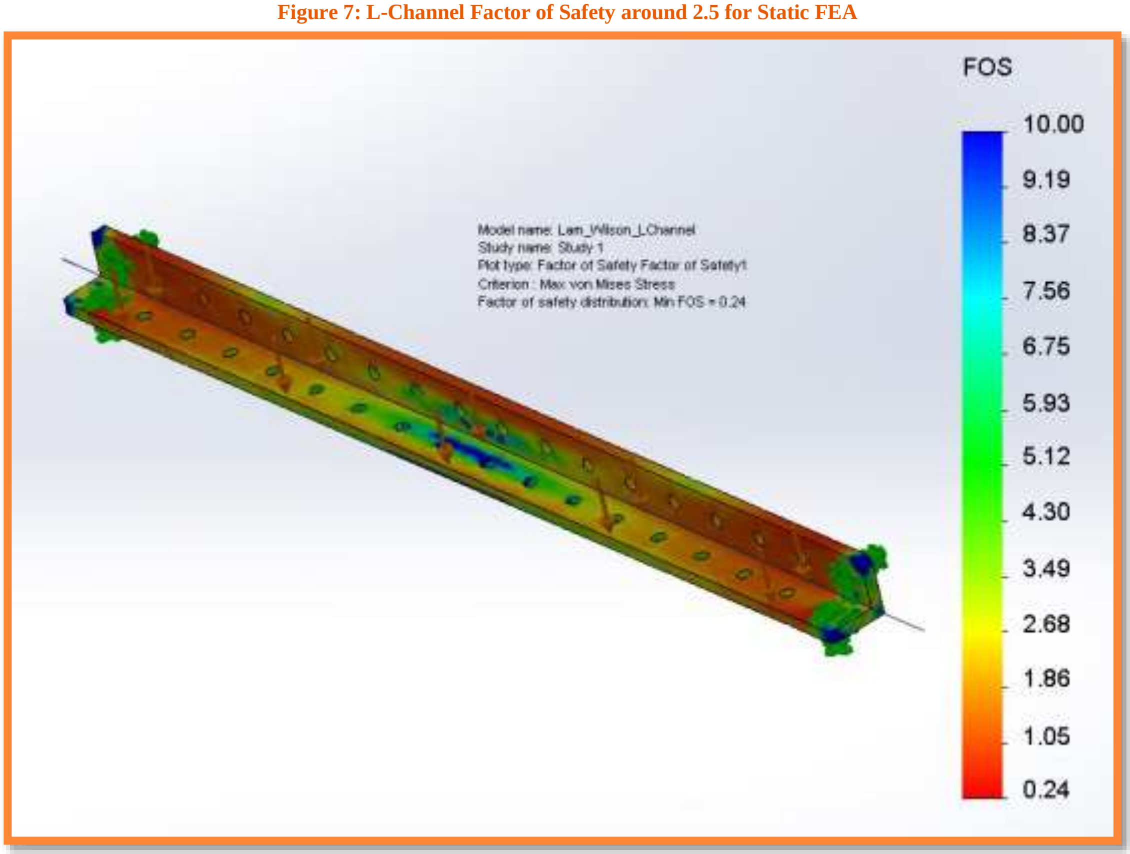


Figure 8: L-Channel Factor of Safety for Static FEA

U-Channel

In this Finite Element Analysis (FEA) we are going to be using the Solidworks model as illustrated below to perform the analysis. This U-Channel is part of the DANI Robot originally used during our previous labs. In this lab we assumed certain restraints and loads conditions.

