Mechanics of Structures 2 Project Report

Analysis of Strap Handle in Public Transport

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0. Introduction

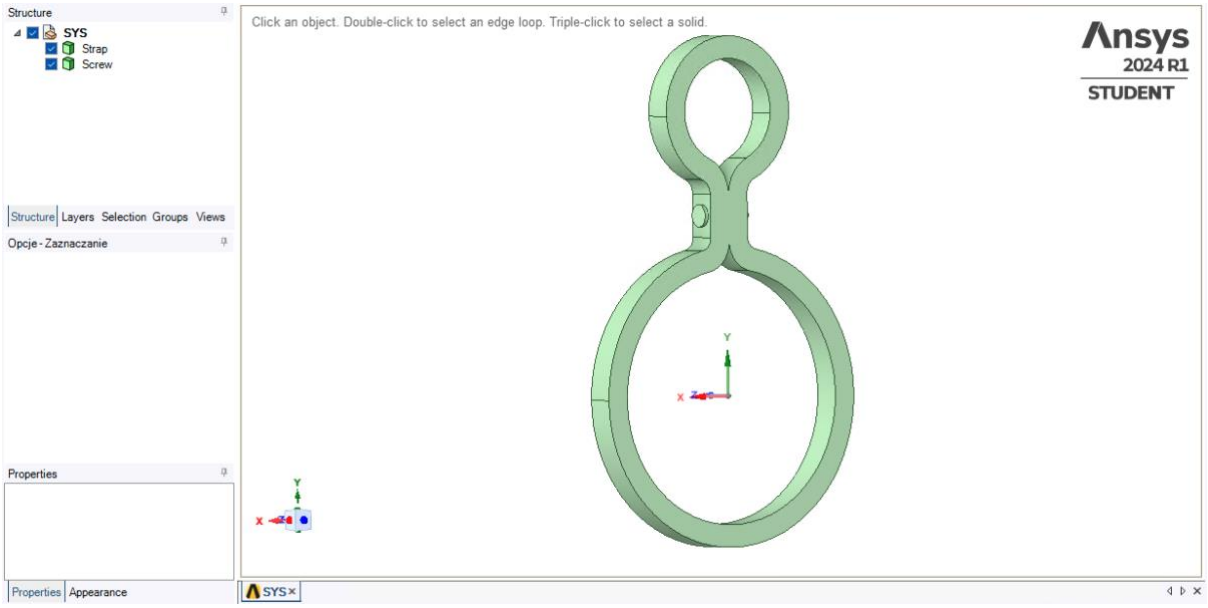
Objective of this report, is to analyze the structural behaviour of a strap handle used in public transport under the applied load of a person hanging from it.

The project will draw inspiration from available data, particularly referencing materials and suggested loading conditions as provided by Faigle's IGOSTRAP handle design and their official webpage descriptions.

Hence, vertical load of 1500N, and bolt pretension of 2650N will be applied to strap made of polyurethane, and bolt made of stainless steel.

1. The geometry, geometrical simplifications and materials.

Geometry will be simplified to more circular shape adjusted with a bolt to obtain a form of asymetrical number eight. Such change should retain real-world case’s properties.



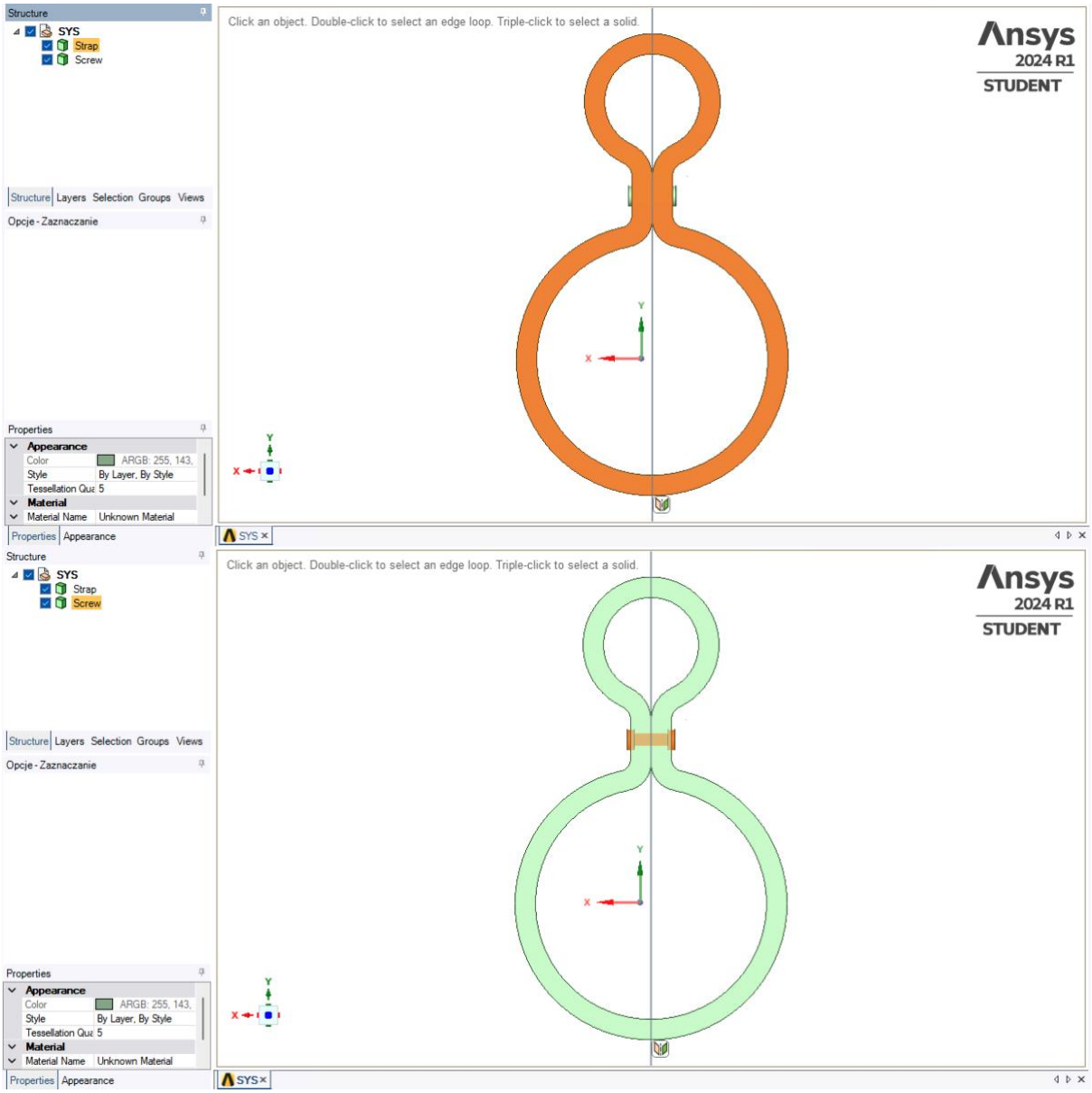


Fig. 1. Strap and bolt model made in SpaceClaim.

