MECH2409 –Machine Element Design

Final Report

Topic: MonoSki

By:

Anthony Reyes

Kishon Webb

Aashish Dumasia

March 2018

York University

Index

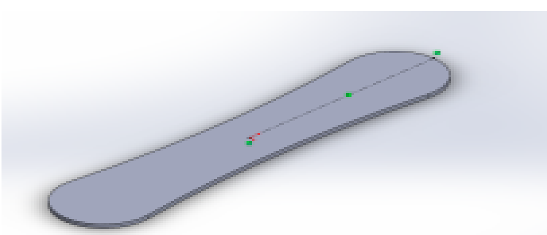
Introduction

This report outlines the process of moving from identifying a problem, to coming up with a possible design solution and then testing and modifying that design for a mono-ski (aka sit ski). This design takes information from the Design Specification Report and expands on its ideas. The design should accommodate the weight and waist size of an average male. The design also needs a shock absorption system to reduce impact of forces on the user. A less important feature was the need for the design frame to be able to be a suitable size (length and width) to fit on a ski. An additional feature added, was the idea to simplify our design by using a centralized base instead of multiple supports.

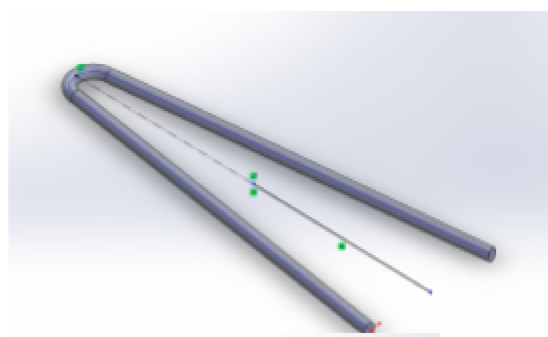
For the FEM analysis, we used the cyclic and static loading conditions outlined in the previous report. The static loading uses the average weight of a male distributed on the upper support. Our cyclic loading will use the compression and decompression due to the loading and unloading.

Idea Generation and Concept Selection

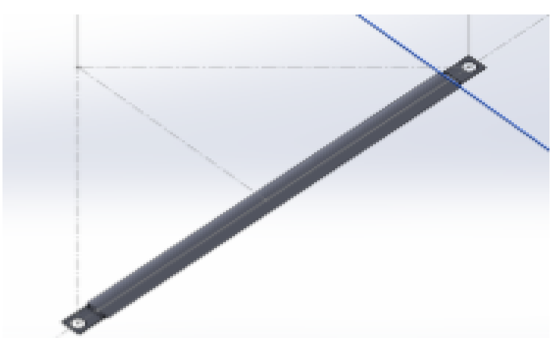
Below are a few design ideas our group came up with in composing the main parts of the monoski. These components will eventually be modified to meet specifications.



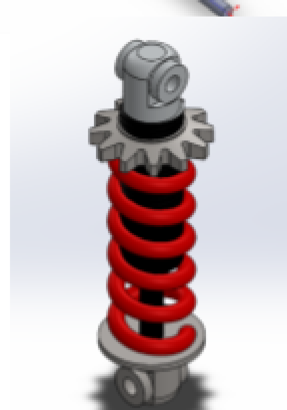
MonoSki base



MonoSki frame



MonoSki support



Monoski Suspension System

We decided that the suspension and board were good solid ideas for our design since they were reliable and also provided much needed support and making our design realistic.

support and frame were very weak and poorly designed

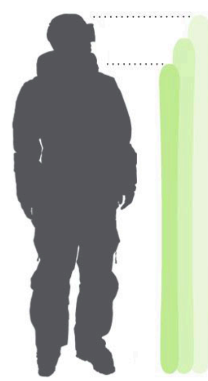
Preliminary Design

After looking at the different design options we decided to try and use these components with a base for the skier to sit upon. This is because these components allow for support for the user and also give a wide base for them to sit on. They also are designed to fit an average sized male, and a average sized ski. We used a ski sizing chart (shown below) when deciding some of our dimensions. We used the average height of a male which is around 5’9”, and used the corresponding ski height and length as our dimensions

.

SKI SIZING CHART

SKIER HEIGHT IN FEET & INCHES	SKIER HEIGHT IN CENTIMETERS (CM)	SUGGESTED SKI LENGTHS (CM)	SHOP SKIS BY LENGTH (CM)
4'4"	132<	115-130	130-139
4'6"	137	125-140	
4'8"	142	130-145	140-149
4'10"	147	135-150	
5'	152	135-155	150-159
5'2"	158	145-165	
5'4"	163	150-170	160-169
5'6"	168	155-175	
5'8"	173	160-180	170-179
5'10"	178	165-185	
6'	183	170-190	180-189
6'2"	188	175-195	
6'4"	193	180-200	>190



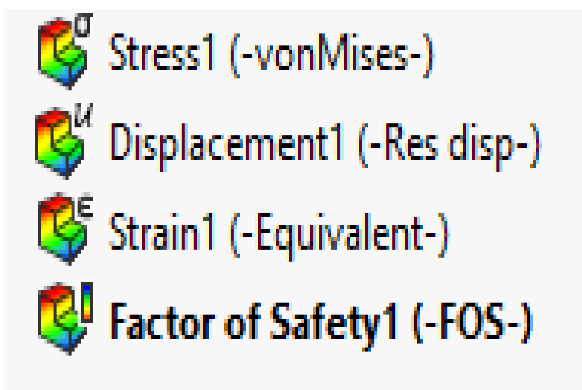
We also needed to decide on how we were going to attach our supports to seat holder. We decided to test our design with one set of supports (not including the suspension) that was attached to a base at the centre of the ski. Alternate designs included multiple holes at the base and multiple bases.

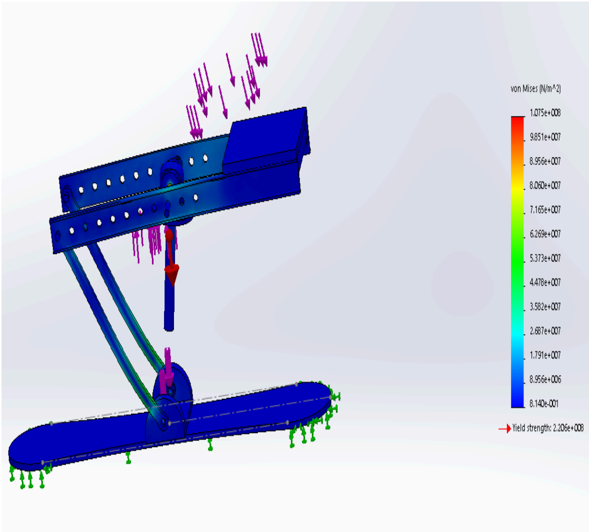
Our initial design consisted of basic parts. The design was mostly to test the feasibility of different components of our design. It had a simple base attached to the ski at the centre. This was used to support the support bars and the shock absorber. Then we used supports attached to a "frame" that we designed. It had multiple holes to add modularity for consumers, and for our own testing purposes.

For our material selection, we wanted to choose something that has a high yield stress and low density to maximize the monoski's performance under loading conditions. We ended up using plain carbon steel for our material.

<u>FEM Analysis & Iterative Design</u>

Images of the initial design, and it undergoing different loading conditions in solidworks simulation are shown below.

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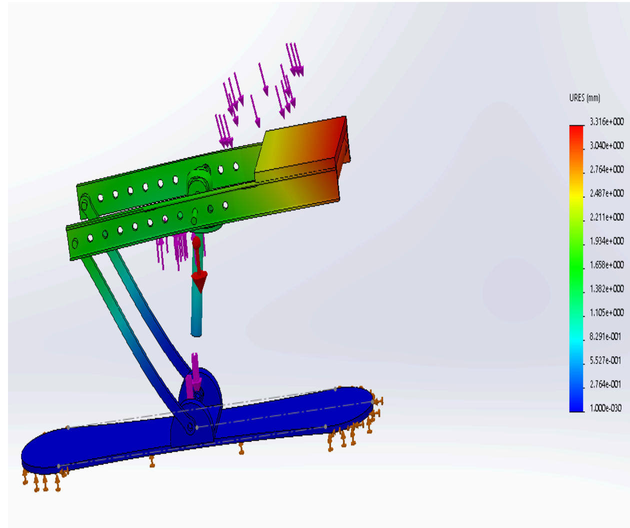
9.851e+007
8.956e+007
8.060e+007
7.165e+007
6.269e+007
5.373e+007
4.478e+007
3.582e+007
2.687e+007
1.791e+007
8.956e+006
8.140e-001
Yield strength: 2.206e+008


URES (mm)
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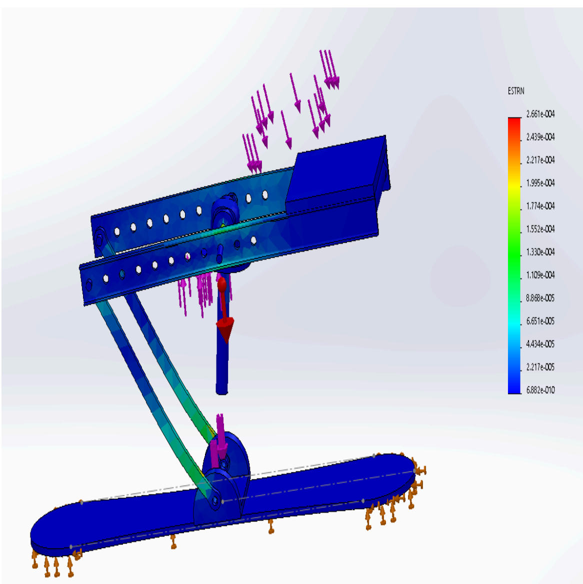
3.040e+000
2.764e+000
2.487e+000
2.211e+000
1.934e+000
1.658e+000
1.382e+000
1.105e+000
8.291e-001
5.527e-001
2.764e-001
1.000e-030


ESTRN
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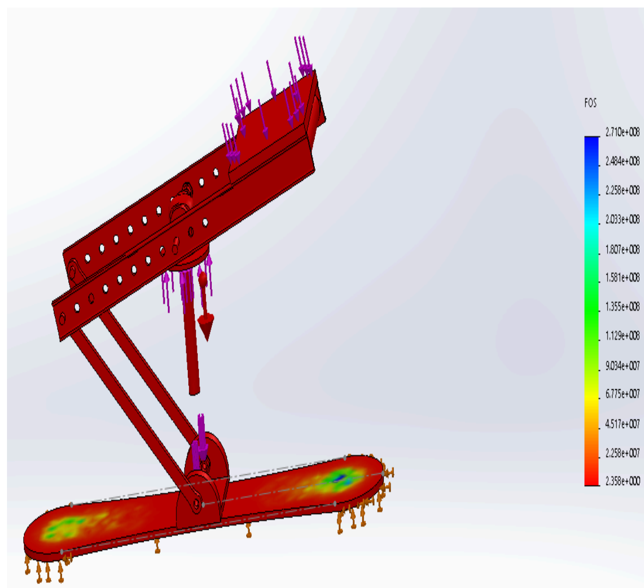
2.439e-004
2.217e-004
1.995e-004
1.774e-004
1.552e-004
1.330e-004
1.109e-004
8.868e-005
6.651e-005
4.434e-005
2.217e-005
6.882e-010


FOS
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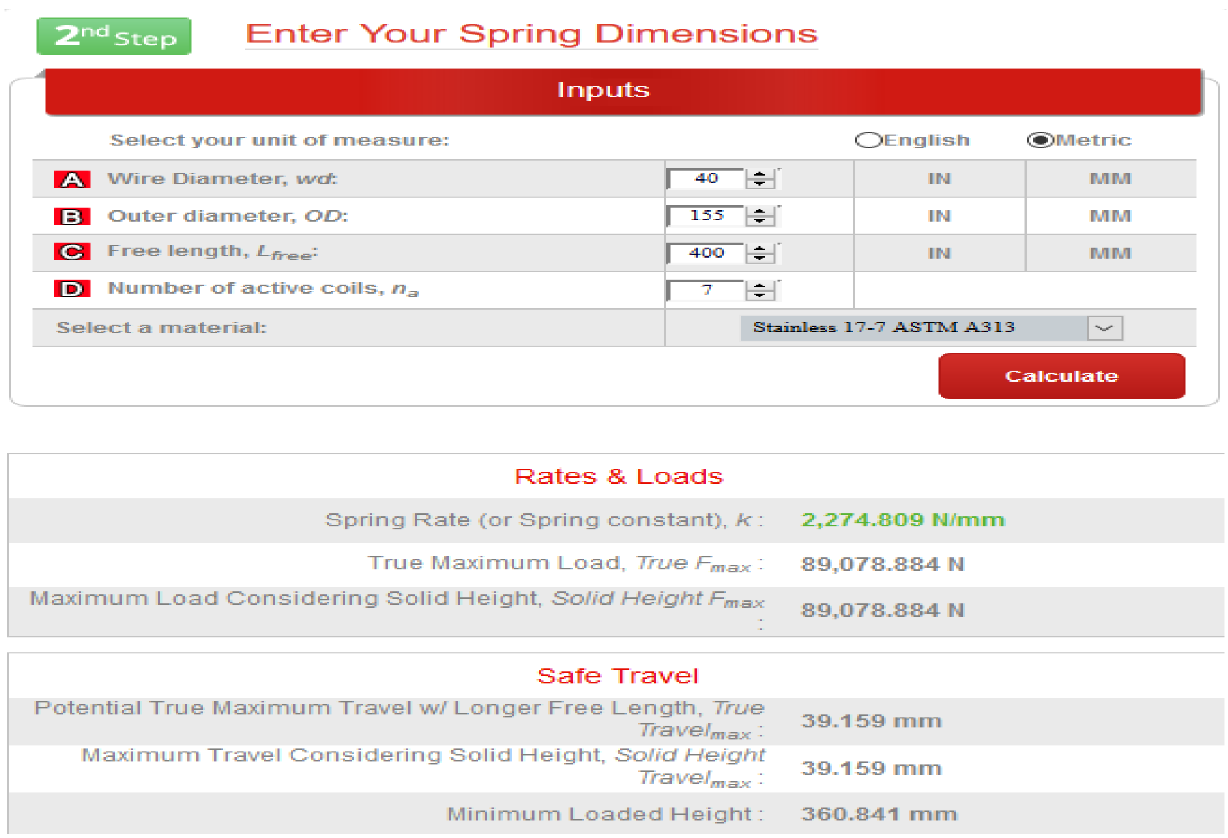
2.484e+008
2.258e+008
2.033e+008
1.807e+008
1.581e+008
1.355e+008
1.129e+008
9.034e+007
6.775e+007
4.517e+007
2.258e+007
2.358e+000

Our design, does not actually include the spring as a component in the analysis. Instead, we determined the spring constant for the spring designed in SolidWorks. This was done by using online software called the Spring Creator from a company called *Acxess Spring.* The results of the calculations are shown in the figure below.