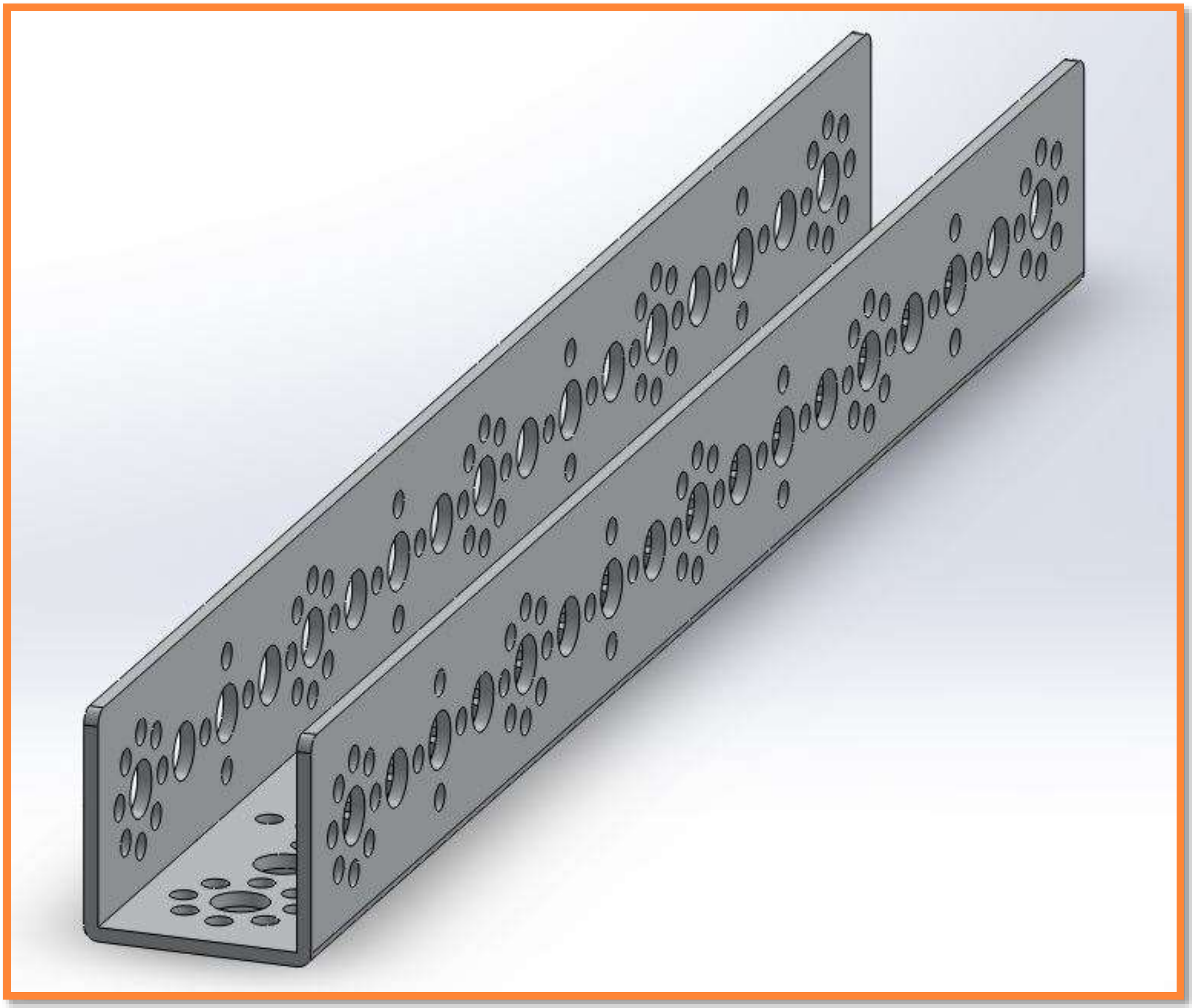


Figure 9: Solidworks U-Channel Model used in FEM analysis.

Assumptions

To begin the FEA we first have to make certain assumptions about the type of fixtures, loads, and element analysis type. We assume the restraints are screws around the 4 outer large holes and load of 750N to one of the inner surface. In this analysis we will be using sheet metal and performing a shell mesh analysis.

Table 2: U-Channel assumptions for FEA

Analysis type	Static
Mesh type	Shell Mesh
Incompatible bonding options	Automatic
Fixtures	Four large outer holes (green)
Loading	750 N on one inside surface (purple arrows)