Dimensions:
Strap
Big outer diameter = 80mm
Small outer diameter = 40mm
Distance between inner and outer circles = 6mm
Distance between big and small circle = 15mm
Thickness = 8mm

Bolt M3,5, nut diameter = 6mm

According to the Faigle's IGOSTRAP design [1], the strap is made of PAS-PU 90A-H [2], and the bolt is made of stainless steel.

Properties of Outline Row 3: PAS-PU 90A-H

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	1,15	g cm^-3		
4	Isotropic Elasticity				
5	Derive from	Young...			
6	Young's Modulus	6	MPa		
7	Poisson's Ratio	0,43			
8	Bulk Modulus	1,4286E+07	Pa		
9	Shear Modulus	2,0979E+06	Pa		
10	Tensile Yield Strength	50	MPa		
11	Tensile Ultimate Strength	100	MPa		

Properties of Outline Row 4: Stainless Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7750	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
5	Coefficient of Thermal Expansion	1,7E-05	C^-1		
6	Isotropic Elasticity				
7	Derive from	Youn...			
8	Young's Modulus	1,93E+11	Pa		
9	Poisson's Ratio	0,31			
10	Bulk Modulus	1,693E+11	Pa		
11	Shear Modulus	7,3664E+10	Pa		
12	Tensile Yield Strength	2,07E+08	Pa		
13	Compressive Yield Strength	2,07E+08	Pa		
14	Tensile Ultimate Strength	5,86E+08	Pa		
15	Compressive Ultimate Strength	0	Pa		

Fig. 2. Material details.

2. The boundary conditions

Fixed support will be applied to bottom face of the top part of the model, where it would hang on the pipe.

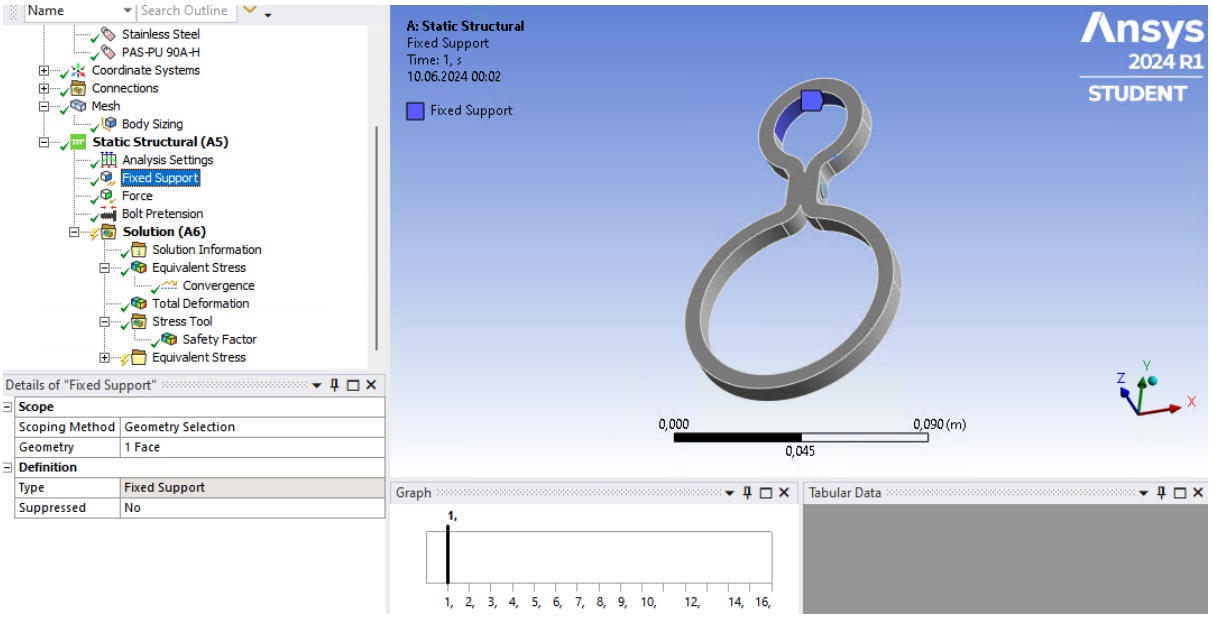


Fig. 3. Fixed support applied to the strap's face.

IGOSTRAP is designed to withstand loads of up to 150kg.
Hence, load of 1500N will be applied at the bottom face of the part.
Load was applied linearly, at each step increasing by 100N up to 1500N, to better identify significant deformations or stress concentrations.