2nd Step Enter Your Spring Dimensions

Inputs

Select your unit of measure:		English	Metric (selected)
A Wire Diameter, *wd*:	40	IN	MM
B Outer diameter, *OD*:	155	IN	MM
C Free length, L_{free}:	400	IN	MM
D Number of active coils, n_a	7		
Select a material:	Stainless 17-7 ASTM A313		

Calculate

Rates & Loads

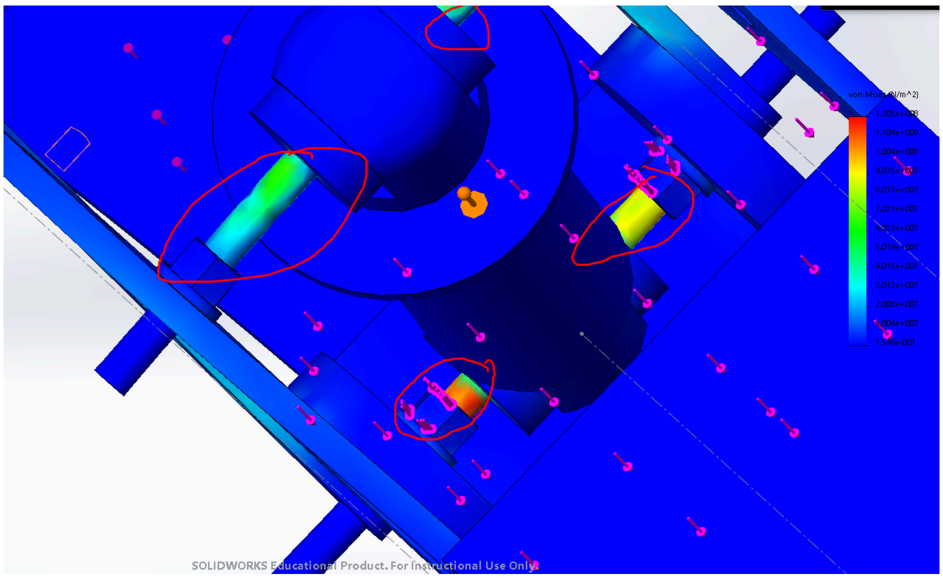
Spring Rate (or Spring constant), *k* :	2,274.809 N/mm
True Maximum Load, *True* F_{max} :	89,078.884 N
Maximum Load Considering Solid Height, *Solid Height* F_{max} :	89,078.884 N

Safe Travel

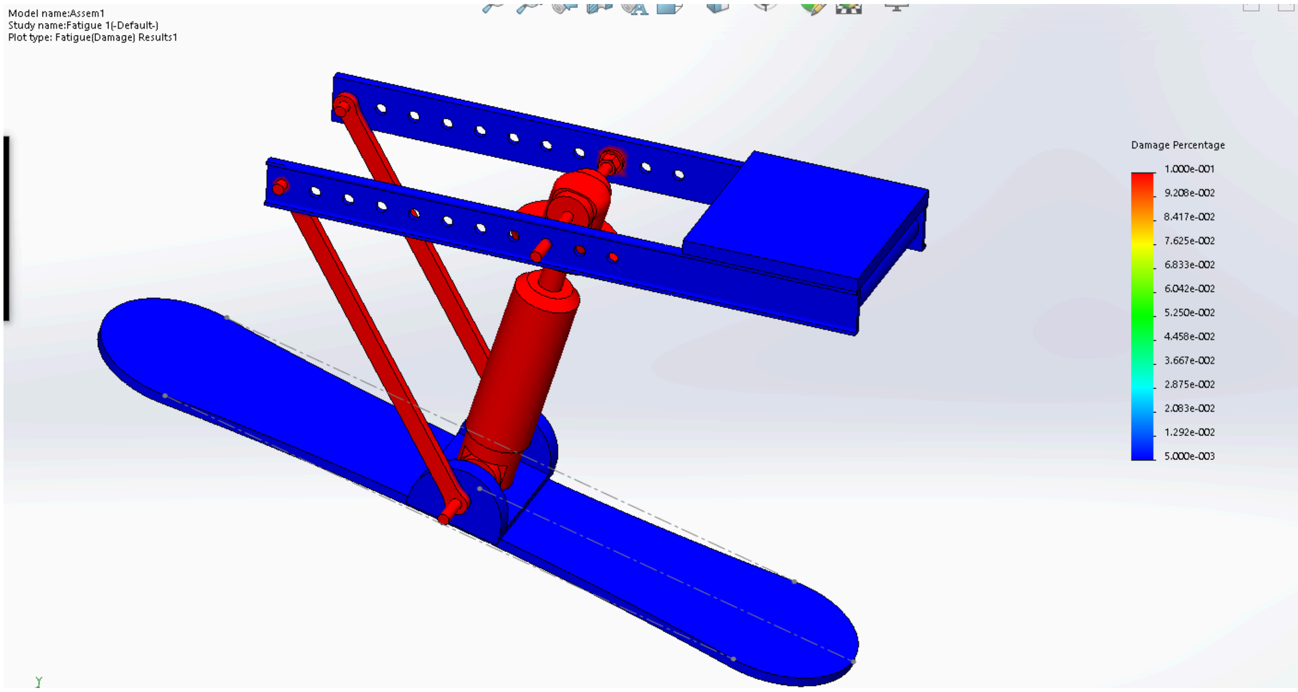
Potential True Maximum Travel w/ Longer Free Length, *True* $Travel_{max}$:	39.159 mm
Maximum Travel Considering Solid Height, *Solid Height* $Travel_{max}$:	39.159 mm
Minimum Loaded Height :	360.841 mm

Using the Spring constant , knowing that $F = -kx$ and having a max displacement of -10mm we have a spring force of around 230N. This force is placed and divided among the bolts that hold the shock absorber. For our loading condition, we took the average weight of a person which was 75 kg and multiplied it by 9.81 m/s^2 (gravity), which resulted in a downward force of 735.75 N.

However, for simplification purposes, we approximated the force to be 750 N in our simulation. From our initial analysis, we can see that our design has some choke points. Namely, bending in the support beams and in the support rods. As expected from the results, our design isn't very safe in most places and has a low factor of safety, which can be improved greatly with better design of safety simulation.



For our fatigue analysis, we used our static study as our event, but we needed to decide on the amount of uses for our design. We first found info on the number of people who ski a year and the number of active skiers[1] . Taking the averages of 2011/12 we found that people go skiing approximately 7 times a year. (18 million visits/year ÷ 2.5 million skiers/year). We then found that, on average, skis should last about 80-100 ski days[2] or visits. If we make the assumption that a person will ski about 2-3 times in a vist, the ski should last 160-300 skis or about 40 years. For our fatigue analysis we used 300 cycles. The results are present in the figures below.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Study name:Fatigue 1(-Default-)
Plot type: Fatigue(Damage) Results1
Damage Percentage
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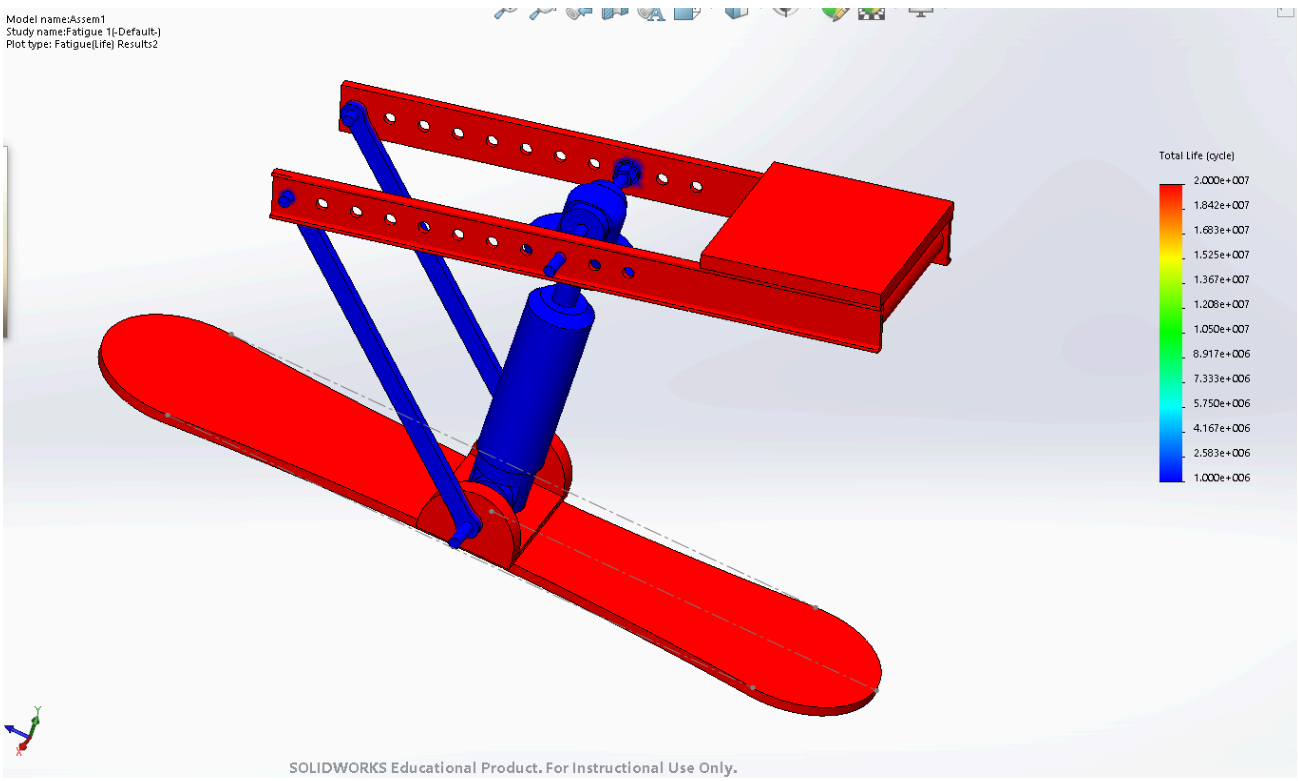
9.208e-002
8.417e-002
7.625e-002
6.833e-002
6.042e-002
5.250e-002
4.458e-002
3.667e-002
2.875e-002
2.083e-002
1.292e-002
5.000e-003