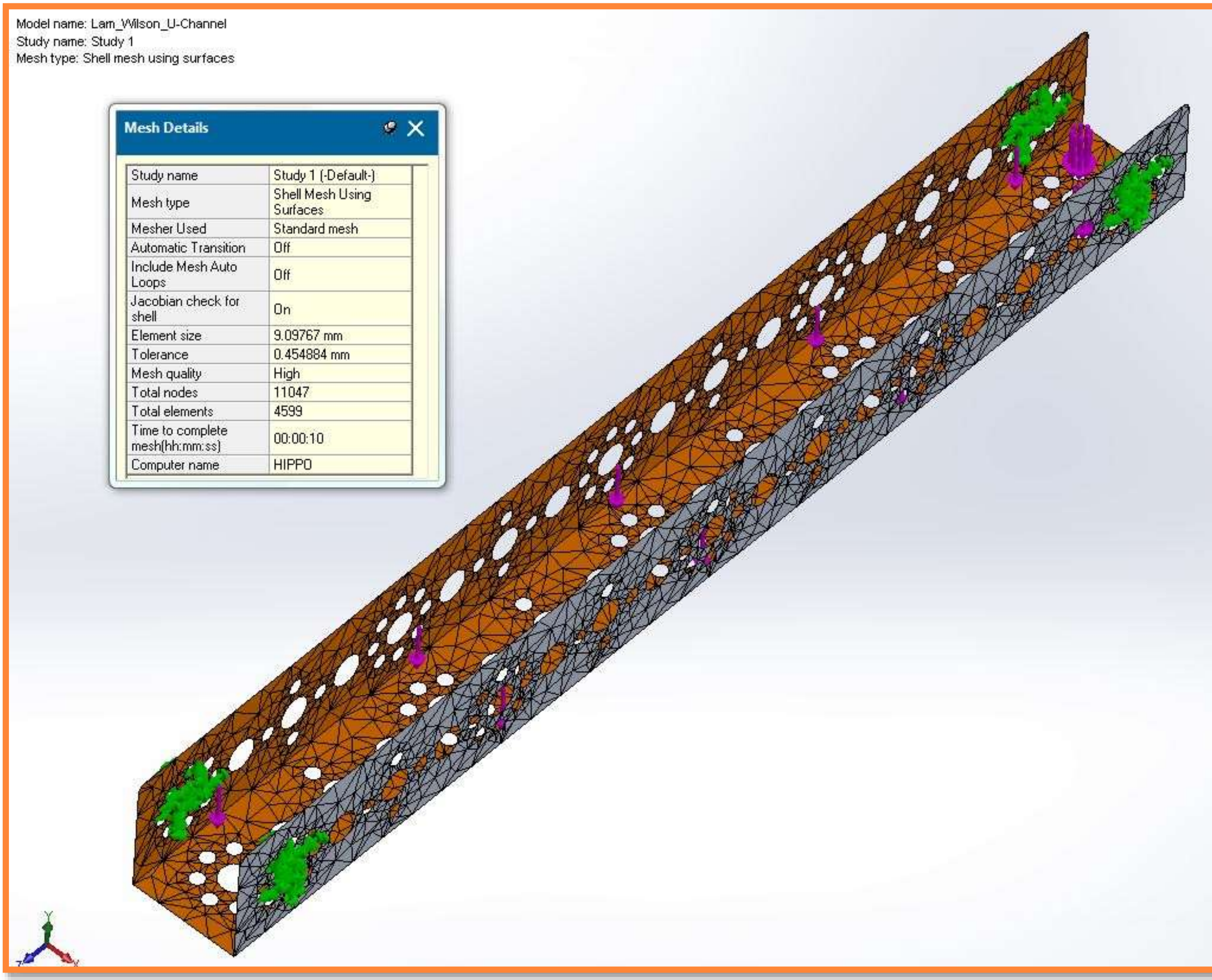


Figure 10: Shell Meshed Model with applied loads (purple) and restraints (green). (Meshed Details Table)