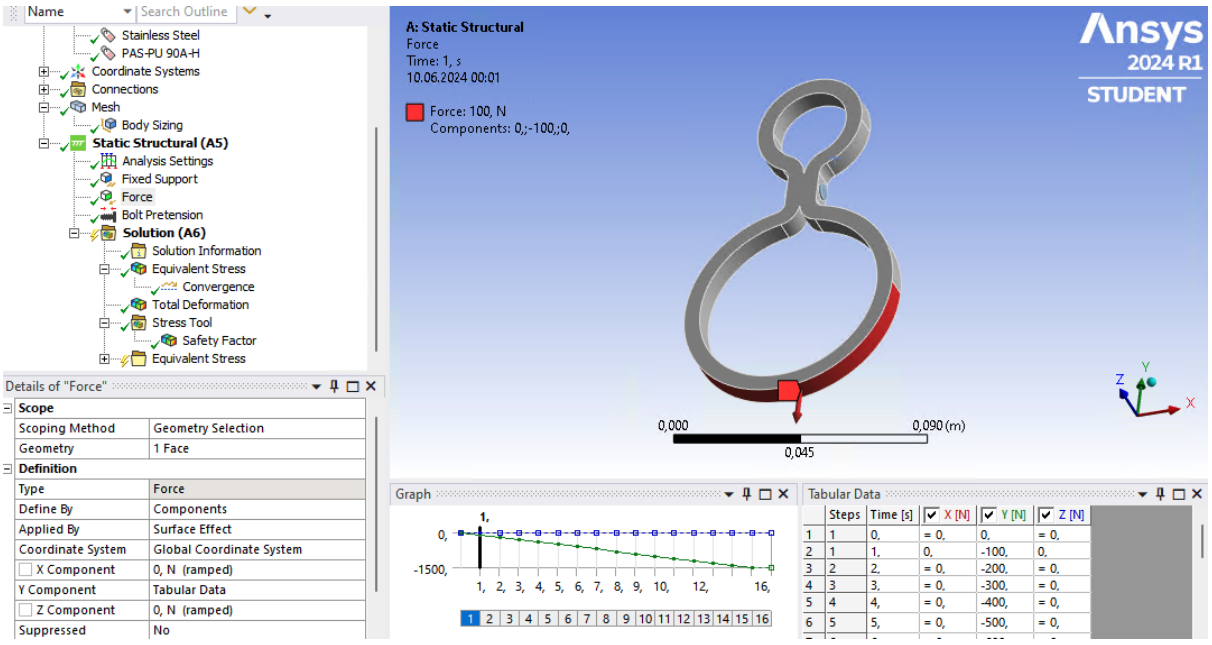


Fig. 4. Force of 1500N applied to the strap's bottom face.

Bolt pretension of 2650N will be applied, according to minimized values from TSF'a table of preloads [3].
After first step, the load get Locked.

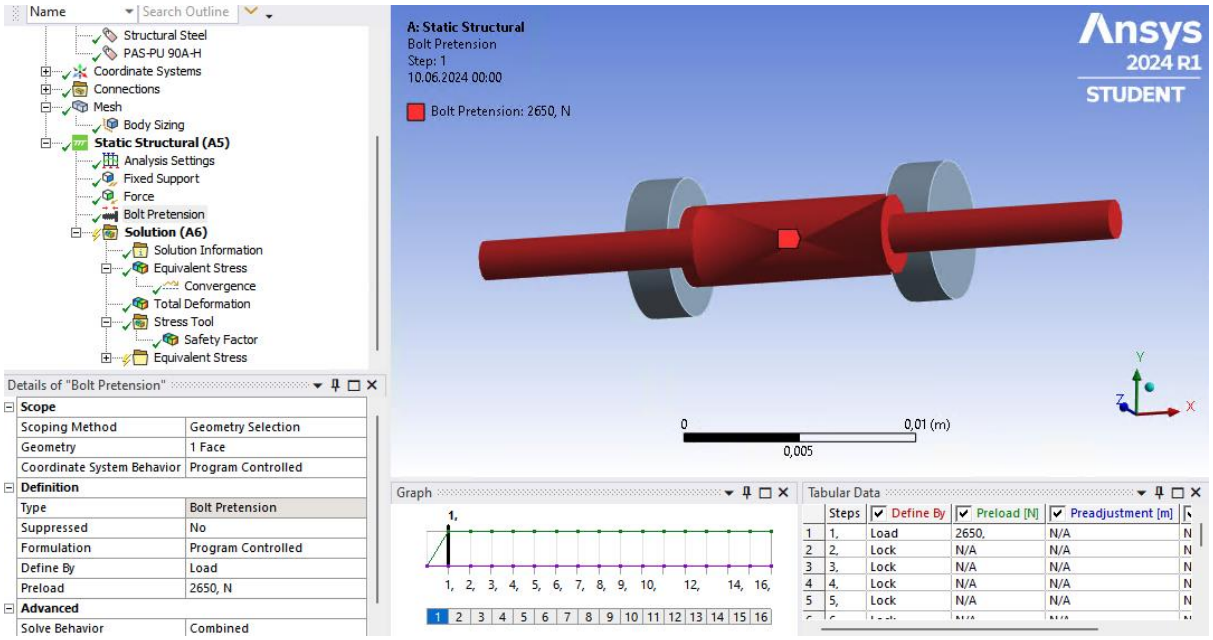
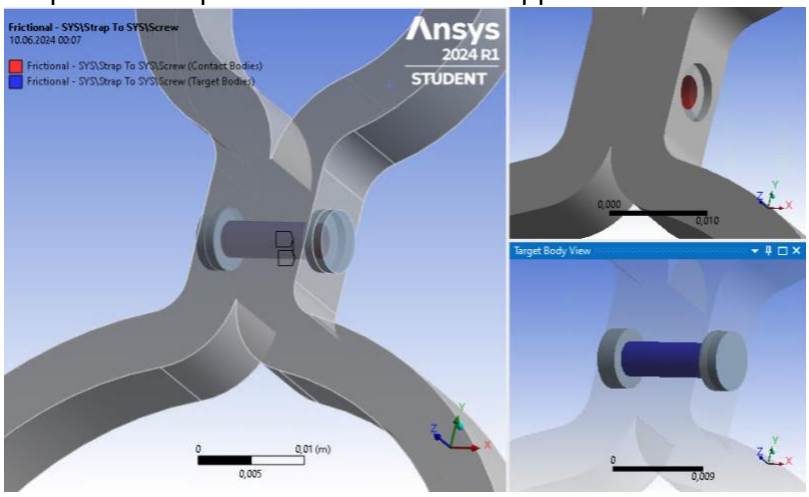


Fig. 5. Bolt pretension of 2650N applied to bolt.

Respective strap to bolt contacts were applied.



