24-650 Applied Finite Element Analysis

Assignment 4

submitted by

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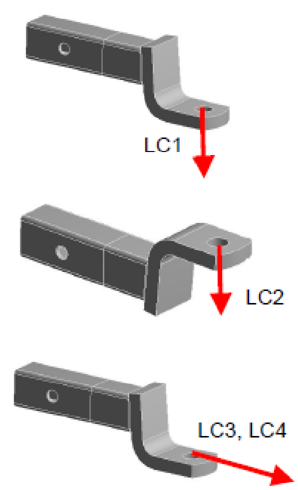
Objective

The goal of this assignment is to perform a stress analysis, fatigue analysis, and propose design modifications for a trailer hitch as shown in Fig. 1. The material is structural steel, and there are 4 different loading conditions.

Assumptions and Loading Conditions

1) Tongue Load of 2500 N, Drop, design life = infinite(1e6). Load is applied and then removed.
2) Tongue Load of 2500 N, Rise, design life = infinite(1e6). Load is applied and then removed.
3) Trailer Load Small Hill: 5,000 N, design life = 1e5 cycles. The load is applied and then reversed in the opposite direction.
4) Trailer Load Steep Hill: 11,000 N, design life = 5000 cycles. The load is applied and then reversed in the opposite direction.
5) Apply the loads to the cylindrical hole, where the ball would be attached.



Model and Geometry

The standard trailer hitch has a 7.6 cm drop or rise, 22,000 N max towing capacity, and 2,500 N tongue weight. The Stress Life Fatigue Properties are presented in Fig. 2.

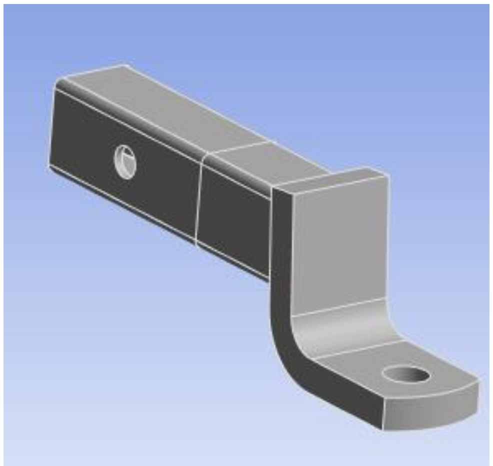


Figure 1. The Model

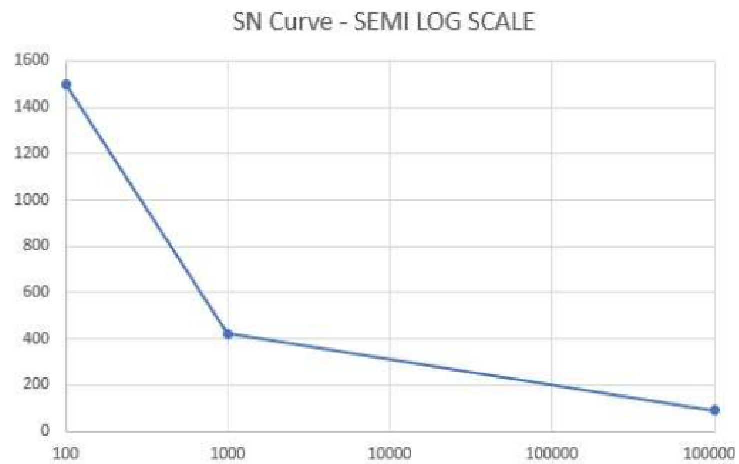


Figure 2. S-N Curve

Boundary Conditions (Part A)

The boundary conditions of support on four side and radial are indicated below:

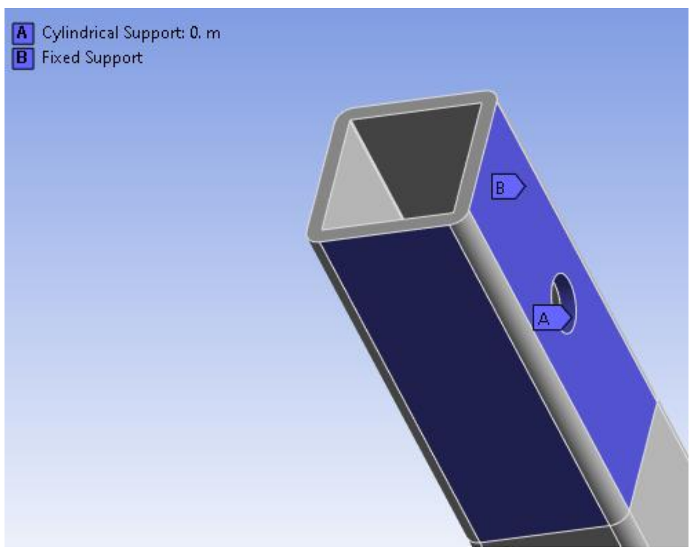


Figure 3. BCs

Scope	
Scoping Method	Geometry Selection
Geometry	2 Faces
Definition	
Type	Cylindrical Support
Radial	Fixed
Axial	Fixed
Tangential	Fixed
Suppressed	No

Scope	
Scoping Method	Geometry Selection
Geometry	4 Faces
Definition	
Type	Fixed Support
Suppressed	No

Force BCs are indicated below:

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Force
Define By	Vector
Applied By	Surface Effect
Magnitude	2500. N (ramped)
Direction	Click to Change
Suppressed	Yes

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Force
Define By	Vector
Applied By	Surface Effect
Magnitude	2500. N (ramped)
Direction	Click to Change
Suppressed	Yes

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Force
Define By	Vector
Applied By	Surface Effect
Magnitude	5000. N (ramped)
Direction	Click to Change
Suppressed	No

Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Force
Define By	Components
Applied By	Surface Effect
Coordinate System	Global Coordinate System
X Component	11000 N (ramped)
Y Component	0. N (ramped)
Z Component	0. N (ramped)
Suppressed	Yes

Results (Part A)