FEA Results

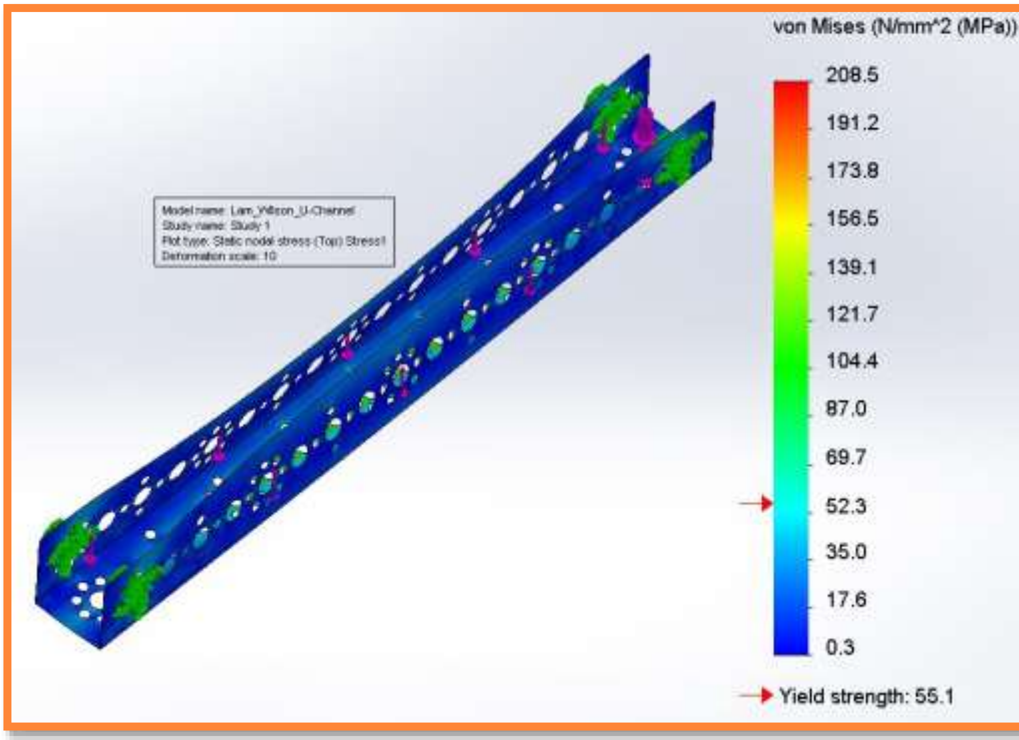


Figure 11: U-Channel Von Mises Stress for Static FEA

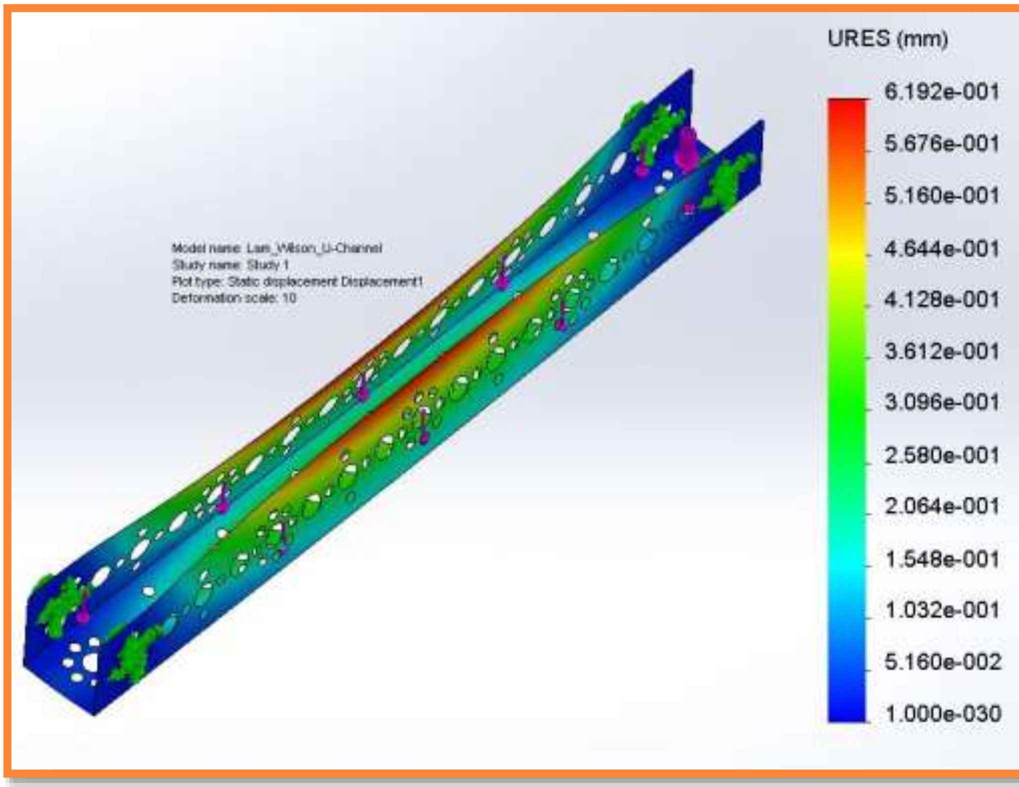


Figure 12: U-Channel Loading Displacement for Static FEA

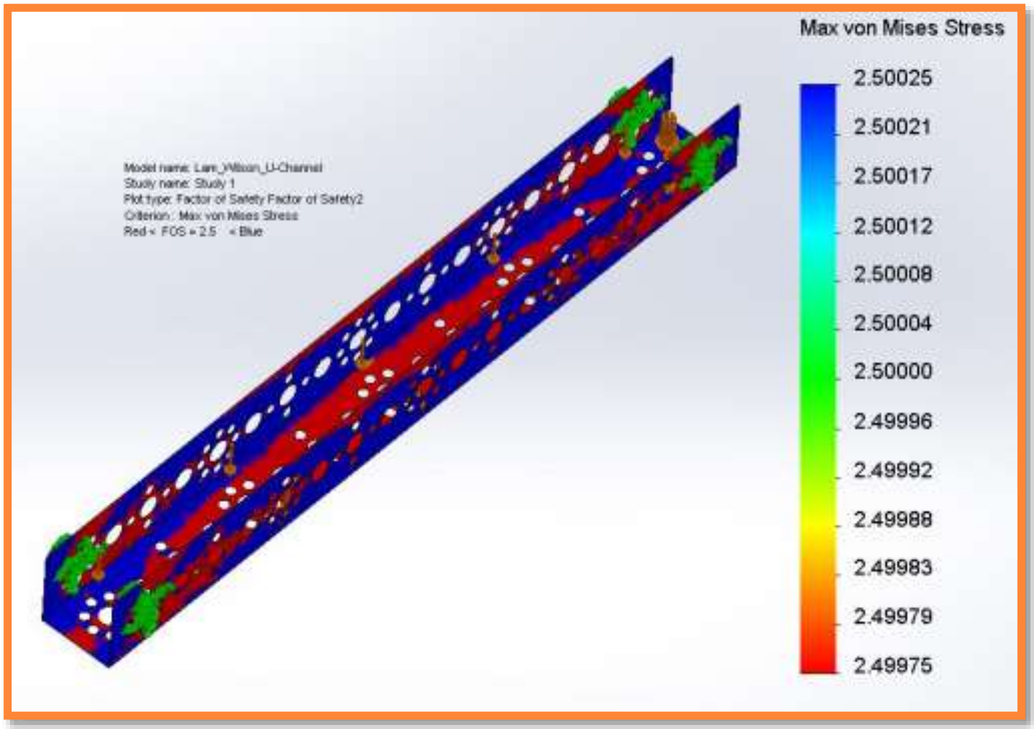


Figure 13: U-Channel Factor of Safety around 2.5 for Static FEA

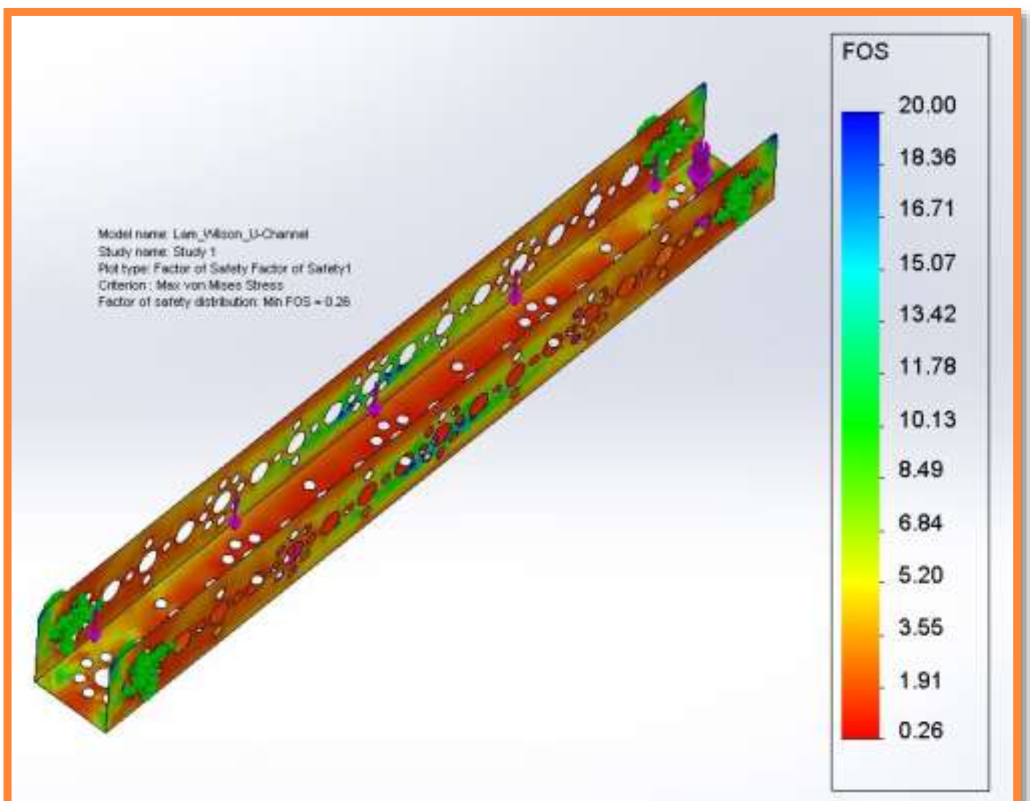


Figure 14: U-Channel Factor of Safety for Static FEA

BICYCLE

To begin the FEA we first have to make certain assumptions about the type of fixtures, loads, and element analysis type. In this analysis we are looking for possible stress, displacement, and factor of safety contour plots to analyze the effect on the bike frame. In this assumption we assume that the bicycle collide against the wall where the impact is completely absorbed by the wheel. This force is then transfer from the wheel to the slot where the front wheel is connected to the bike frame. To begin the assumption we have to provide a certain scenario of what might occur.