Model name:Assem1
Study name:Fatigue 1(-Default-)
Plot type: Fatigue(Life) Results2
Total Life (cycle)
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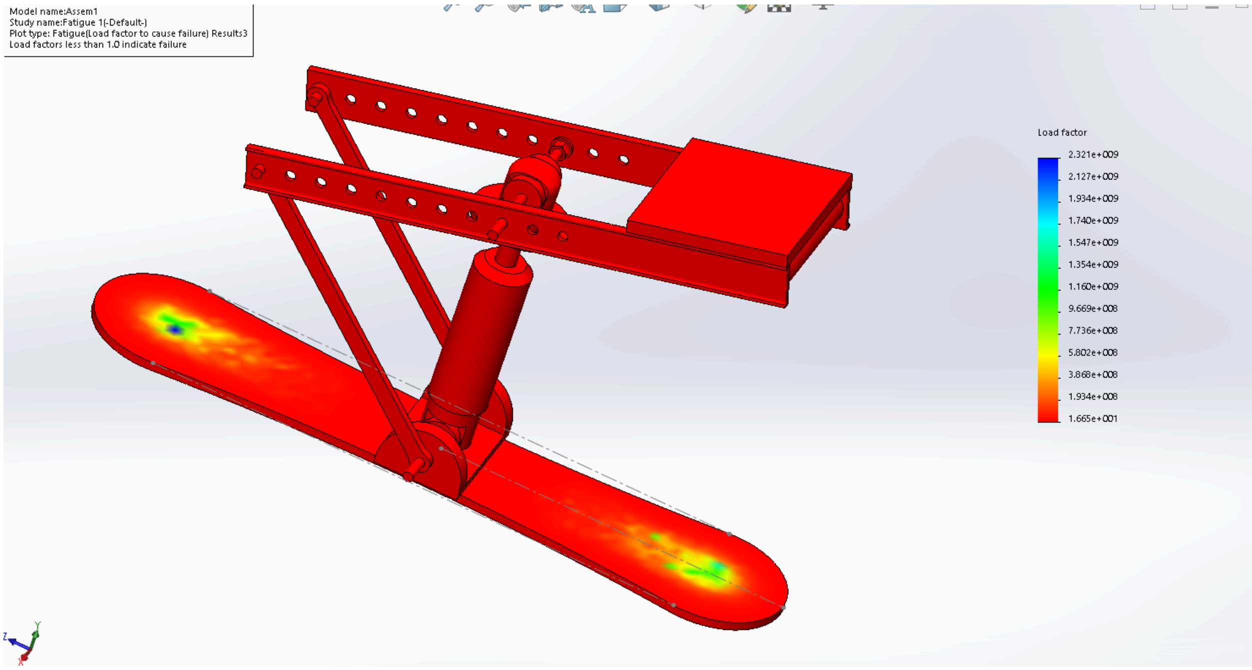
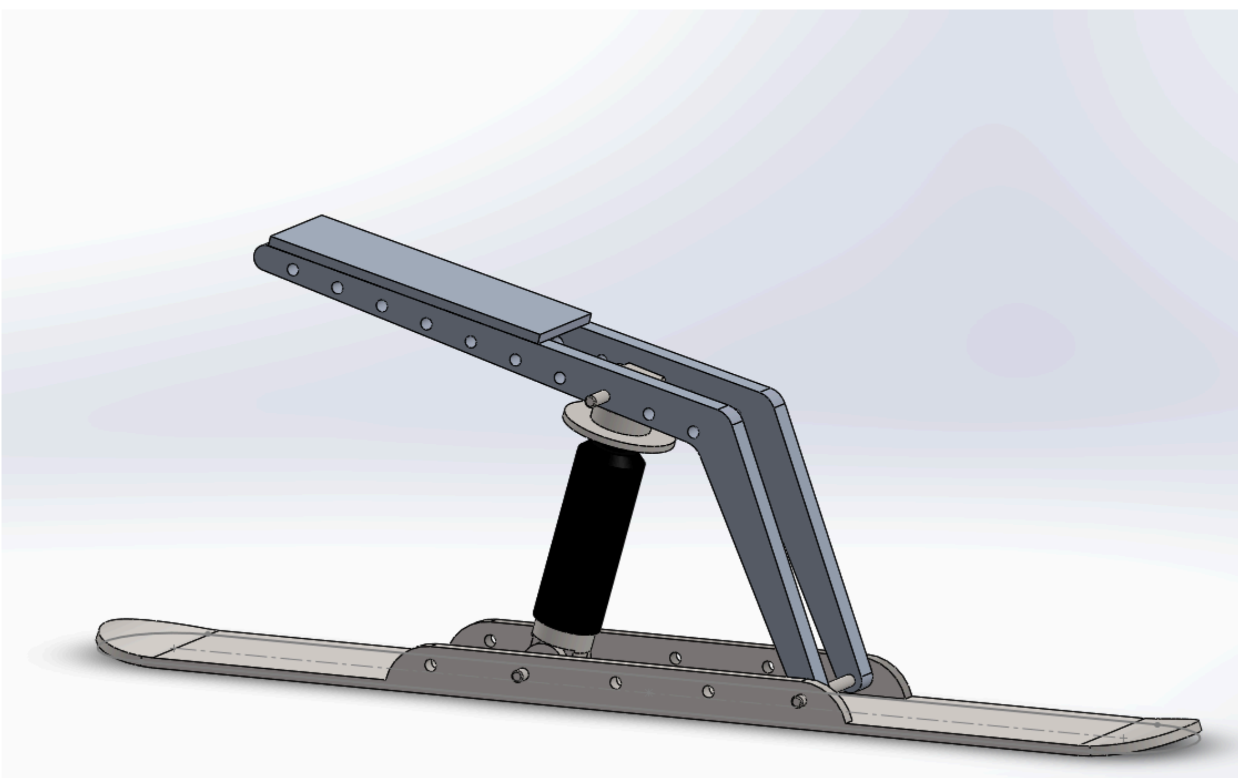
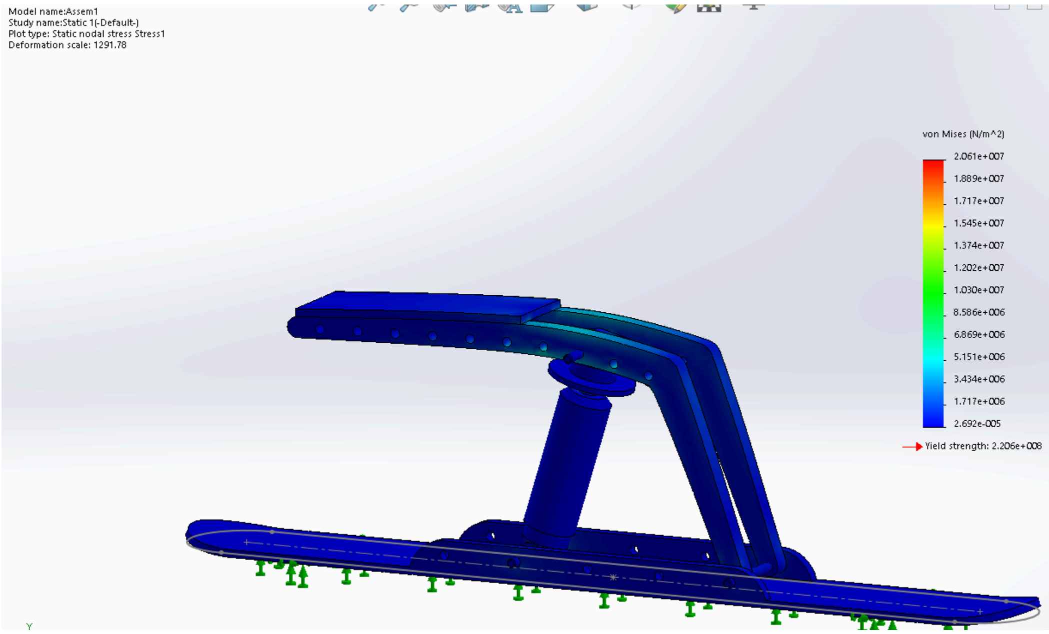
1.842e+007
1.683e+007
1.525e+007
1.367e+007
1.208e+007
1.050e+007
8.917e+006
7.333e+006
5.750e+006
4.167e+006
2.583e+006
1.000e+006
SOLIDWORKS Educational Product. For Instructional Use Only.

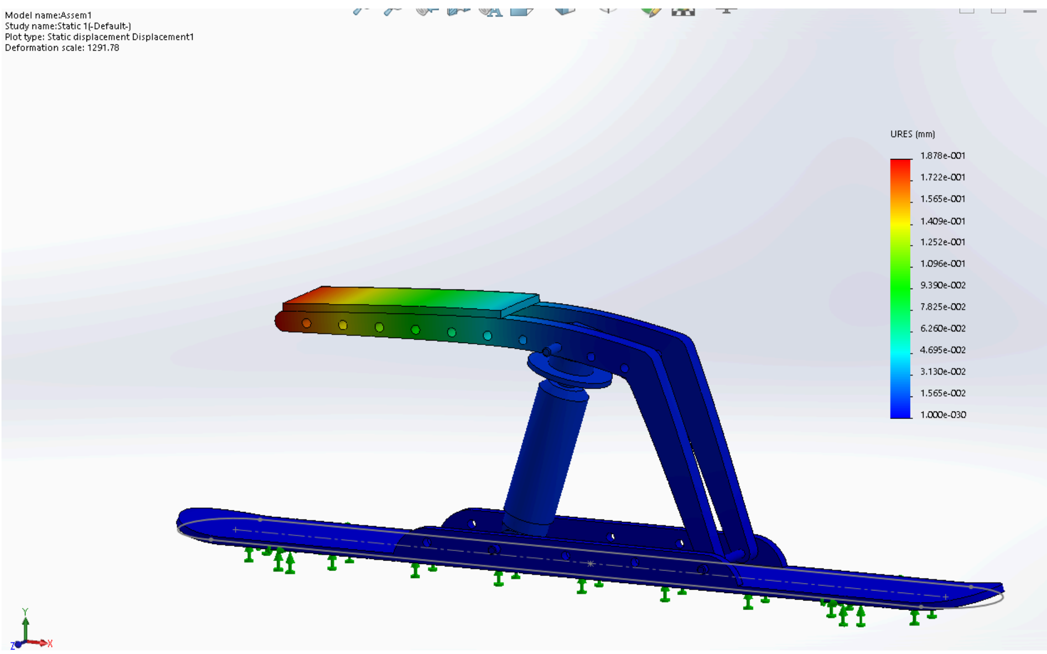


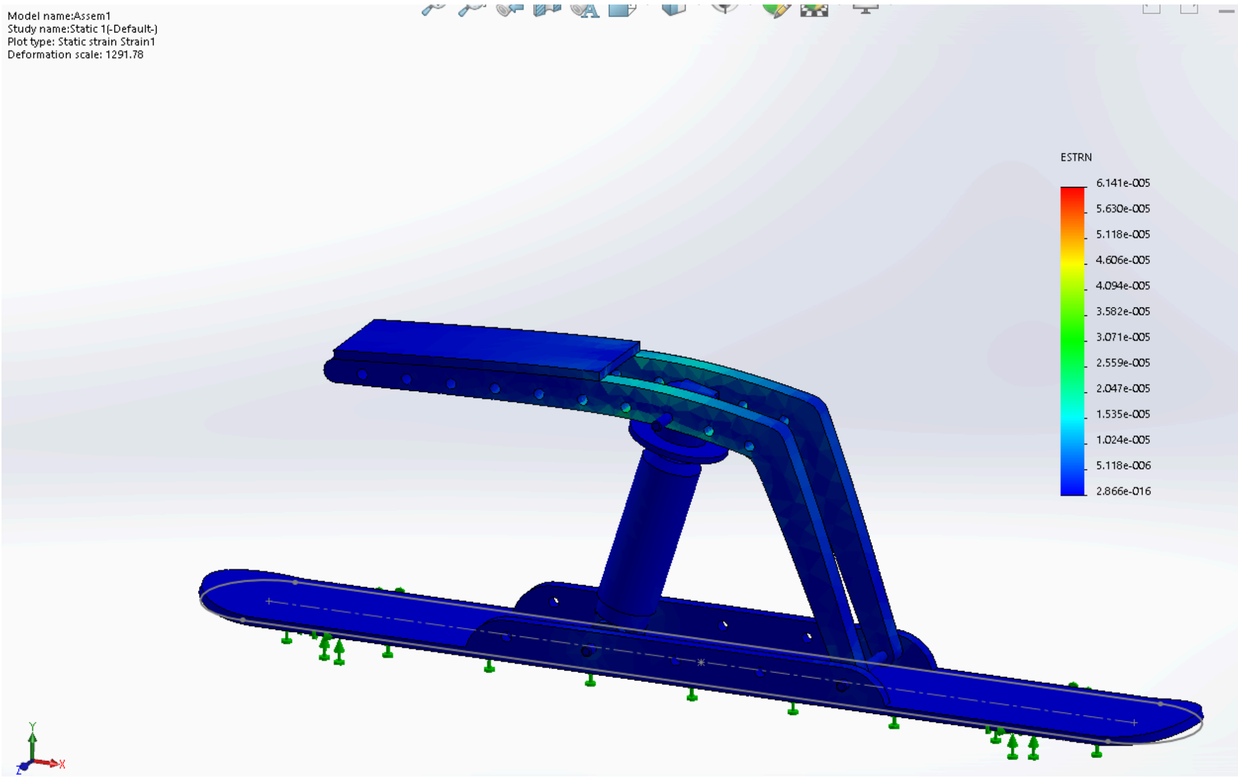
Looking at our results, the central components, the piston and support, take the most damage, and thus have the smallest life. We will try to reduce damage by balancing loads.

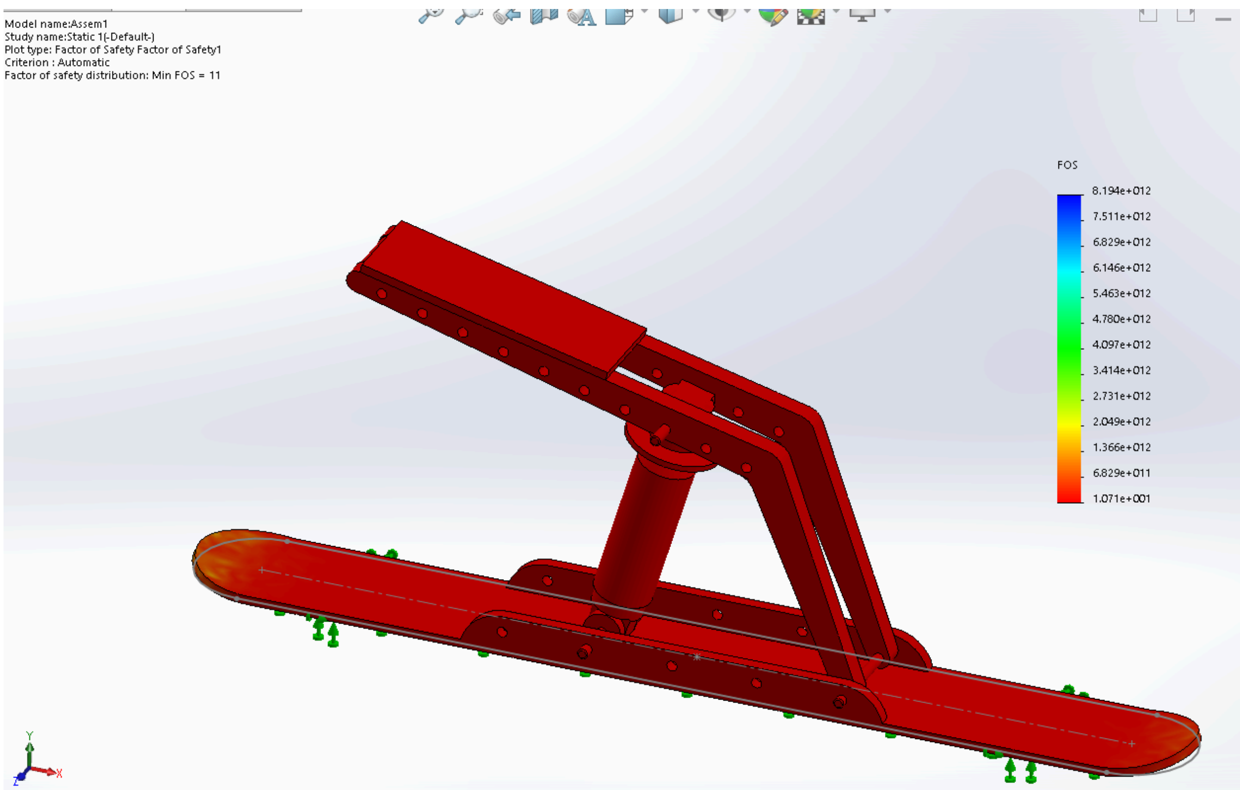
For our new design, we tried to keep the same basic principle, but with a sleeker design.




Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1291.78
von Mises (N/m^2)
2.061e+007
1.889e+007
1.717e+007
1.545e+007
1.374e+007
1.202e+007
1.030e+007
8.586e+006
6.869e+006
5.151e+006
3.434e+006
1.717e+006
2.692e-005
Yield strength: 2.206e+008
Y


Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static displacement Displacement1
Deformation scale: 1291.78
URES (mm)
1.878e-001
1.722e-001
1.565e-001
1.409e-001
1.252e-001
1.096e-001
9.390e-002
7.825e-002
6.260e-002
4.695e-002
3.130e-002
1.565e-002
1.000e-030


Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static strain Strain1
Deformation scale: 1291.78
ESTRN
6.141e-005
5.630e-005
5.118e-005
4.606e-005
4.094e-005
3.582e-005
3.071e-005
2.559e-005
2.047e-005
1.535e-005
1.024e-005
5.118e-006
2.866e-016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Study name:Static 1(-Default-)
Plot type: Factor of Safety Factor of Safety1
Criterion : Automatic
Factor of safety distribution: Min FOS = 11
FOS
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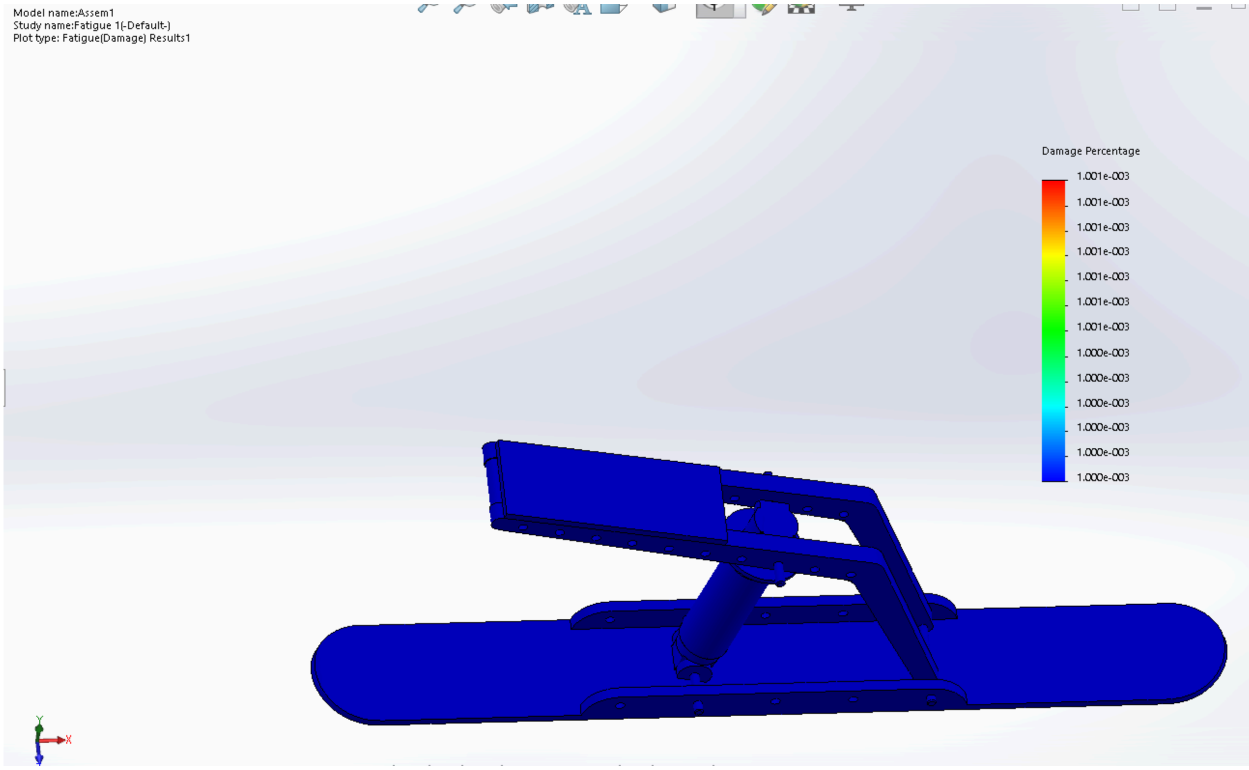
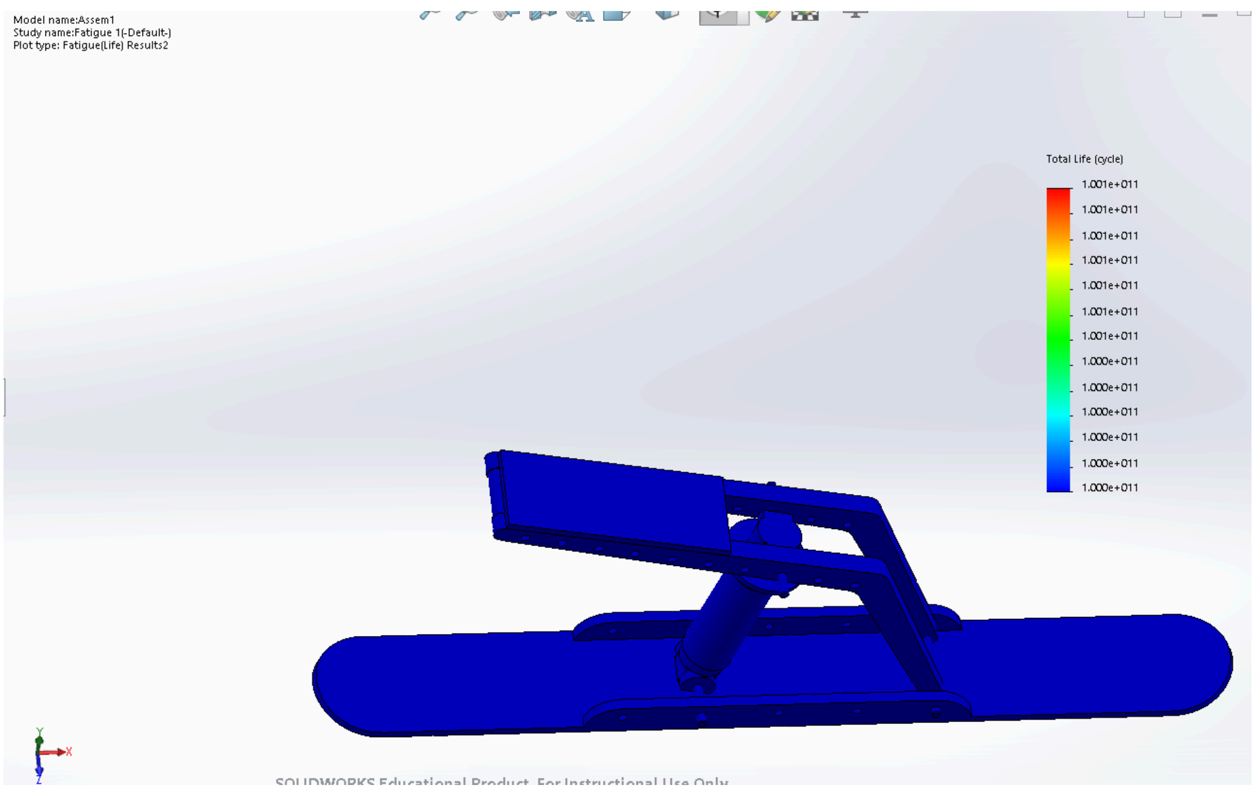
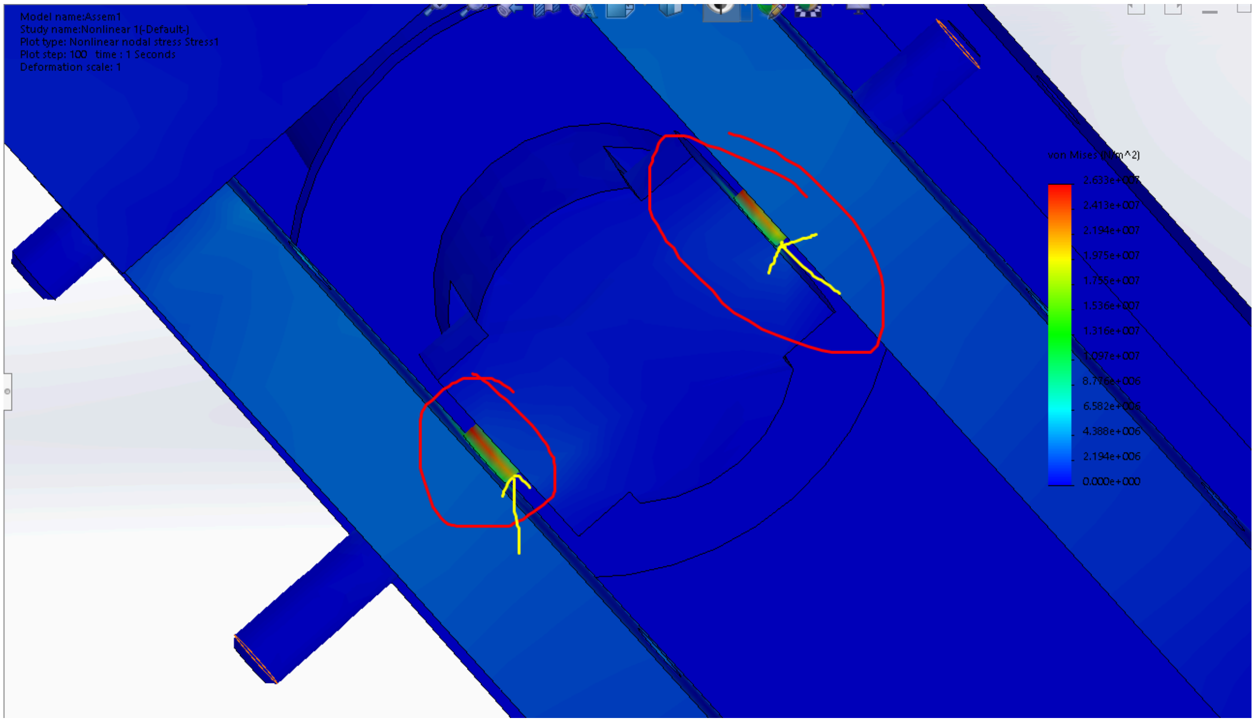
7.511e+012
6.829e+012
6.146e+012
5.463e+012
4.780e+012
4.097e+012
3.414e+012
2.731e+012
2.049e+012
1.366e+012
6.829e+011
1.071e+001