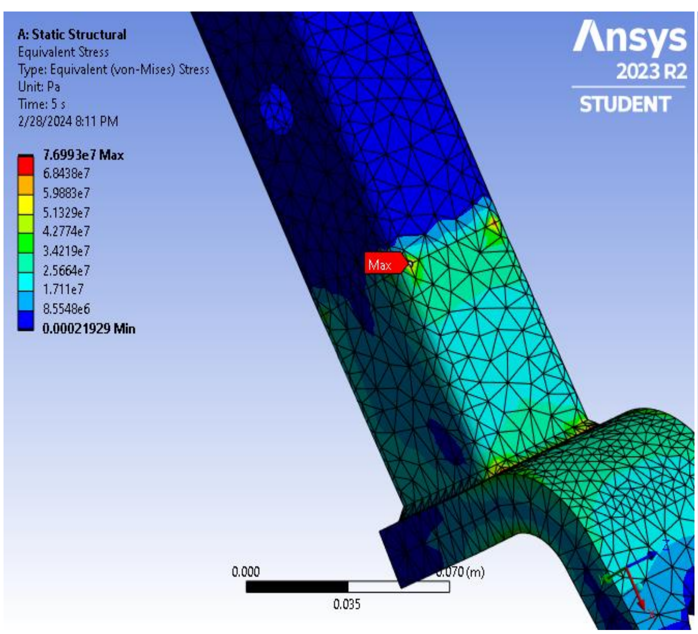


Figure 4. Singularity Point

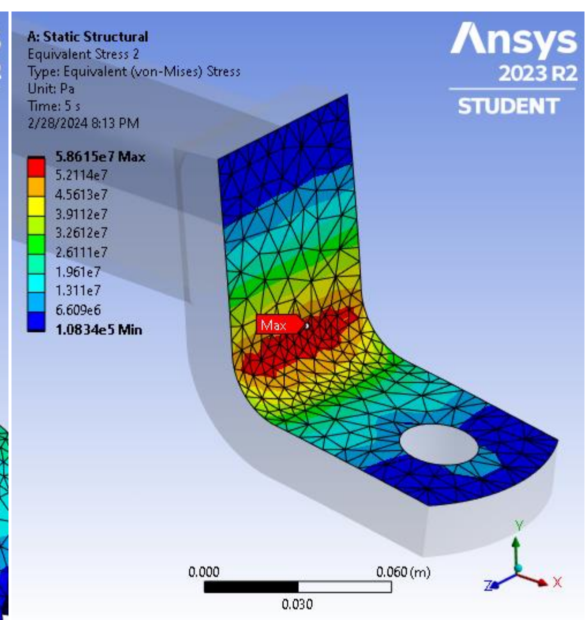


Figure 5. Critical Position

From figure above, the peak equivalent stress happens at the curve surface of the hitch (see in Fig. 5, the red “Max” mark). The location of an artificial stress singularity is the red “Max” mark on Figure 4.

The stress value is presented below:

Mesh convergence study table:

Mesh Settings	Element Size: **0.005m** Critical Size: **0.005m**	Element Size: **0.005m** Critical Size: **0.0025m**	Element Size: **0.001m** Critical Size: **0.0005m**
Result LC1 (stress, MPa)	**58.615**	**58.582**	**58.417** (within +/- 5%)
Result LC2 (stress, MPa)	**58.615**	**58.582**	**58.417** (within +/- 5%)
Result LC3 (stress, MPa)	**36.106**	**36.457**	**36.846** (within +/- 5%)
Result LC4 (stress, MPa)	**79.432**	**80.205**	**81.132** (within +/- 5%)

From the table above, one can see that as the mesh element increases from 0.005m to 0.0005m, the peak equivalent stress increment is below the +/- %5 requirement. Also, we do not need to consider all 4, a subset is sufficient, which means the stress location does **NOT** change with either the direction of the load nor its magnitude.

Boundary Conditions (Part B)

The boundary conditions are same with Part A. Fatigue setting are below:

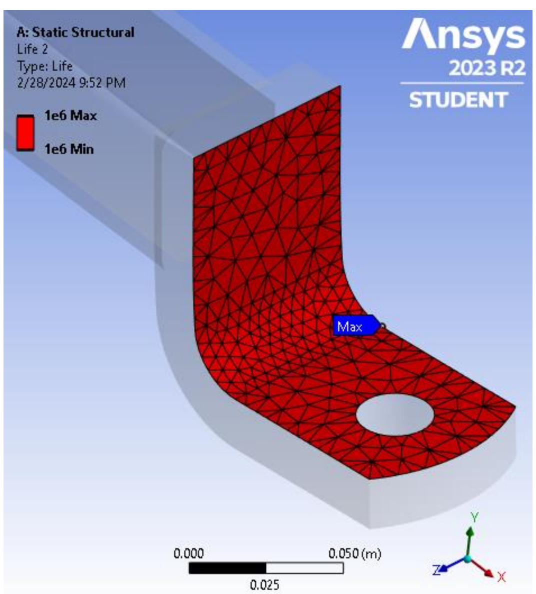
Details of "Fatigue Tool"	
Domain	
Domain Type	Time
Materials	
Fatigue Strength Factor (Kf)	1.
Loading	
Type	Zero-Based
Scale Factor	1.
Definition	
Display Time	End Time
Options	
Analysis Type	Stress Life
Mean Stress Theory	Goodman
Stress Component	Signed von-Mises
Life Units	
Units Name	cycles
1 cycle is equal to	1. cycles

(For LC 1 &2)