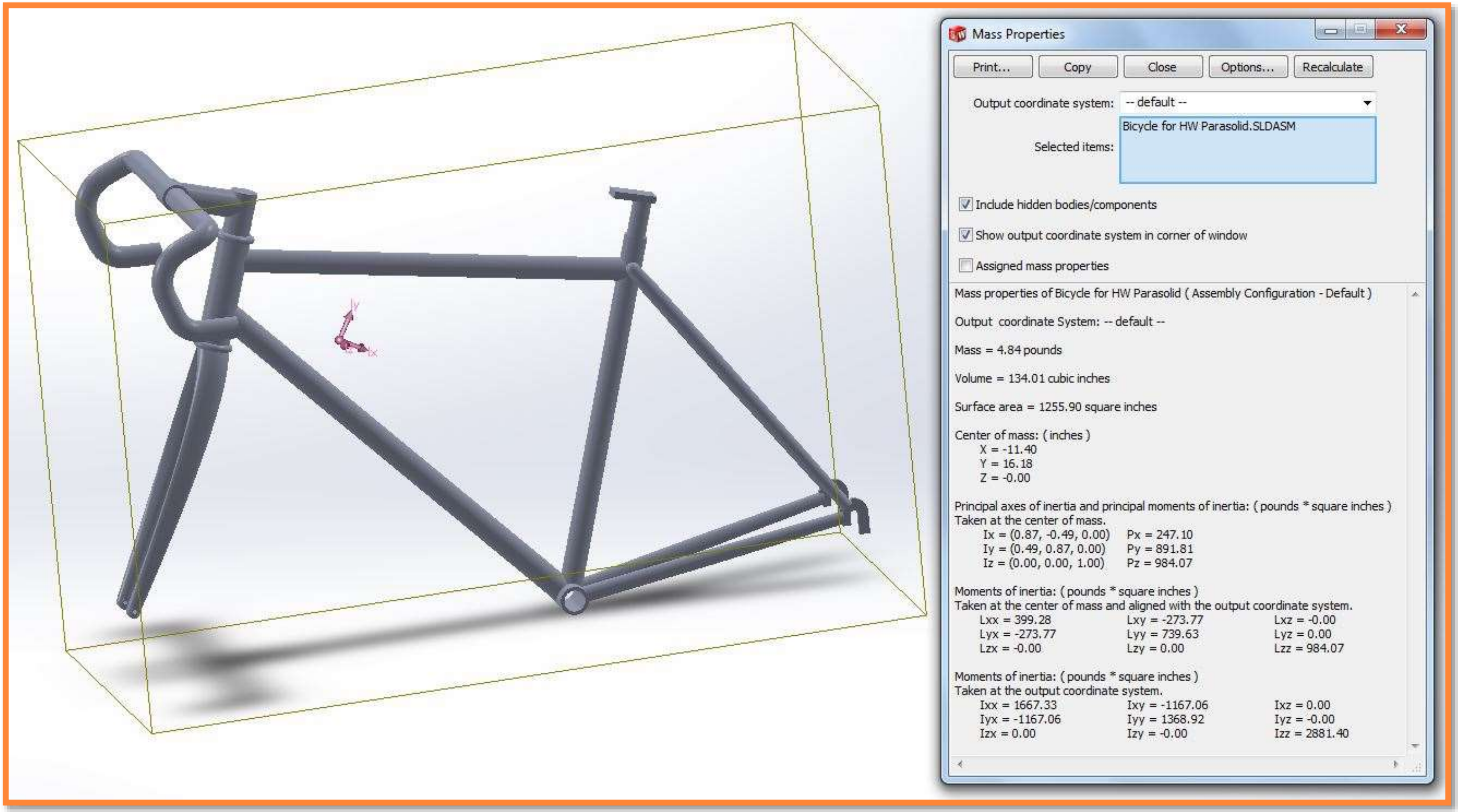


Figure 15: Figure 16: Solidworks Bicycle Model used in FEM analysis. (Mass Properties Table)