Fatigue Results






Model name:Assem1
Study name:Nonlinear 1(-Default-)
Plot type: Nonlinear nodal stress Stress1
Plot step: 100 time : 1 Seconds
Deformation scale: 1
von Mises (N/m^2)
2.633e+007
2.413e+007
2.194e+007
1.975e+007
1.755e+007
1.536e+007
1.316e+007
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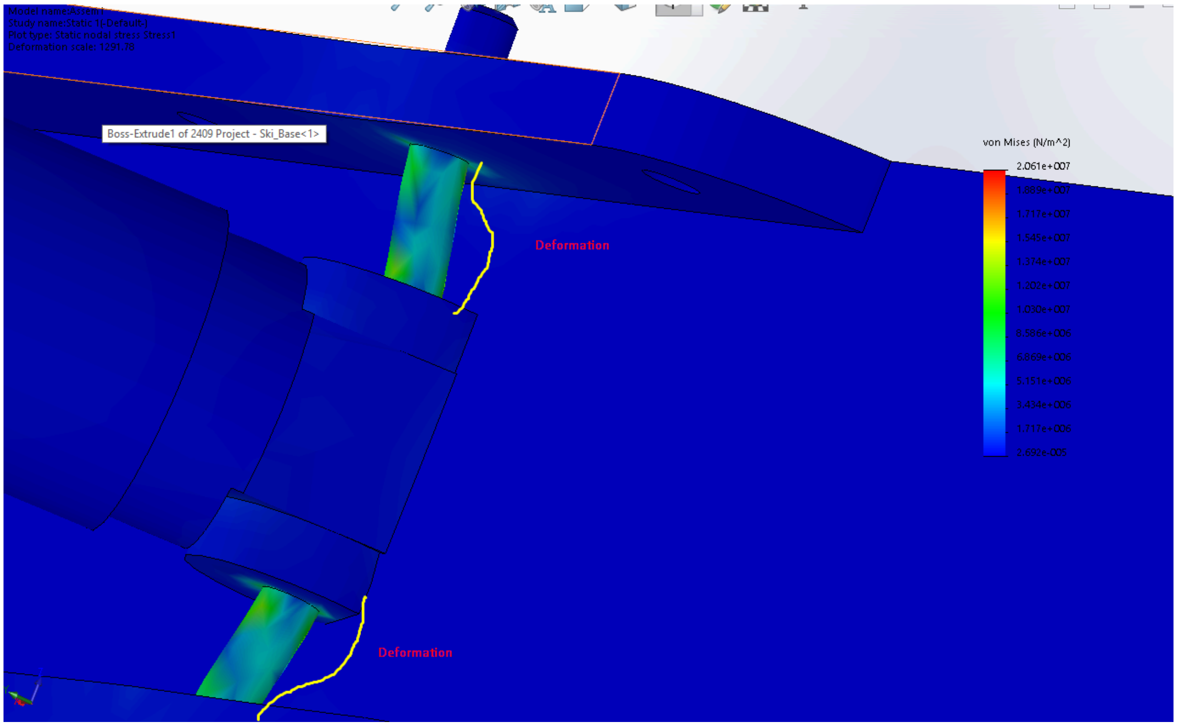
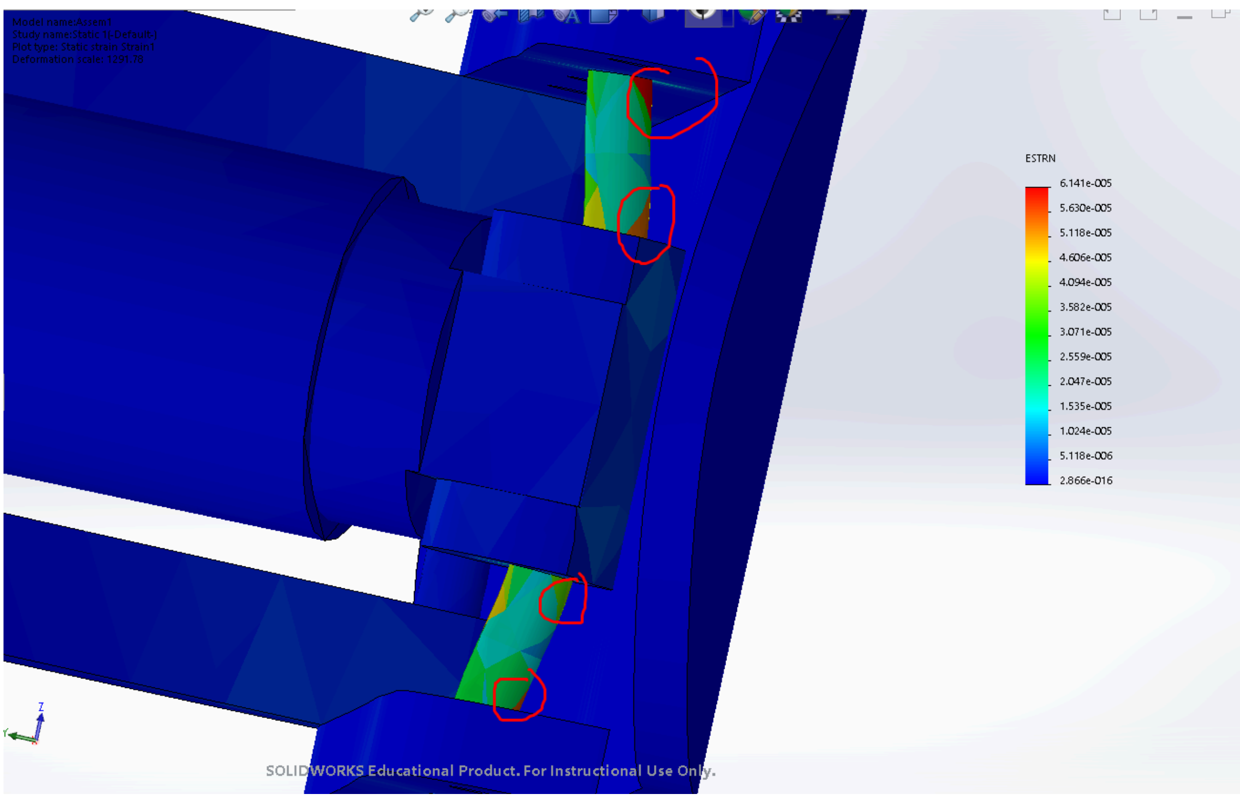
2.194e+006
0.000e+000


Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1291.78
Boss-Extrude1 of 2409 Project - Ski_Base<1>
Deformation
Deformation
von Mises (N/m^2)
2.061e+007
1.889e+007
1.717e+007
1.545e+007
1.374e+007
1.202e+007
1.030e+007
8.586e+006
6.869e+006
5.151e+006
3.434e+006
1.717e+006
2.692e-005


Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static strain Strain1
Deformation scale: 1291.78
ESTRN
6.141e-005
5.630e-005
5.118e-005
4.606e-005
4.094e-005
3.582e-005
3.071e-005
2.559e-005
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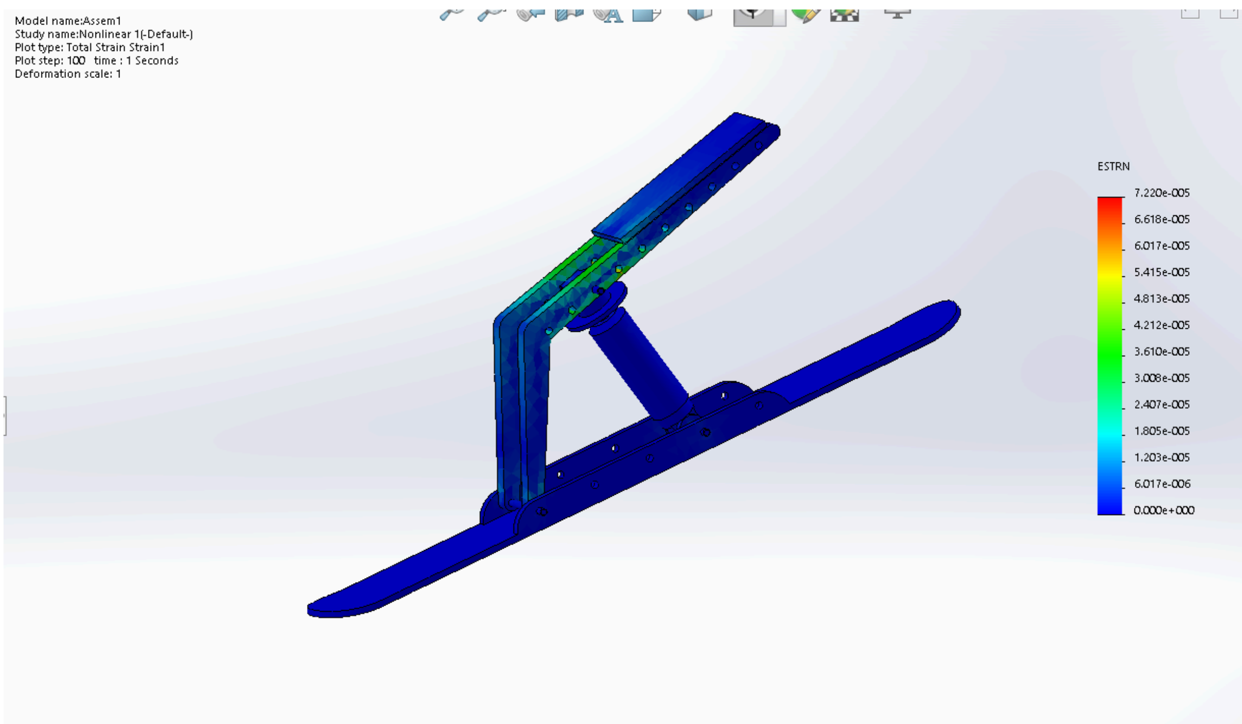
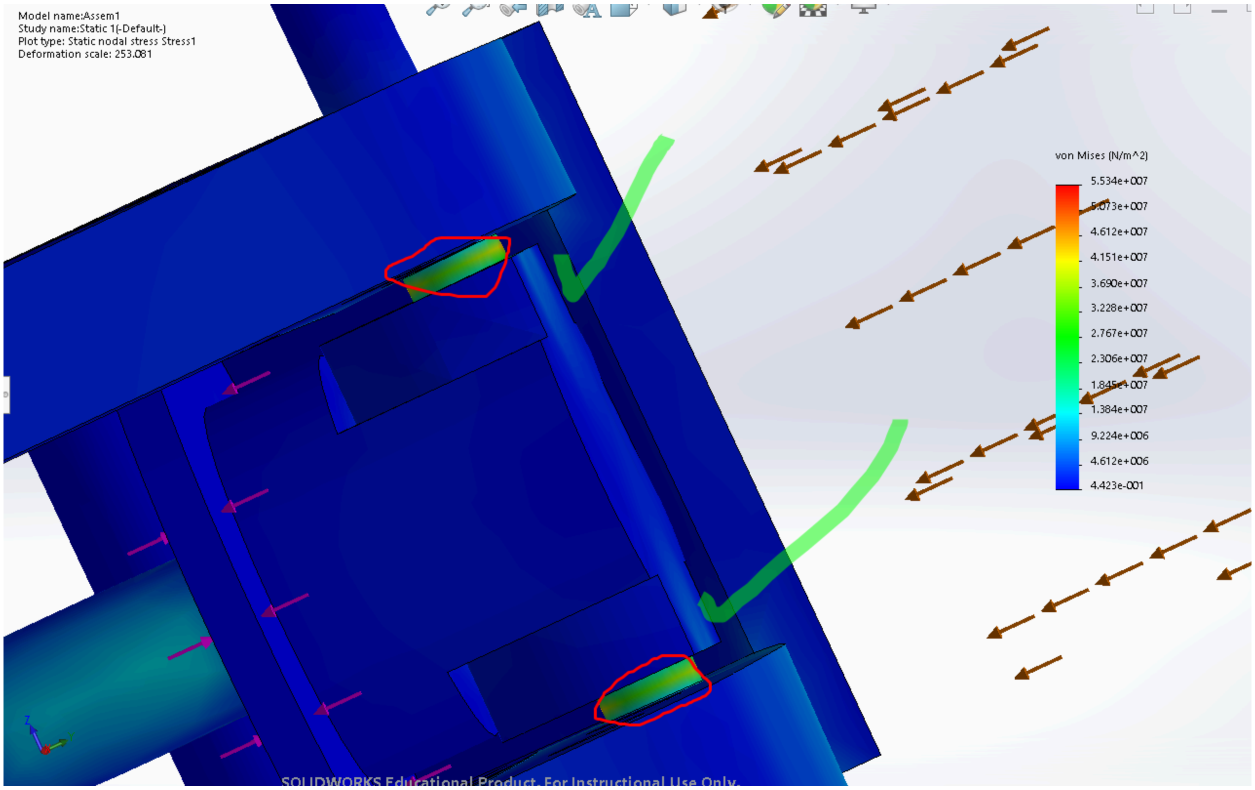
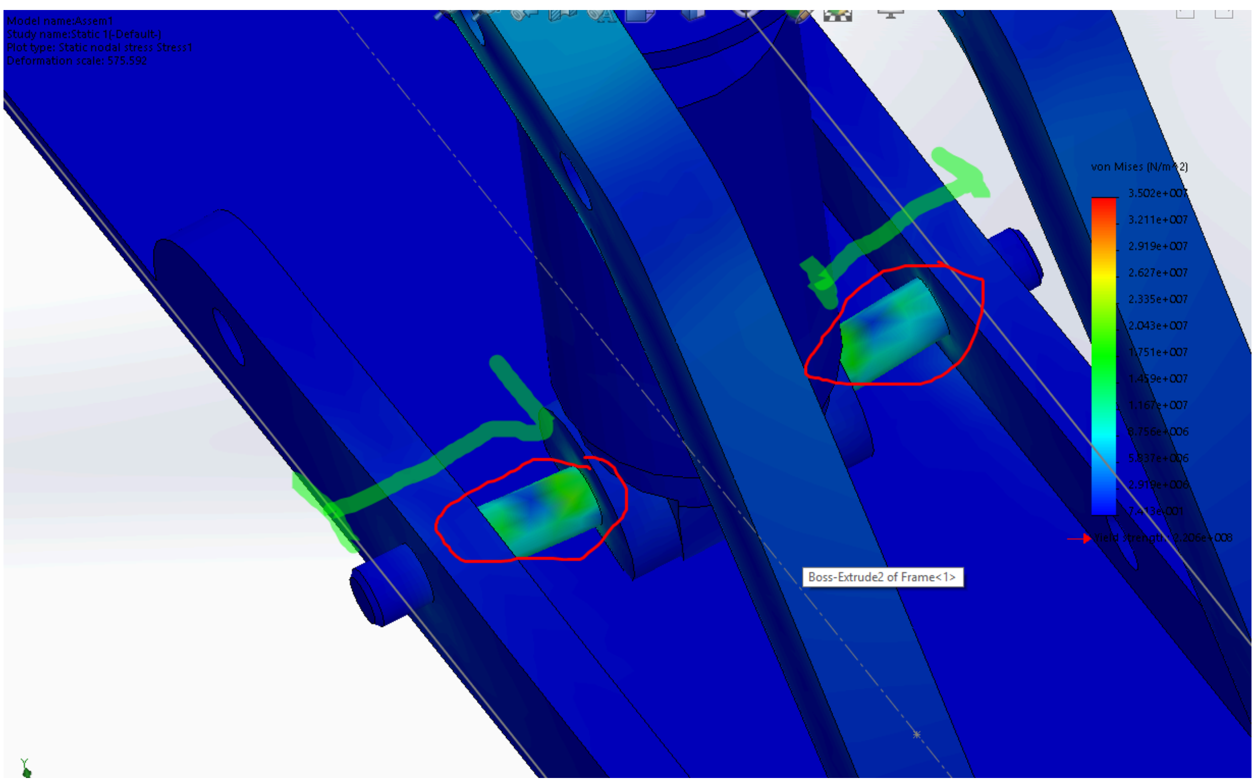
1.024e-005
5.118e-006
2.866e-016
SOLIDWORKS Educational Product. For Instructional Use Only.