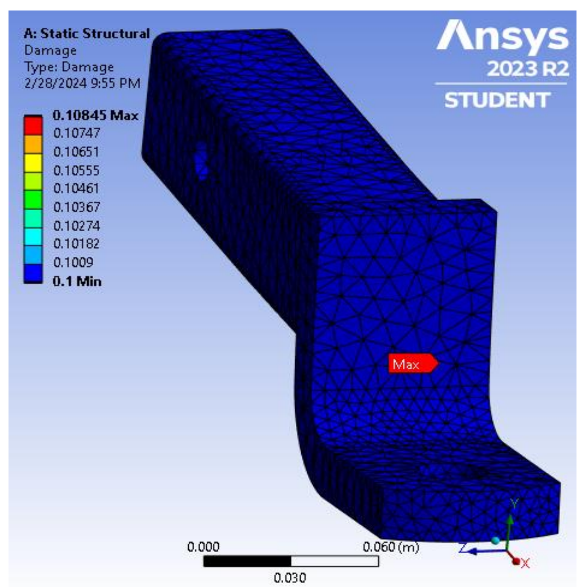
Details of "Fatigue Tool"	
Domain	
Domain Type	Time
Materials	
Fatigue Strength Factor (Kf)	1.
Loading	
Type	Fully Reversed
Scale Factor	1.
Definition	
Display Time	End Time
Options	
Analysis Type	Stress Life
Mean Stress Theory	Goodman
Stress Component	Signed von-Mises
Life Units	
Units Name	cycles
1 cycle is equal to	1. cycles

(For LC 3 &4)

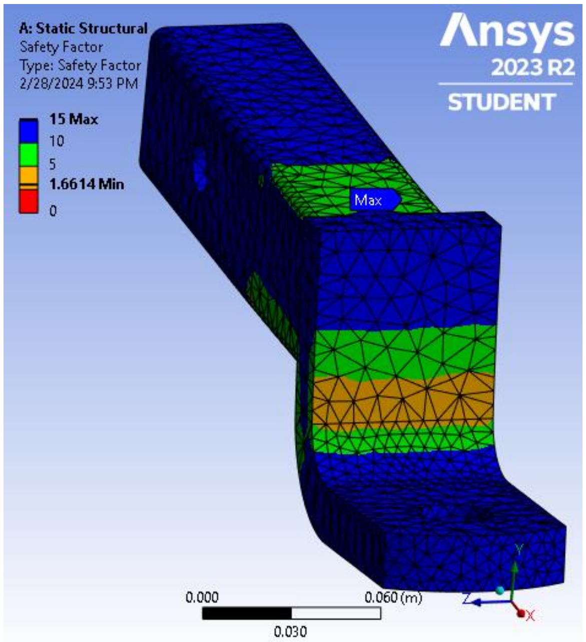
Results (Part B)