Assumptions

To begin our FEA we need to make certain assumptions of the possible scenario. In our case, there is a person riding a bike down a hill at a constant initial velocity before he realize his break suddenly fail so he jumped off the bicycle 10 ft before the bike slams straight into a concrete wall. So in this case we choose to break up the situation into four sections:

1. Constant velocity 4.5 m/s during the first 190 ft long road (before the break fail)
2. Conservation of momentum when the person jumps off the bike
3. Energy conservation when the bike is moving down the hill 10 ft before collision (after the guy is off)
4. Impulse momentum during the wall collision

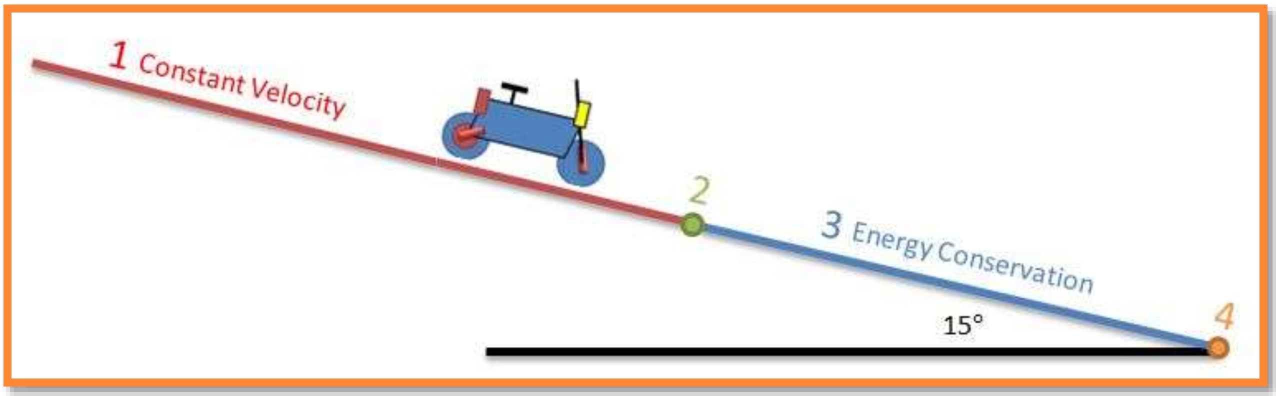


Figure 17: Assumed scenario schematic diagram.

Our assumptions and equations are listed as follows:

1. Constant Velocity

$$V_{guy+bike} = 4.5\ m/s$$

- Restraints at seat support rod (green)
  Note: This location is chosen because the force acts normal to this rod. The most important fact for choosing this location is due to its effect in different reference frame. In other reference frame during impact we can assume the wall is moving and compressing the bike while this chosen seat support rod is stationary.
- Bike mass from solidworks model: 4.84 lb = 2.195 kg. Assuming each wheel is 1 kg then the total mass of bike is about 4.195 kg.
- The person and bike before the guy jumped off has a velocity of about 4.5 m/s.
- At 10 ft or 3.048 m (height: 0.789m) he jumped off at a speed of 4.221 m/s

2. Conservation of Momentum

During this situation conservation of momentum is applied.

$$(m_{guy} + m_{bike})V_{guy+bike} = m_{guy}V_{guy} + m_{bike}V_{bike1} \qquad \text{[eq. 0-1]}$$

Table 3: Conservation of momentum and energy assumptions we made for the bike and person.

Total Bike Mass (with wheels of 1 kg)(m_{bike})	4.195 kg
Person Mass (m_{guy})	155 lb → 70.31 kg
Velociy of guy and bike ($V_{guy+bike}$)	4.5 m/s
Bike velocity after momentum conservation (V_{bike1})	13.44 m/s
Guy velocity after he jump off (V_{guy})	4.22 m/s
Gravity (g)	9.8 m/s^2
Height (h) (convert length 10 ft to height)	0.789 m
Bike speed after wall collision (V_{bike3})	0.3 m/s
Impulse time (Δt)	0.1 s

$$\frac{[(m_{guy}+m_{bike})V_{guy+bike}- m_{guy}V_{guy}]}{m_{bike}} = V_{bike1} \quad \text{[eq. 0-2]}$$

Solving for the first equation we can get the velocity of the bike at the instant the guy jump off at 10 ft $V_{bike1} = 13.44 \text{ m/s}$

3. Energy Conservation

During step 3 the bike cruises to the bottom and collide against the wall. We can assume there is only conservation of energy. So using the equations below we can calculate for the V_{bike2}.

$$PE + KE_i = KE_f \quad \text{[eq. 0-3]}$$

$$m_{bike}gh + \frac{1}{2}m_{bike}{V_{bike1}}^2 = \frac{1}{2}m_{bike}{V_{bike2}}^2 \quad \text{[eq. 0-4]}$$

Solving for V_{bike2} we get $\boxed{V_{bike2} = 14\ m/s}$.