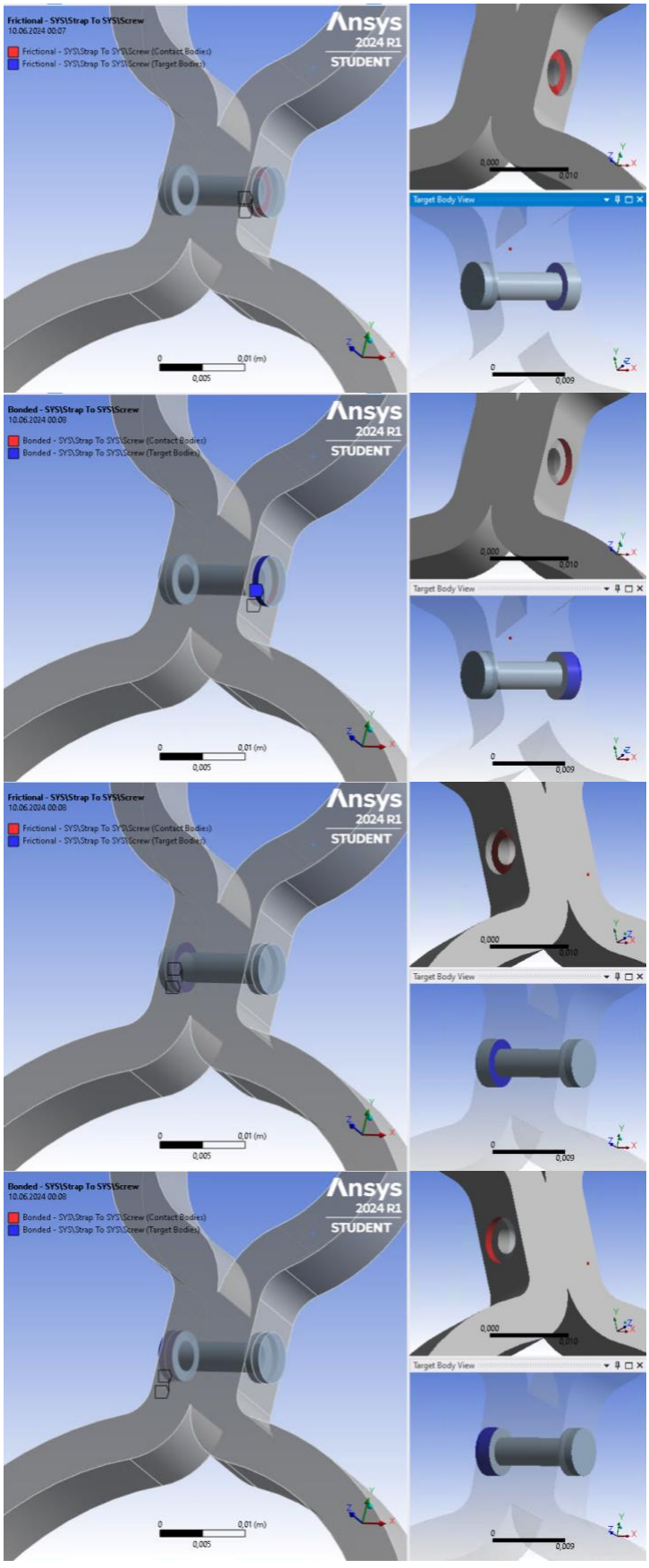


Fig. 6. Applied strap to bolt contacts.

2. The mesh

After applying Body Sizing element size to 4e-03mm to strap, automatically made mesh seemed sufficient, denser near bolt part, more widely distributed on outer parts.

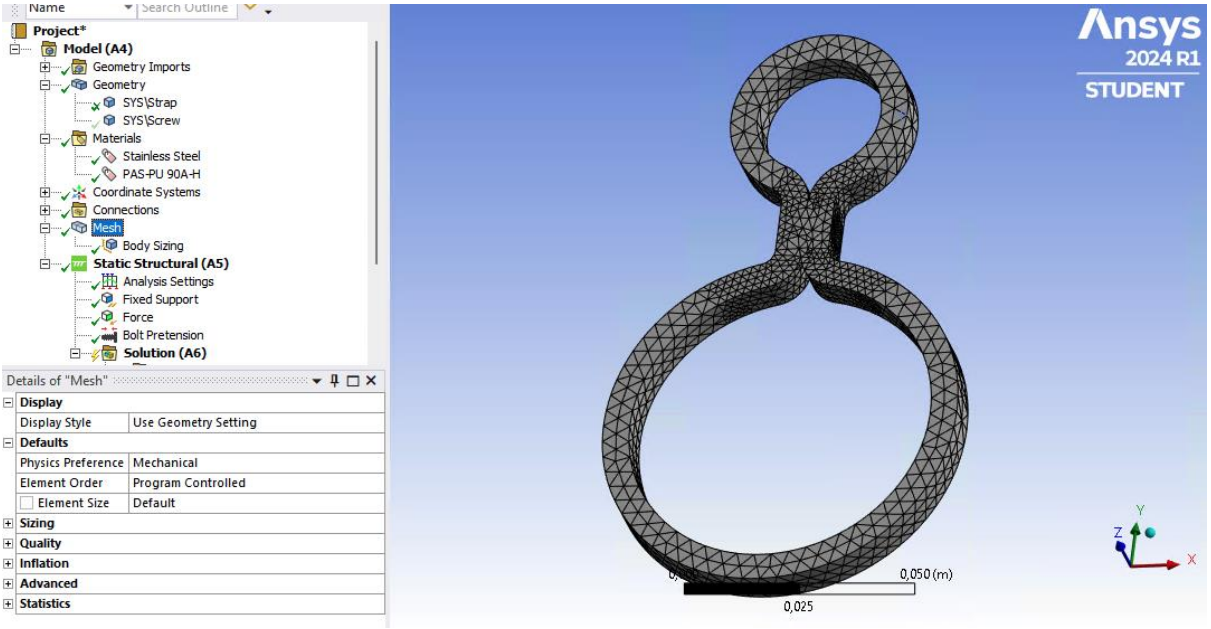


Fig. 7. Strap's mesh.