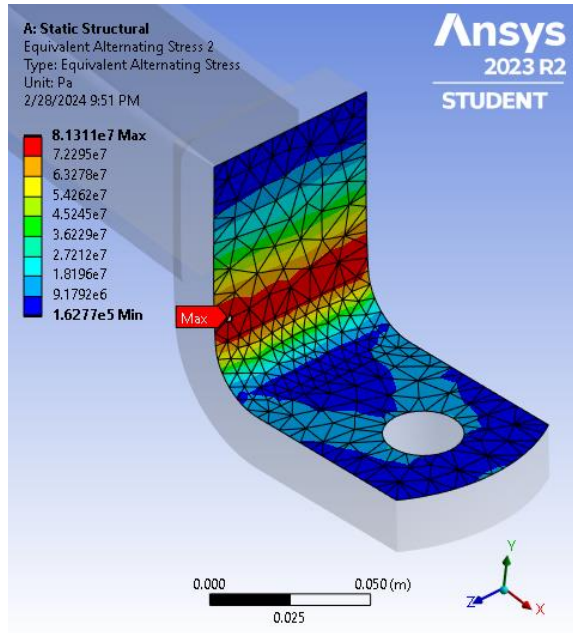
Life



Damage



Safety Factor

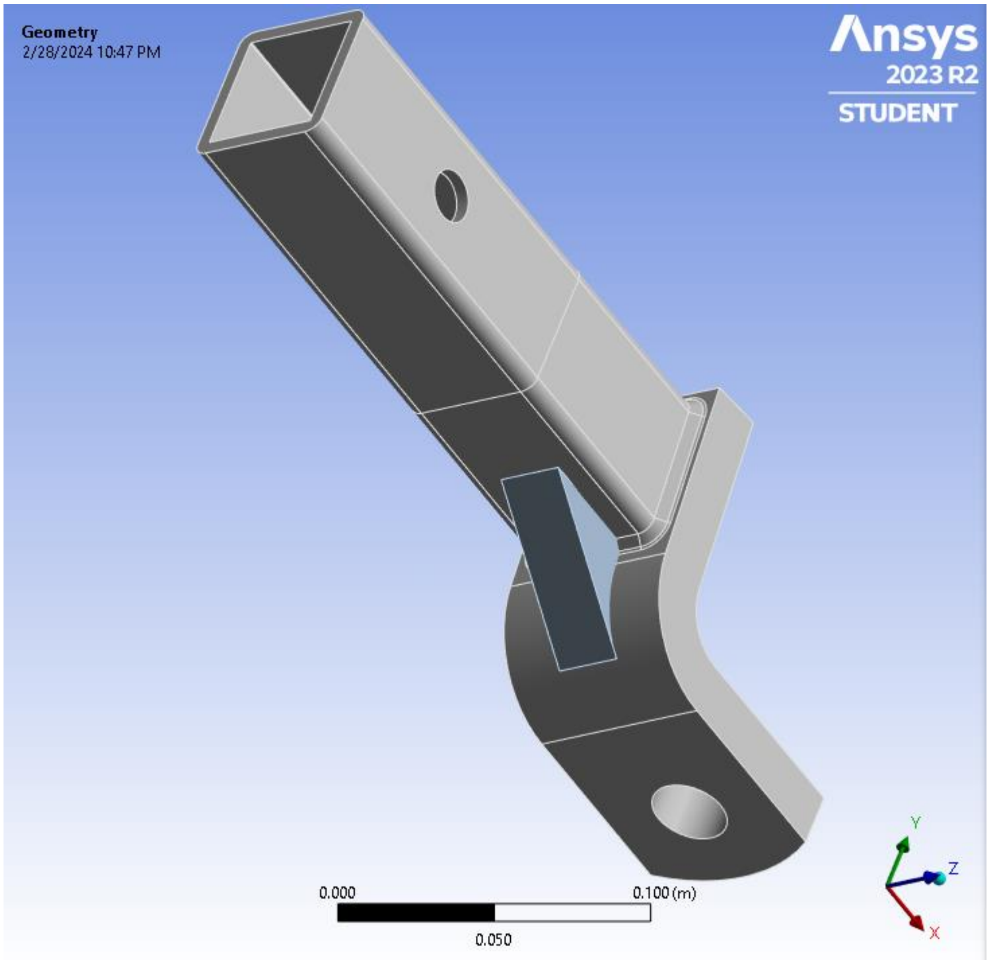


Fatigue Equivalent Alternating Stress

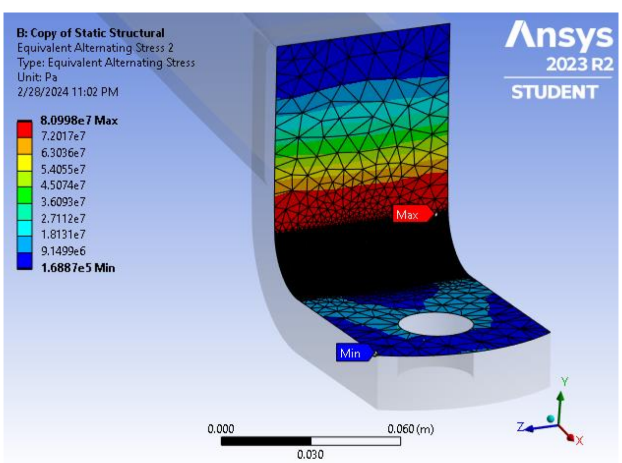
The Master Table:

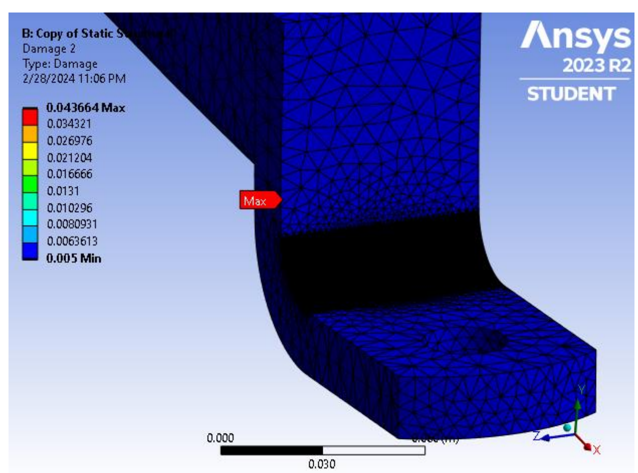
Result Case	Peak Stress (MPa)	Life	Damage	Safety Factor (Min，All Max is 15)	Fatigue Equivalent Alternating Stress (MPa)
Load Case 1	58.417	1E6	N/A	2.5738	3.1232
Load Case 2	58.417	1E6	N/A	3.0773	2.9246
Load Case 3	36.846	1E6	0.1	5.4280	36.846
Load Case 4	81.132	5.53E5	0.005	4.2328	81.311

Results (Part C)



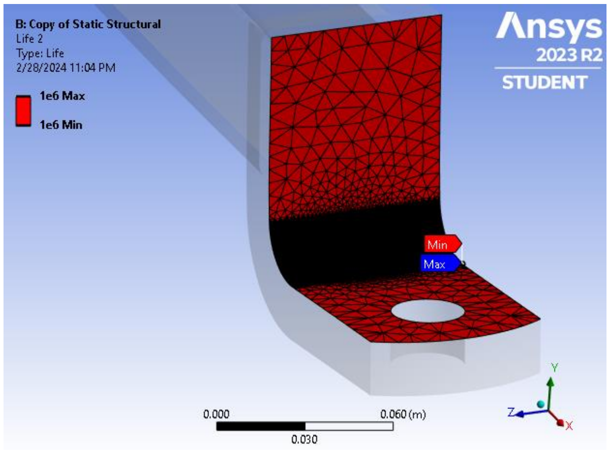
Modified Hitch (Blue Support Part Added)



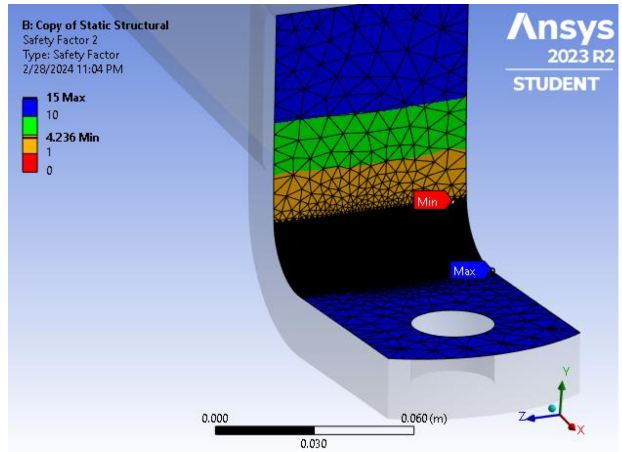


Fatigue Equivalent Alternating Stress

Damage



Life



Safety Factor

Load Cases	LC1	LC2	LC3	LC4
Safety Factor (Original)	2.5738	3.0773	5.4280	4.2328
Safety Factor (Modified)	2.5836	3.089	5.4332	4.2360

Conclusion

In this assignment, we can find that how different load cases and fatigue settings influence the stress, life, safety factor, and damage of a steel part. Moreover, those performances can be improved by improving the weak part of the original model.