4. Impulse Momentum

After we find $V_{bike\mathbf{2}}$ we can now use impulse momentum during the collision to calculate for the estimated force applied to the wheel. Note: $V_{bike\mathbf{3}} = \ 0.3\ m/s$

$$F * \Delta t = m_{bike}(\Delta V_{bike23}) \quad \text{[eq. 0-5]}$$

Solving for the force $\boxed{F = 600\ N}$ we can now perform our FEA.

Our final assumption is that all the forced the wheel experienced is acted on the joint of the bike frame holding the wheel in place.

Table 4: Assumptions for bicycle FEA

Analysis type	Static
Mesh type	Solid Mesh
Solver type	FFEPlus
Incompatible bonding options	Automatic
Fixtures	Seat Support rod (green)
Loading	600 N normal to right plane surface (purple)

FEA Results

Figure 18: Bicycle Von Mises Stress for Static FEA

Figure 19: Bicycle Loading Displacement for Static FEA

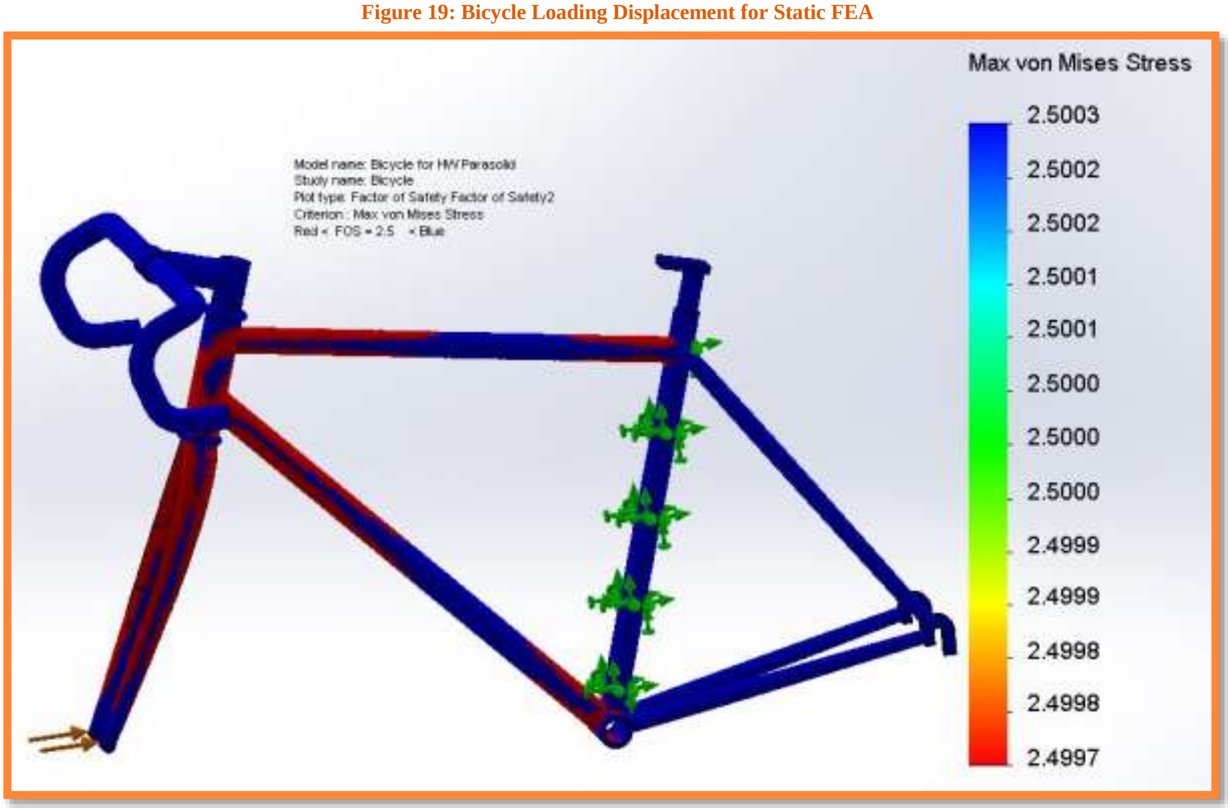


Figure 20: Bicycle Factor of Safety around 2.5 for Static FEA

Figure 21: Bicycle Factor of Safety for Static FEA