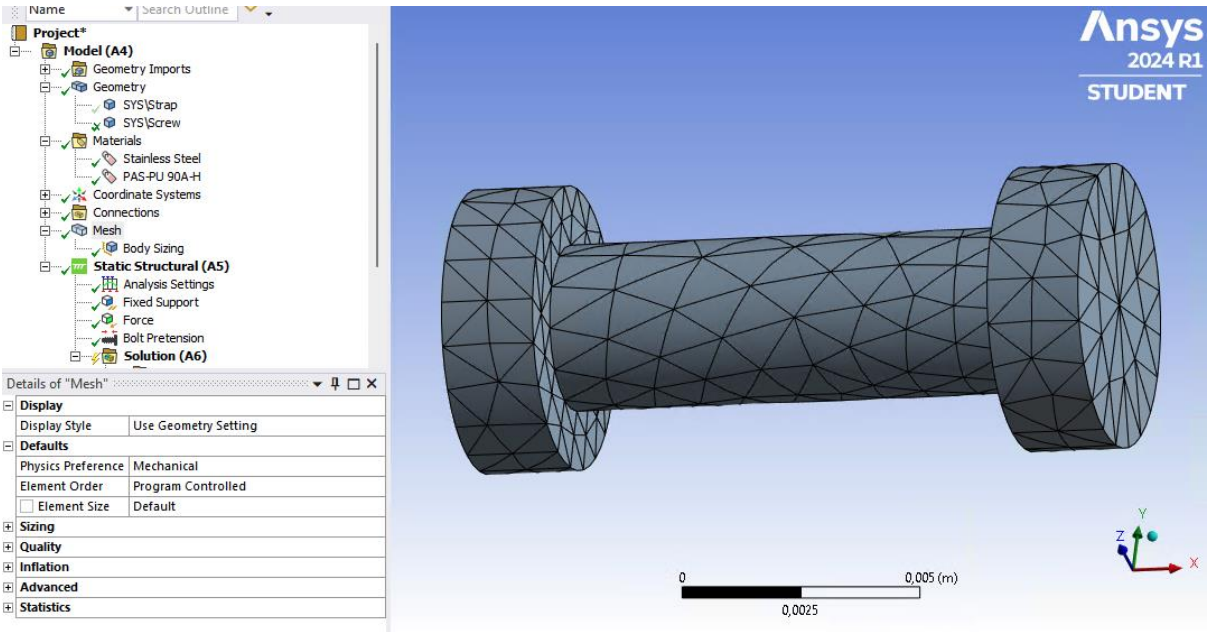


Fig. 8. Bolt's mesh.

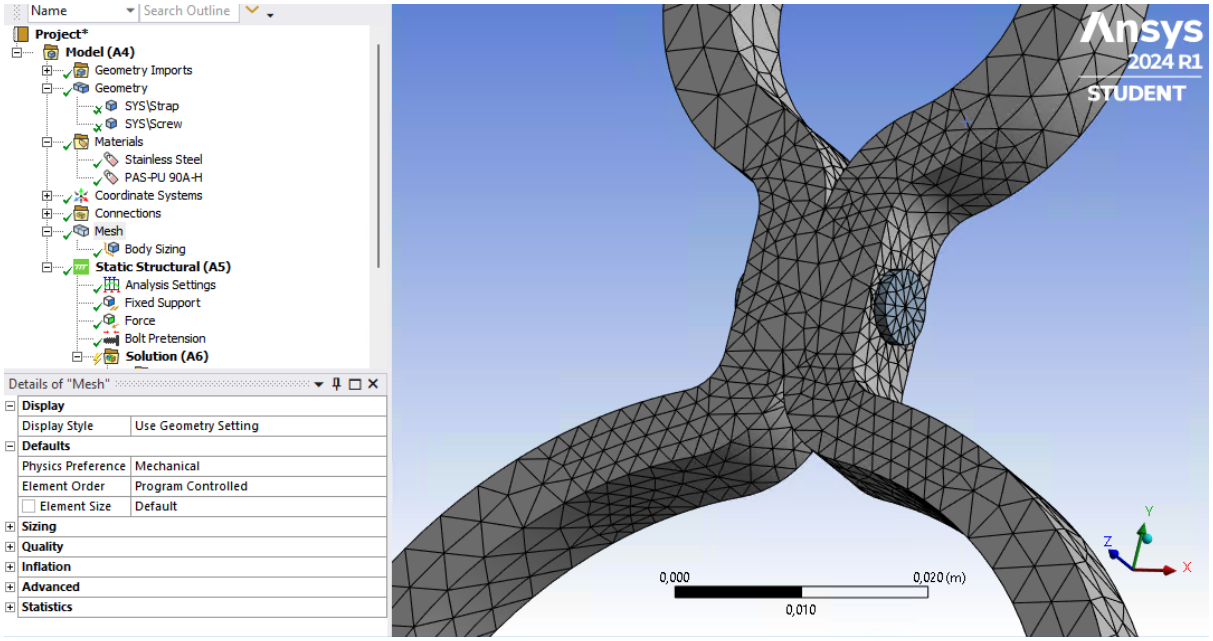


Fig. 9. Mesh on both bodies.

Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	0,15799 m
Average Surface Area	2,8932e-004 m^2
Minimum Edge Length	1,e-004 m
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Element Quality	Default (5,e-002)
Smoothing	Medium
Mesh Metric	None
Statistics	
Nodes	6911
Elements	3503
Show Detailed Statistics	No

Fig. 10. Mesh details.