From our new design it seems that the supports and forces are handled well, but our threaded rods are under alot of pressure and are deforming. They also had areas of high stress concentrations with bands appearing on the upper rod. We hypothesized that they were failing because they were receiving forces directly and not being distributed. Some possible solutions were to add additional rodded components, to add bolts in between the rods, add additional rods, or thicken the rods we had in place.

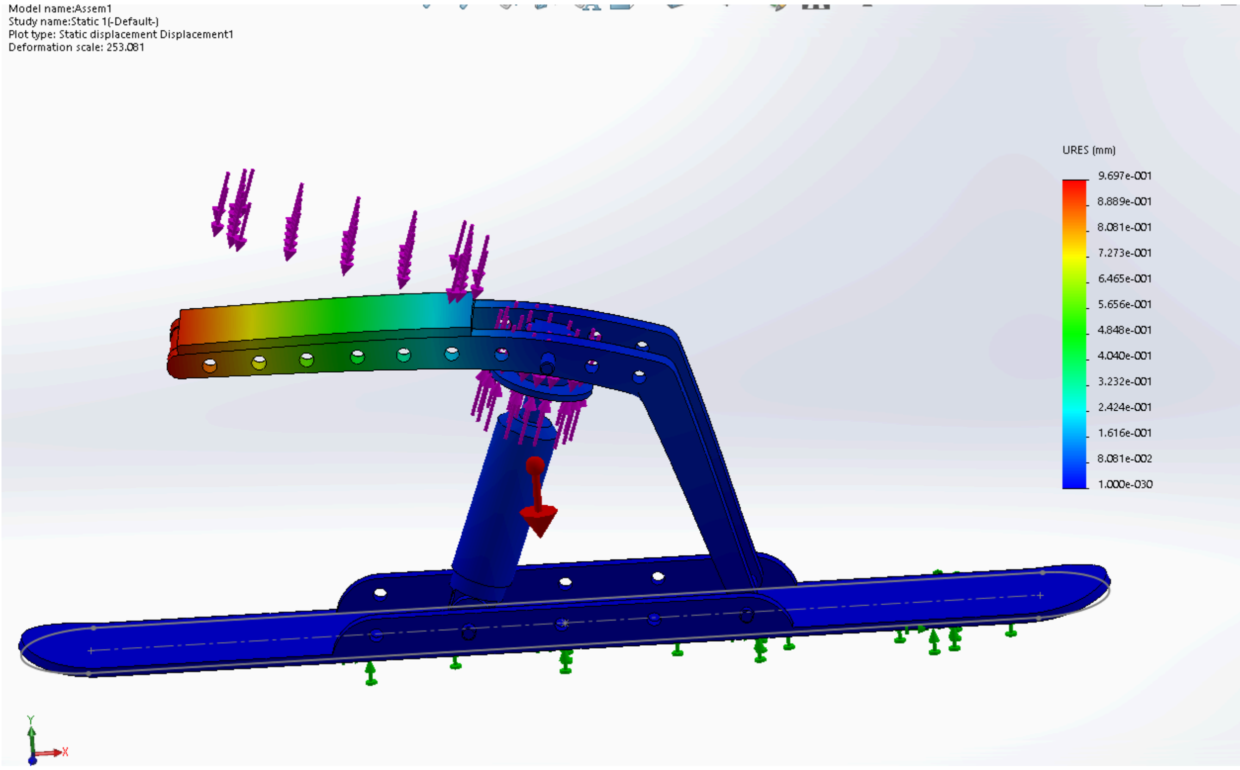
We first attempted to add bolts, but this only acted as a band aid solution and further inspections showed that the high concentration stress bands were still present. Our next solution was to add additional rod components, but we decided that this approach would require us to scrap our main design and because it left too little material between components. We decided to instead thicken our rods. Doing this greatly reduced bending and stresses in the rods. Images from the improved areas are shown in the figures below.





Final Design

Based on our Specification report, our final design (shown below) should be able to support the average weight of a person (around 750 N) and also be able to support its own weight. It should also be bounded by having a fixed reactionary force at its base. It should be durable, and have a moderate weight, with moderately priced materials. All these things are met in our design. Parts used are relatively cheap to buy and can be machined. The design is also made of appropriate materials such as 6066 aluminium for its flexibility and steel for its rigidity and shear modulus. Our design can also handle downward forces upwards from 600-2000N for weight and for forces when skiing. Our design also distributes stress well and has a long cycle life (given the simulations used in this study).


Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static displacement Displacement1
Deformation scale: 253.081
URES (mm)
9.697e-001
8.889e-001
8.081e-001
7.273e-001
6.465e-001
5.656e-001
4.848e-001
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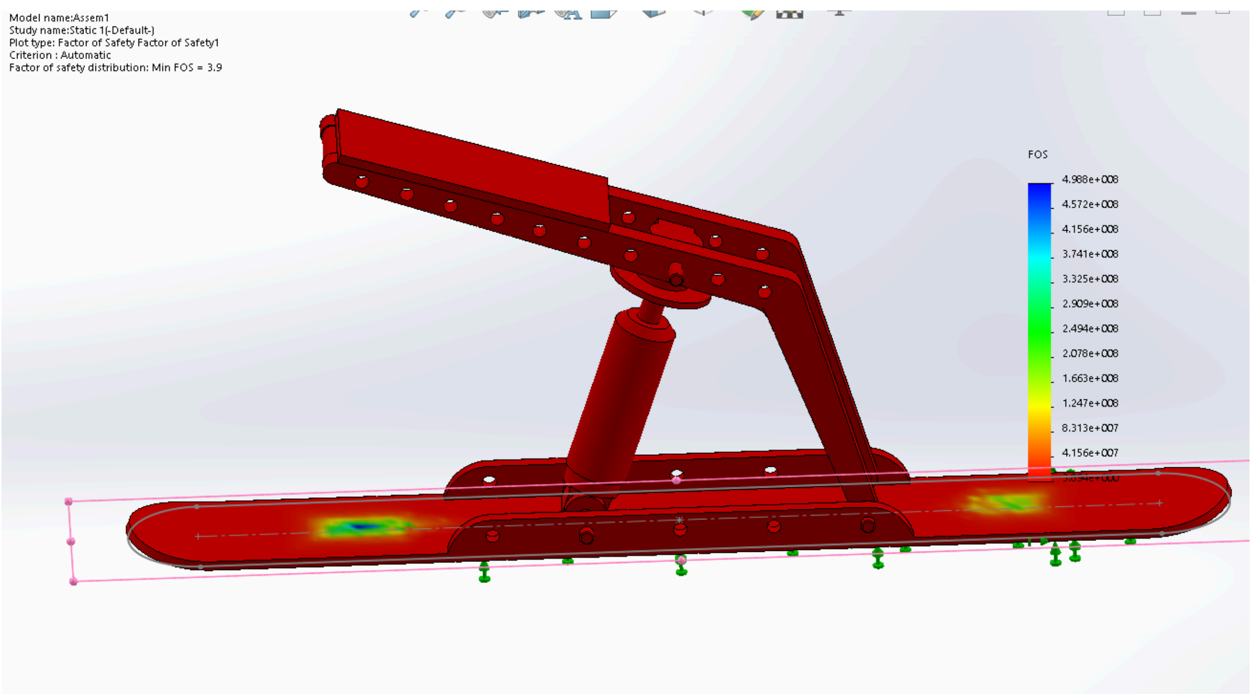
1.000e-030
Y
X


Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Factor of Safety Factor of Safety1
Criterion : Automatic
Factor of safety distribution: Min FOS = 3.9
FOS
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3.741e+008
3.325e+008
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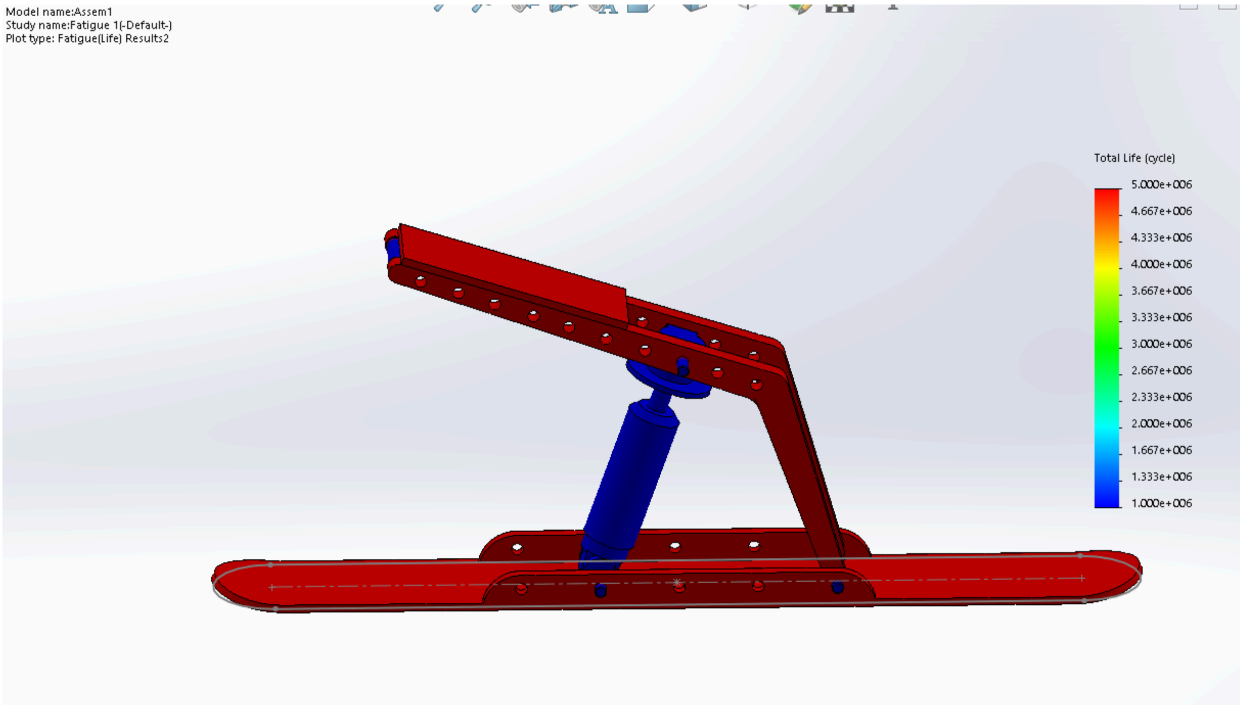
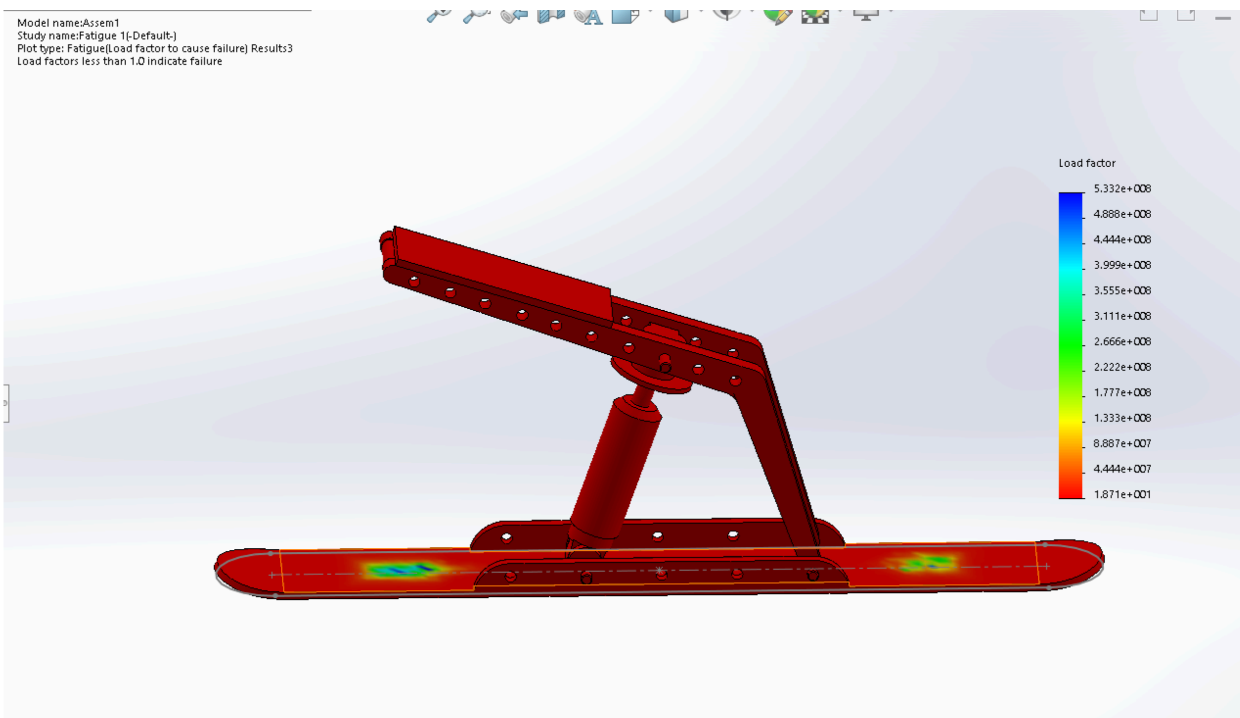
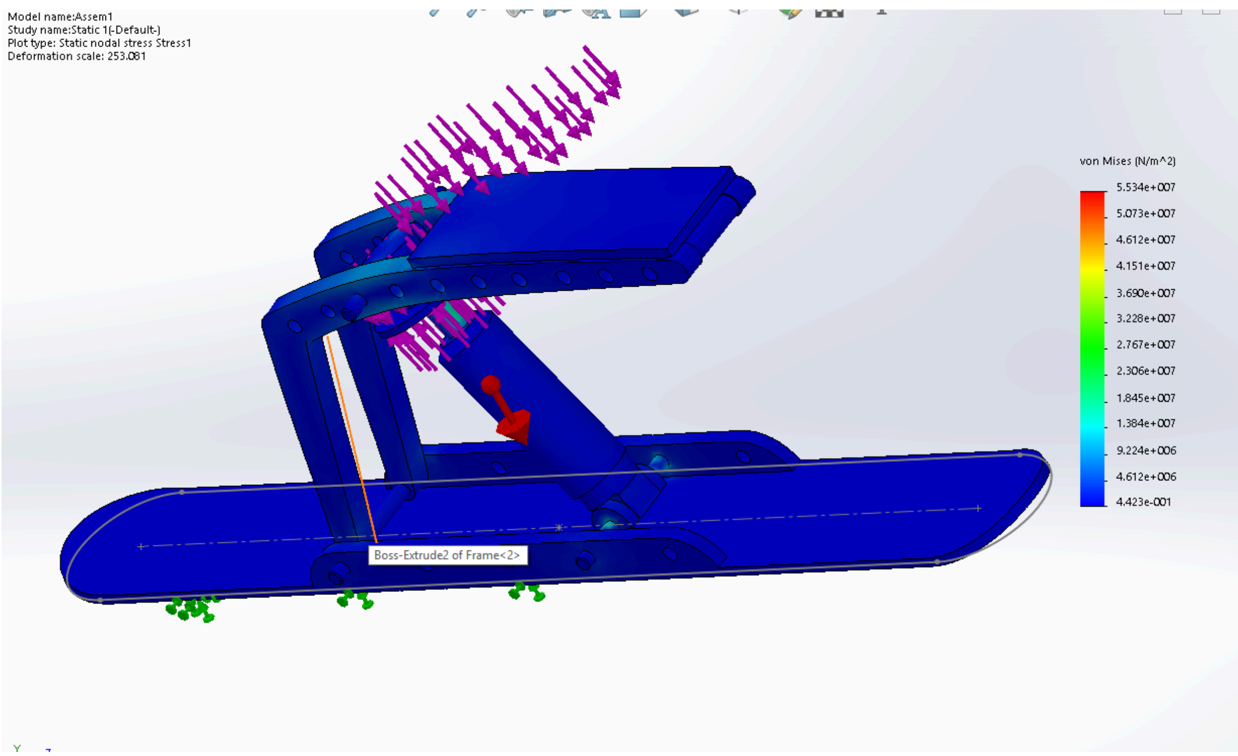
8.313e+007
4.156e+007