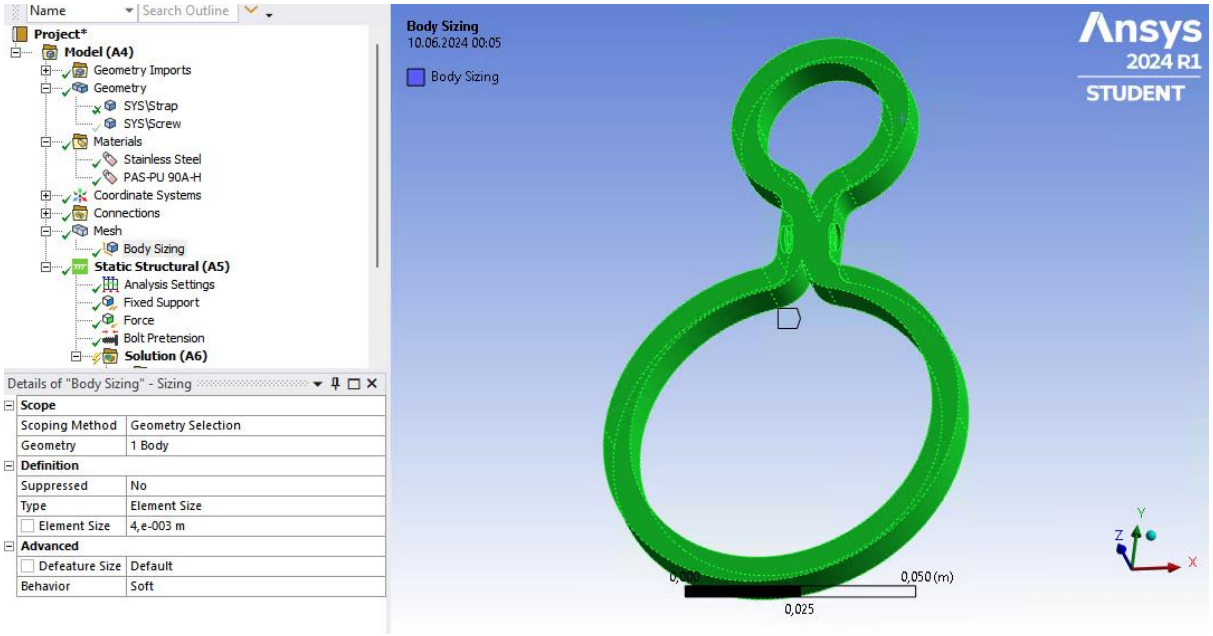


Fig. 11. Strap's mesh element size.

4. Deformation

Total deformation solution was performed. Analysis settings were set to 16 steps.

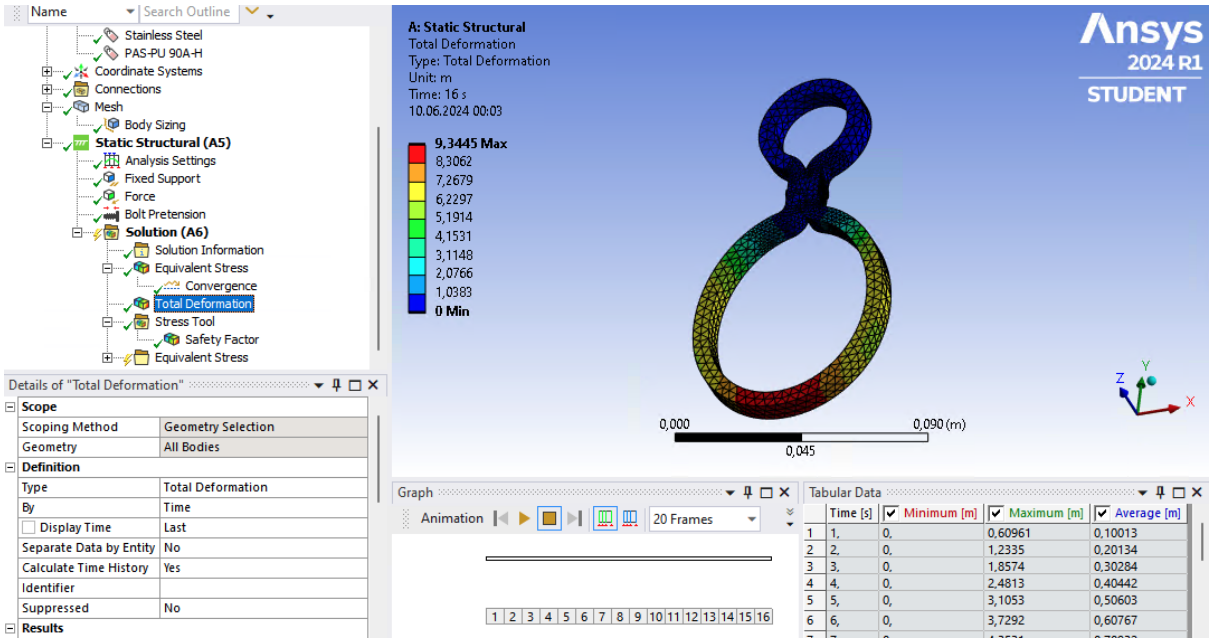


Fig. 12. Total deformation.

Obtained table:

Step	Maximum [m]
1	0,60961
2	1,2335
3	1,8574
4	2,4813
5	3,1053
6	3,7292
7	4,3531
8	4,977
9	5,6009
10	6,2249
11	6,8488
12	7,4727
13	8,0967
14	8,7206
15	9,3445
16	9,3445

Obtained plot:

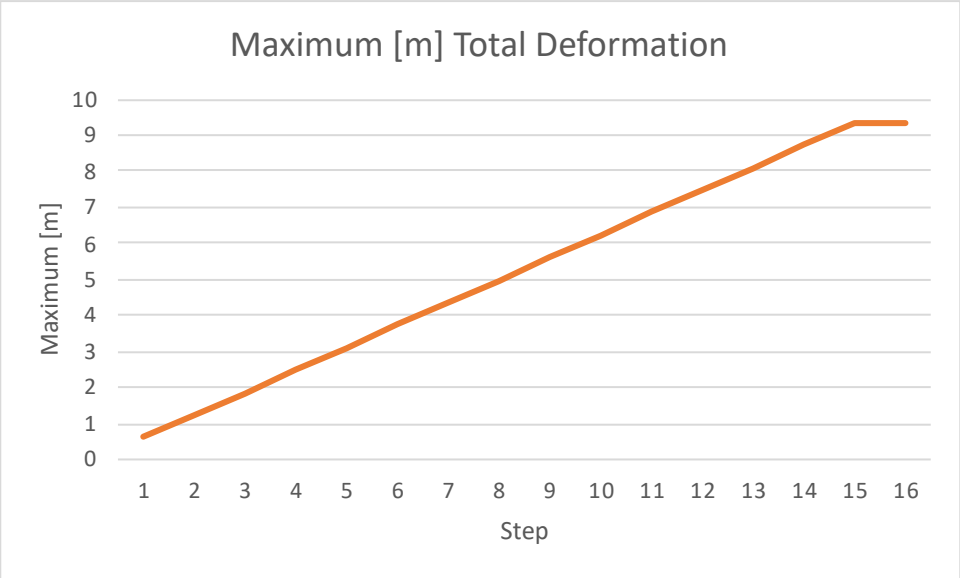


Fig. 13. Maximum [m] Total Deformation.

Maximum total deformation seems to be linear along all steps.

5. Stress

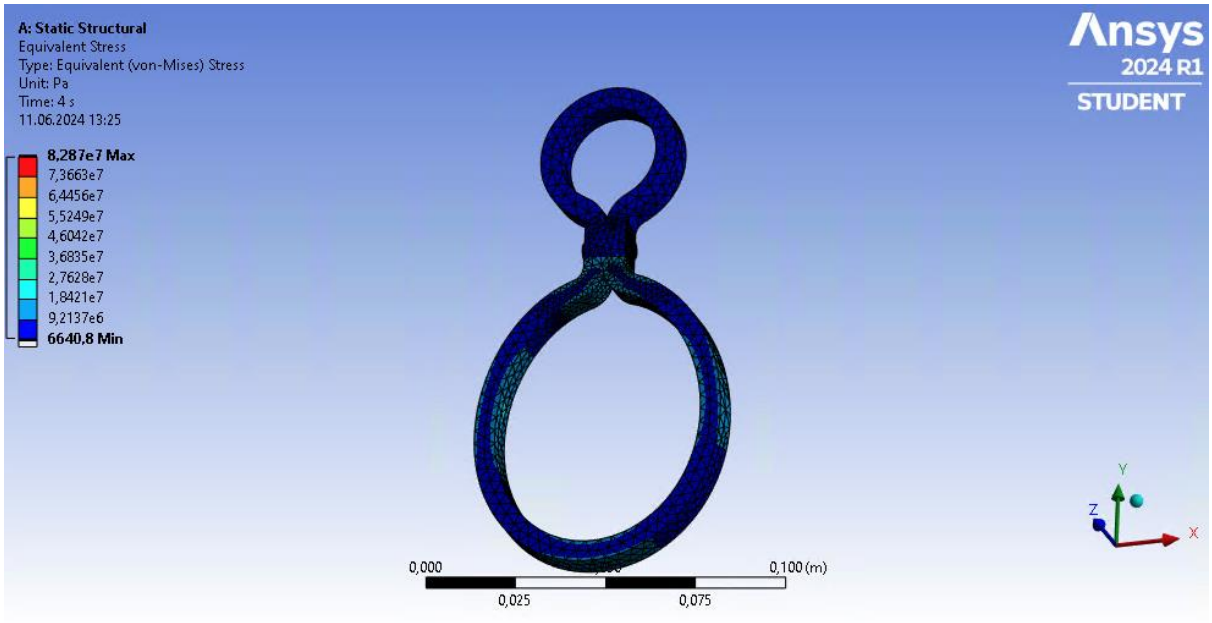


Fig. 14. Equivalent stress.

Obtained table:

Step	Minimum [Pa]	Maximum [Pa]
1	6154,3	5,5247e+006
2	13477	1,1049e+007
3	15945	1,6574e+007
4	18868	2,2099e+007
5	22740	2,7623e+007
6	27161	3,3148e+007
7	31902	3,8673e+007
8	36839	4,4197e+007
9	41905	4,9722e+007
10	47055	5,5247e+007
11	52267	6,0771e+007
12	57522	6,6296e+007
13	62812	7,1821e+007
14	68126	7,7345e+007
15	73461	8,287e+007
16	73461	8,287e+007

Obtained plot:

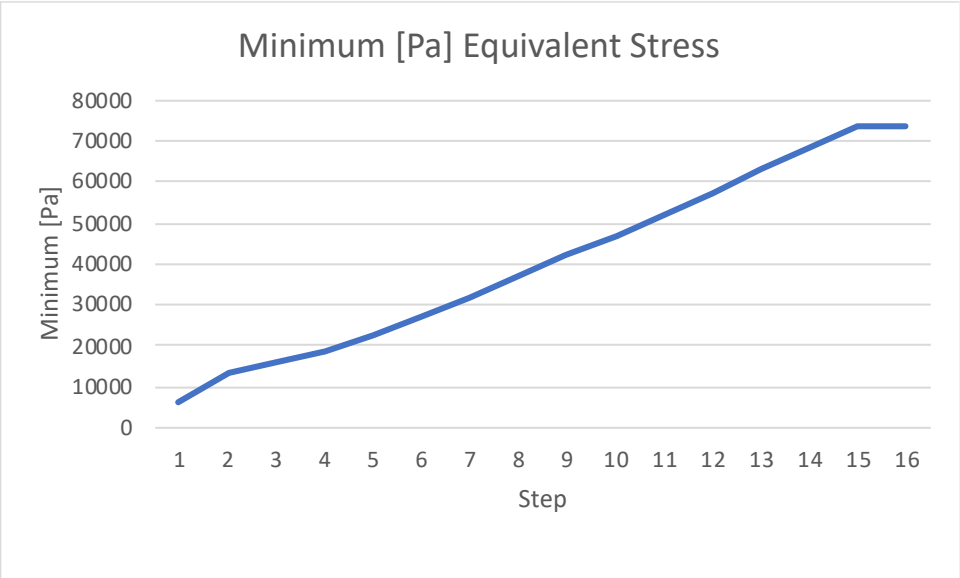


Fig. 15. Minimum [Pa] Equivalent Stress.

Minimum equivalent stress seems to have rapid increase at steps 1-2, stabilizing to linear at further steps.

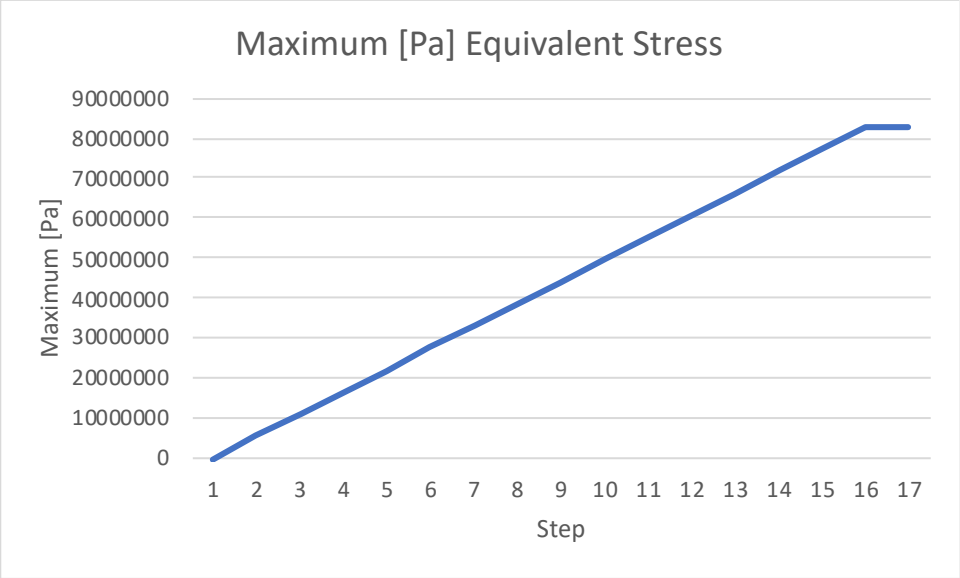


Fig. 16. Maximum [Pa] Equivalent Stress.