The design has an overall factor of safety of approximately 4 based on static loading. Using the cyclic loading (fatigue), we can estimate the fatigue lifetime of about 1-2 million cycles.


Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 253.081
von Mises (N/m^2)
5.534e+007
5.073e+007
4.612e+007
4.151e+007
3.690e+007
3.228e+007
2.767e+007
2.306e+007
1.845e+007
1.384e+007
9.224e+006
4.612e+006
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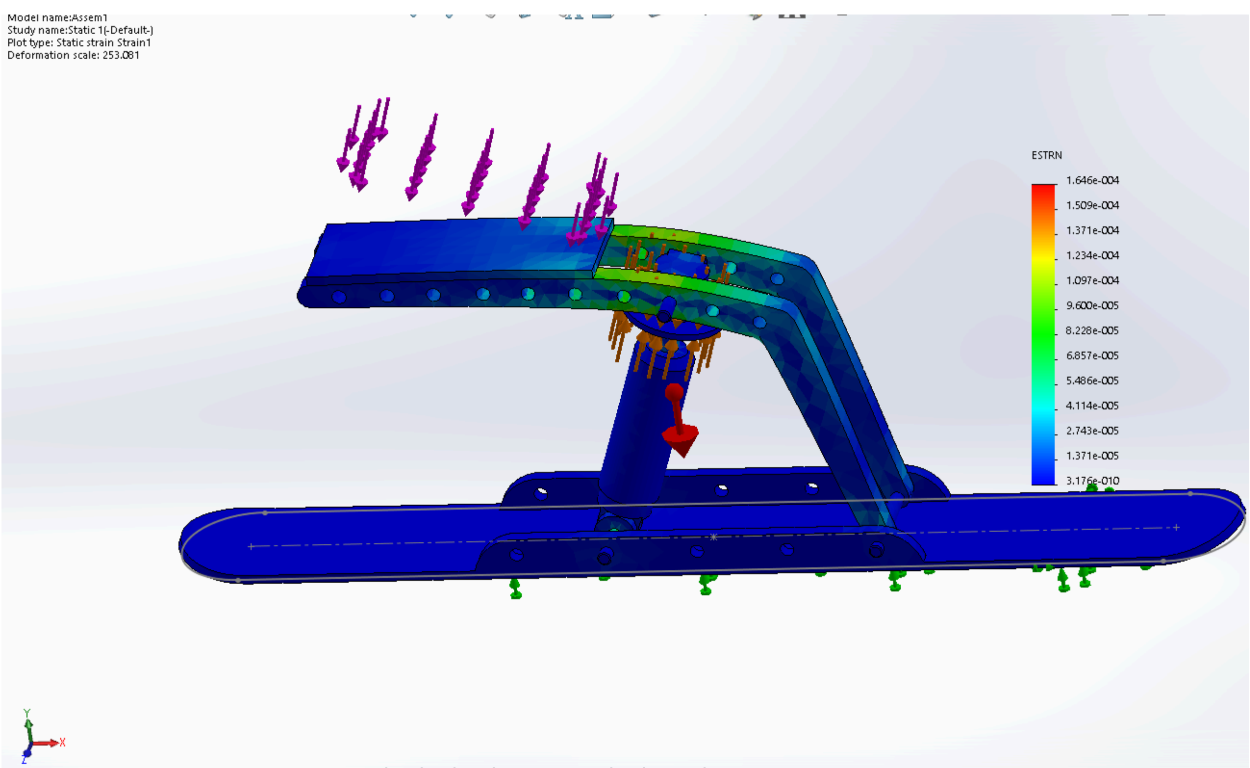
Model name:Assem1
Study name:Static 1(-Default-)
Plot type: Static strain Strain1
Deformation scale: 253.081
ESTRN
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1.509e-004
1.371e-004
1.234e-004
1.097e-004
9.600e-005
8.228e-005
6.857e-005
5.486e-005
4.114e-005
2.743e-005
1.371e-005
3.176e-010

Bill of Materials:

Item NO.	**Part**	**Quantity**
1	Ski Base	1
2	Frame	2
3	Suspension Base Final	1
4	Suspension	1
5	Medium-Strength Steel Threaded Rods—Class 8.8	3
6	Base Plate Final	1
7	Spacer	1
8	Metric Medium-Strength Steel Hex Nuts—Class 8	6

Auxiliary Parts:

Medium-Strength Steel Threaded Rods—Class 8.8

✓ 

An economical alternative to Grade B7 and Grade B16 threaded rods, these metric Class 8.8 rods are suitable for fastening most machinery and equipment.

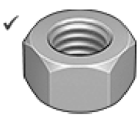
Zinc-plated steel threaded rods resist corrosion in wet environments.

CAD For technical drawings and 3-D models, click on a part number.

Lg.	Thread Pitch, mm	Tensile Strength, psi	Hardness	Specifications Met		Each
Steel						
M30						
300 mm	3.5	110,000	Rockwell C20	DIN 975	99055A251	$26.70
1 m	3.5	110,000	Rockwell C20	DIN 975	99055A160	57.96
Zinc-Plated Steel						
M30						
1 m	3.5	110,000	Rockwell C20	DIN 975	99067A278	100.47

https://www.mcmaster.com/#steel-threaded-rods/=1c6maga

Metric Medium-Strength Steel Hex Nuts—Class 8

✓ 

Class 8 nuts are comparable in strength to Class 8.8 bolts and are suitable for fastening most machinery and equipment.

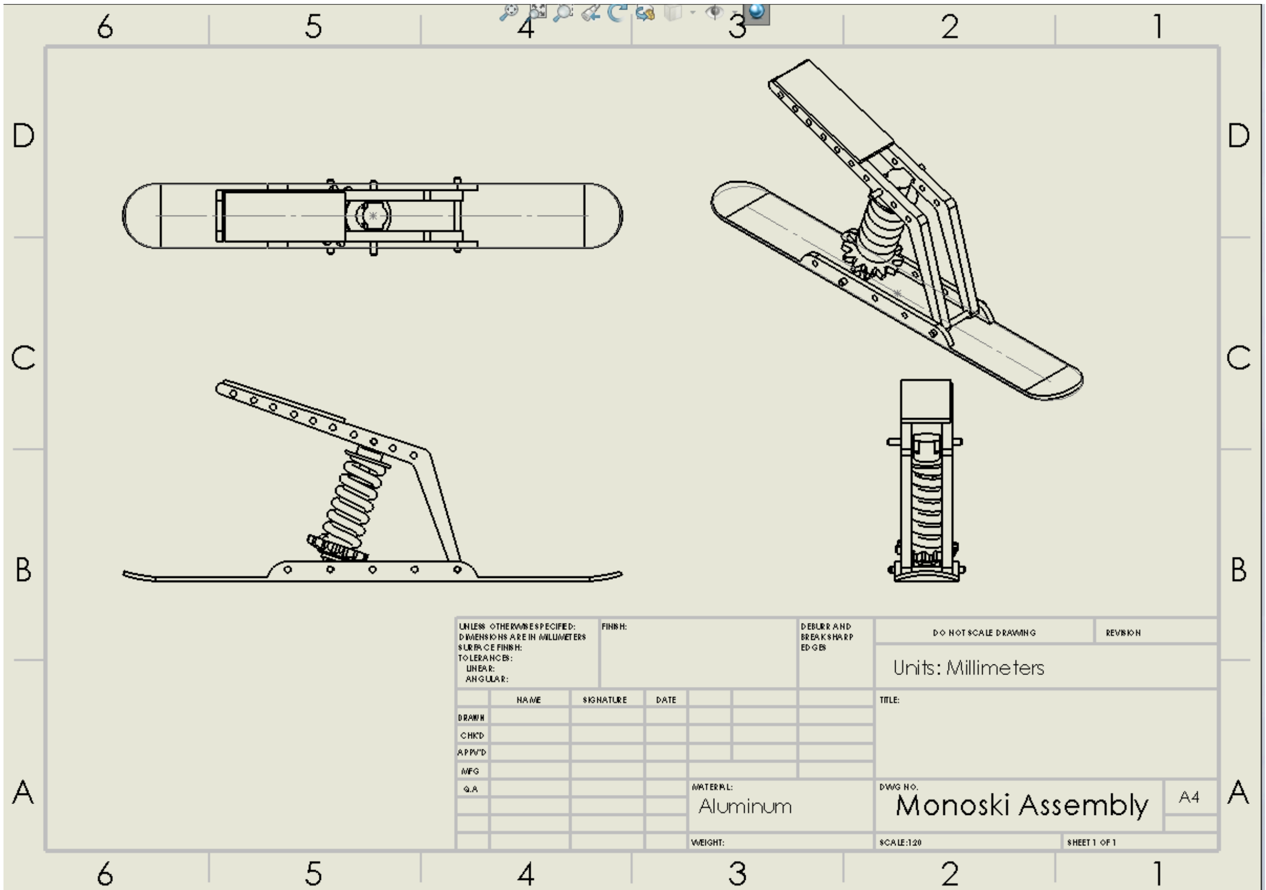
Zinc-plated steel nuts resist corrosion in wet environments.

CAD For technical drawings and 3-D models, click on a part number.