Maximum equivalent stress seems to be linear at all steps.

6. Safety factor

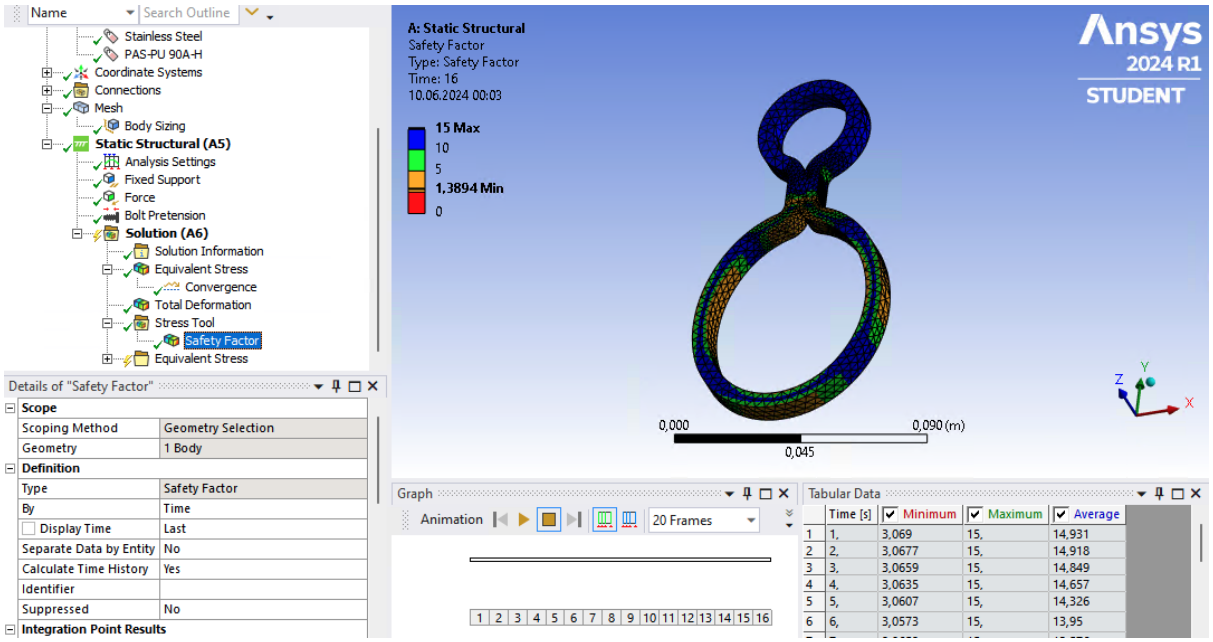


Fig. 17. Safety factor.

Obtained table:

Step	Minimum
1	3,069
2	3,0677
3	3,0659
4	3,0635
5	3,0607
6	3,0573
7	2,9652
8	2,597
9	2,3102
10	2,0804
11	1,8922
12	1,7352
13	1,6023
14	1,4883
15	1,3894
16	1,3894

Obtained plot:

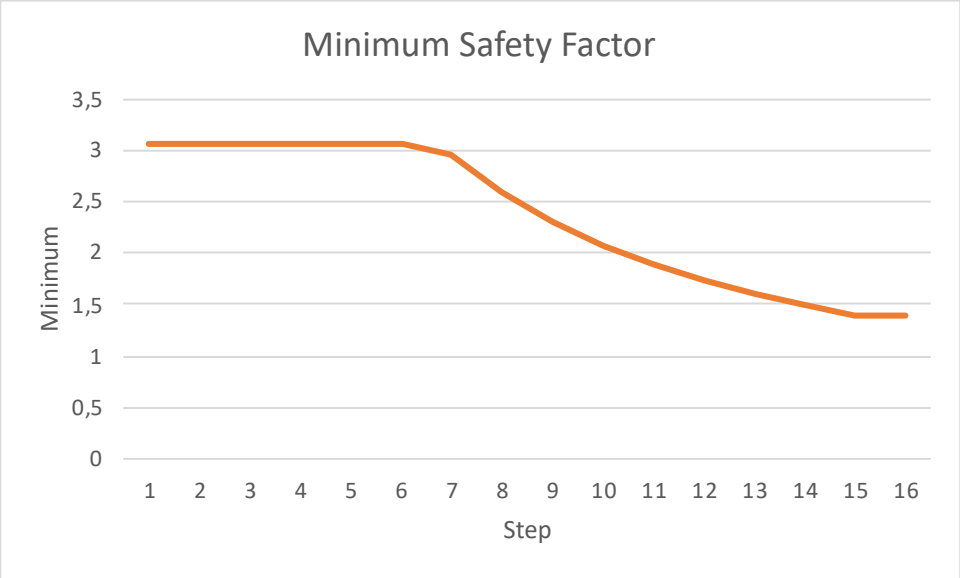


Fig. 18. Minimum Safety Factor.

Safety factor seems to drop at 7th step from being constant before that.

Safety factor of 1,39 was obtained at 1500N load.

7. Conclusions

The total deformation of the strap handle under a load of 1500N is within acceptable limits, ensuring it can safely support the weight of a user.

The equivalent stress remains below the material's yield strength, max stress being 8,3e+07, material's tensile ultimate strength 100MPa=1e+08, indicating that the handle will not fail under the specified loading conditions.

With a safety factor of 1.39, the handle is confirmed to be safe for use in public transport applications.

Further analysis could include fatigue testing to assess the handle's long-term performance.

8. References

[1] Faigle's IGOSTRAP description https://www.faigle.com/en/local-public-transport-and-rail/hanging-straps/igostrap

[2] Faigle's IGOSTRAP material https://www.faigle.com/en/semi-finished-products-and-finished-parts/material-finder?material=pas-pu-90a-h

[3] TSF Table of preloads and tightening approximate values
https://www.tsftsh.com/docs/documentation/Precargas%20Web.pdf

Static structural analysis was performed with ANSYS.

Plots were performed with Excel.