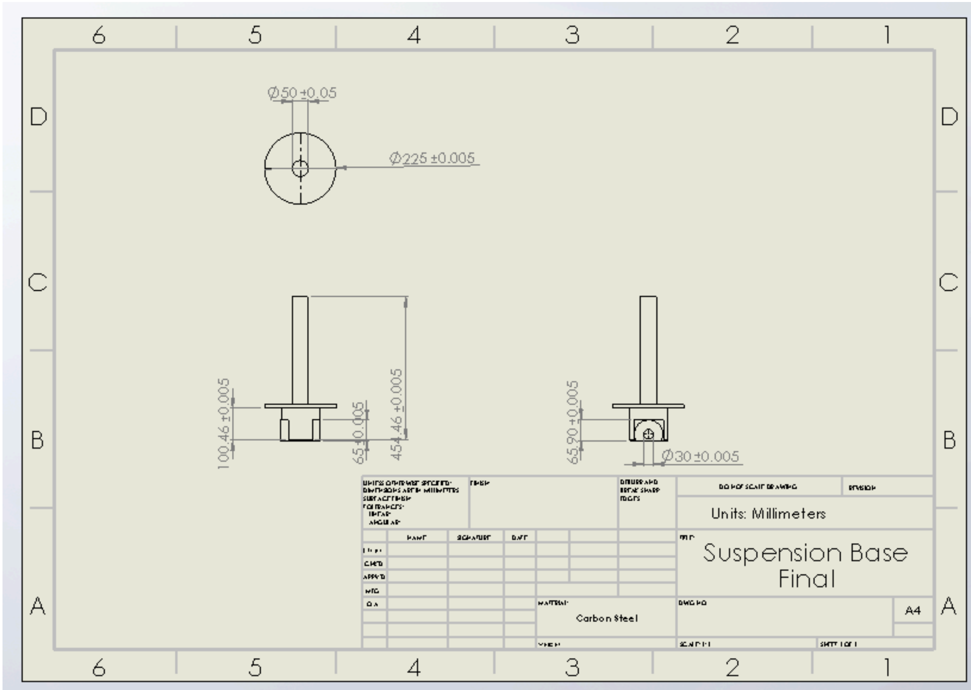
Thread Size	Thread Pitch, mm	Wd., mm	Ht., mm	Specifications Met	Pkg. Qty.		Pkg.
Zinc-Plated Steel—Class 8							
M30	3.5	46	24	DIN 934	1	90591A240	$3.69
Steel—Class 8							
M30	3.5	46	24	DIN 934	5	90592A065	13.38

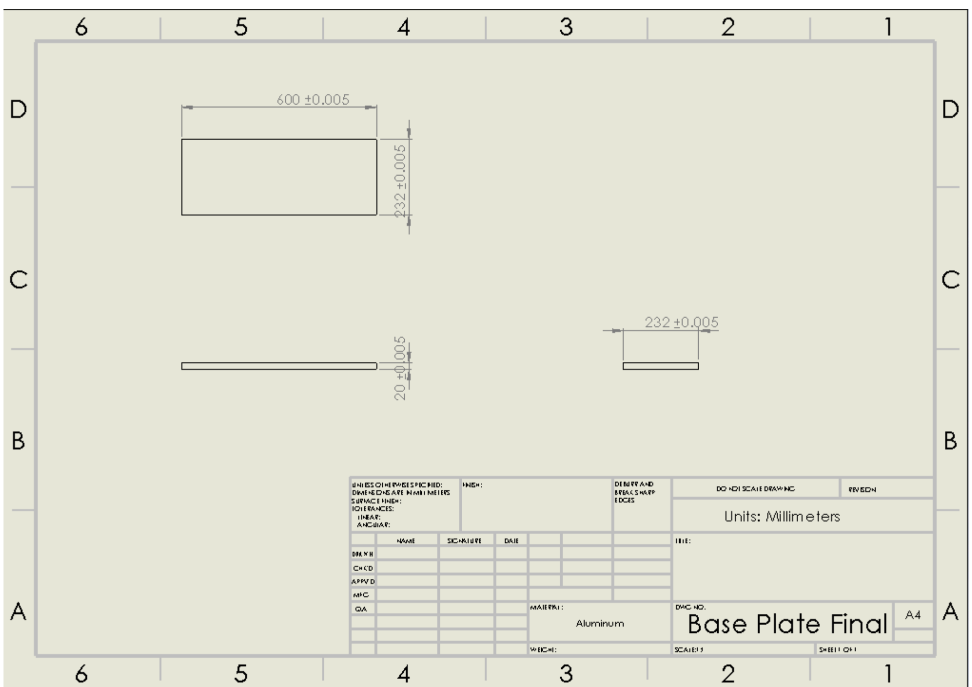
https://www.mcmaster.com/#steel-nuts/=1c6mb73

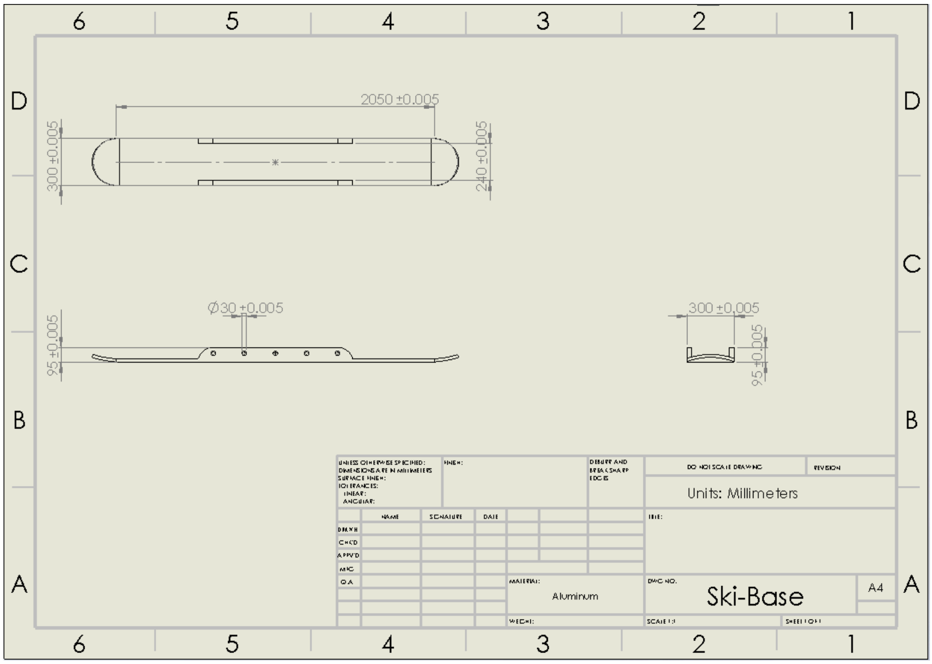
Appendix I: Assembly Drawing

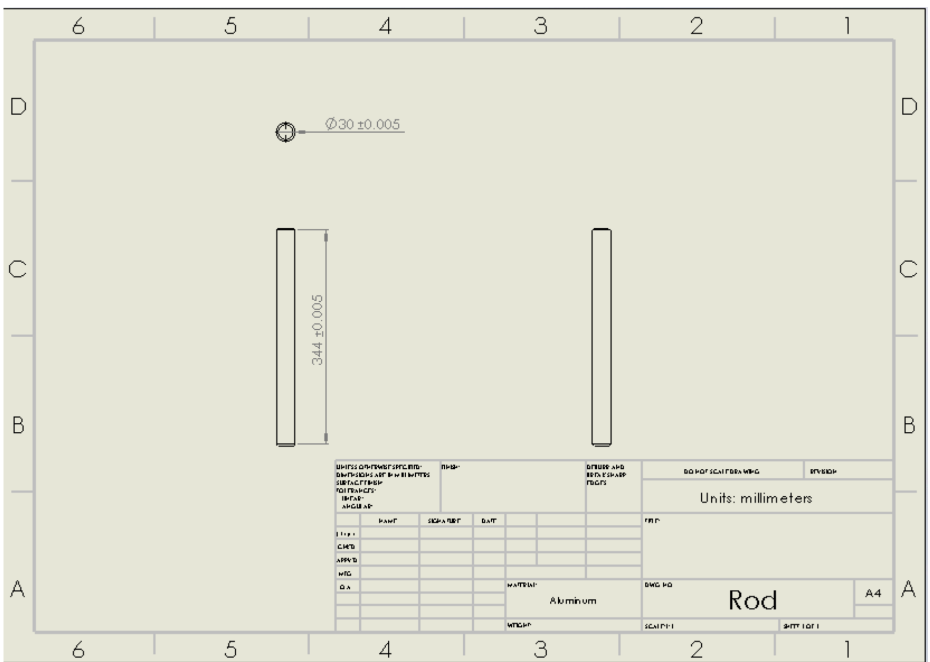


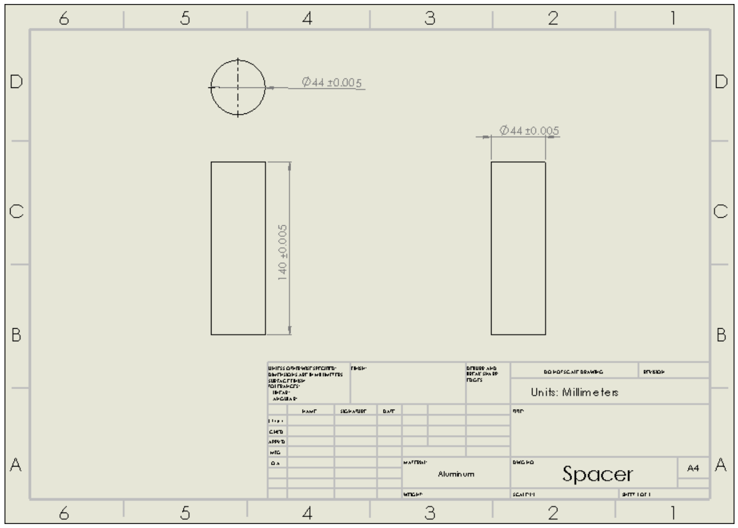
Appendix II: Individual Drawings

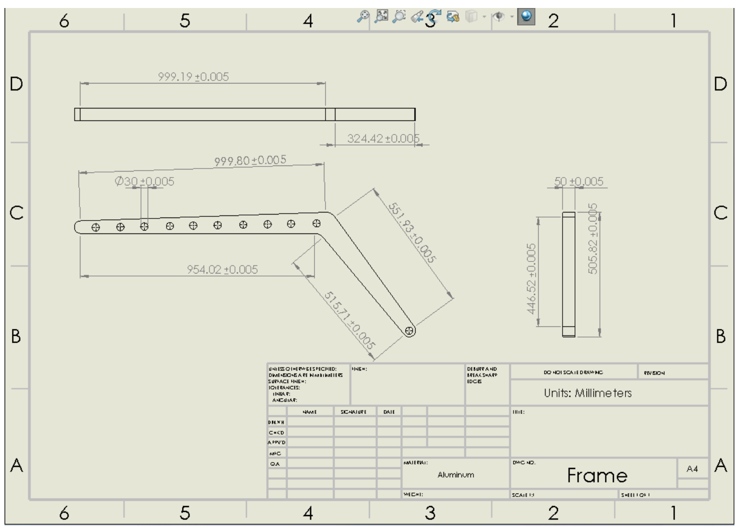


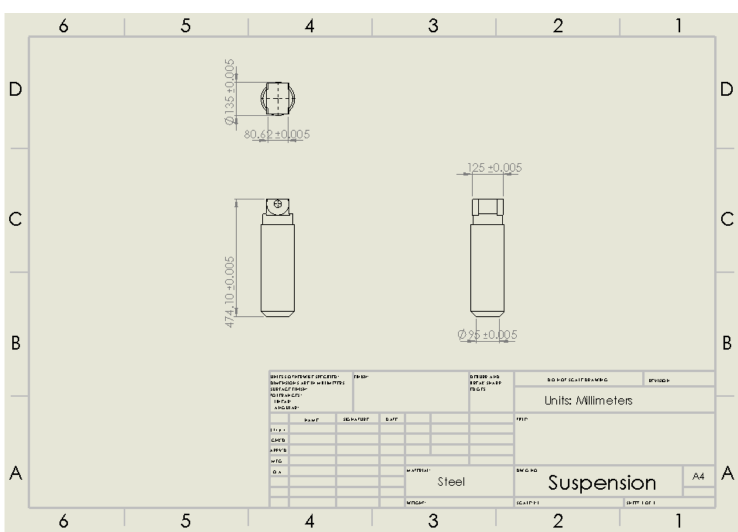



2050 ±0.005
300 ±0.005
240 ±0.005
Ø30 ±0.005
95 ±0.005
300 ±0.005
95 ±0.005
DO NOT SCALE DRAWING
Units: Millimeters
Aluminum
Ski-Base
A4


Ø30 ±0.005
344 ±0.005
DO NOT SCALE DRAWING
Units: millimeters
Aluminum
Rod
A4


Ø44 ±0.005
Ø44 ±0.005
140 ±0.005
Units: Millimeters
Aluminum
Spacer
A4


999.19 ±0.005
324.42 ±0.005
999.80 ±0.005
Ø30 ±0.005
954.02 ±0.005
551.93 ±0.005
515.71 ±0.005
50 ±0.005
446.52 ±0.005
505.82 ±0.005
Units: Millimeters
Aluminum
Frame
A4


Ø135 ±0.005
80.62 ±0.005
125 ±0.005
474.10 ±0.005
Ø95 ±0.005
Units: Millimeters
Steel
Suspension
A4

Appendix III: Detailed FEM

Since the file is a PDF document, click the below link for the whole report on the detailed FEM

https://drive.google.com/drive/folders/1ZHfw805BDOOzfM9fnsvgqG9mK6CoS5zR?usp=sharing

Copy the link into a web browser.

References

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[4] https://www.youtube.com/watch?v=AGbMRFqLZGk

[5] https://www.acxesspring.com/counting-active-coils.html

[6] https://www.acxesspring.com/espanol/spring-constant-calculator.html

Project Member	**Project Contribution**	**Report Contribution**
Aashish Dumasia	Part Design and specification	Bill Of Material, Editing, Final Design
Anthony Reyes	Assembly and parts design	Drawings, Introduction, Preliminary
Kishon Webb	Base and simulations	FEM, Final, Revision