## 24-650 Applied Finite Element Analysis Homework No 10 Fatigue of a Trailer Hitch Ignacio Cordova

The objective of this assignment was to perform a fatigue analysis of a trailer hitch as shown in Figure 1.





## 1. Setup

The first step was to import the model to Ansys Mechanical in a Static Structural module. The global mesh size was **5 mm** and the material was steel with the following properties:

- E= 200 GPa
- *Nu*= 0.3
- Density= 7,850 kg/m<sup>3</sup>
- Ultimate Strength= 460 MPa
- Stress Life Fatigues Properties as shown in Figure 2.





Four cases were studied with different loads. All of them have constrained the 2 pinned faces in the radial direction only and the 4 flat faces which contact the receiver in the normal direction only. The different loads are shown below:

- LC1: Tongue Load of 2,500 N, Drop, Design life=infinite(1e6). Load is applied and then removed (shown in Figure A.1).
- LC2: Tongue Load of 2,500 N, Rise, Design life=infinite (1e6). Load is applied and then removed (shown in Figure A.2).
- LC3: Trailer Load Small Hill: 5,000 N, Design life=1e5 cycles. Load is applied and then reversed in opposite direction (shown in Figure A.3)
- LC4: Trailer Load Steep Hill: 11,000 N, Design life=5,000 cycles. Load is applied and then revered in opposite direction (shown in Figure A.4)

Finally, the same four cases were solved for a different drop height (20 cm) and for a different design of the hitch.

## 2. Results and Analysis

The results are shown below.

Result Case	Height (cm)	Peak Stress (MPa)	Life	Damage	Safety Factor	Fatigue Equivalent Alternating Stress (MPa)
LC1	76	101.33	1.00E+06	N/A	1.7764	50.665
	7.0	(Figure A.7)	(Figure A.8)	(Figure A.9)	(Figure A.10)	(Figure A.11)
LC2	76	101.33	1.00E+06	N/A	1.4857	56.936
	7.0	(Figure A.13)	(Figure A.14)	(Figure A.15)	(Figure A.16)	(Figure A.17)
LC3	7.6	109.31	6.68E+05	0.1498	1.8297	109.31
		(Figure A.19)	(Figure A.20)	(Figure A.21)	(Figure A.22)	(Figure A.23)
LC4	7.6	240.47	42863	0.11665	1.4268	240.47
		(Figure A.25)	(Figure A.26)	(Figure A.27)	(Figure A.28)	(Figure A.29)
LC1	20	100.56	1.00E+06	N/A	1.7899	50.282
	20	(Figure A.36)	(Figure A.37)	(Figure A.38)	(Figure A.39)	(Figure A.40)
LC2	20	100.56	1.00E+06	N/A	1.497	56.453
	20	(Figure A.42)	(Figure A.43)	(Figure A.44)	(Figure A.45)	(Figure A.46)
LC3	20	492.45	856.88	116.7	0.40613	492.45
	20	(Figure A.48)	(Figure A.49)	(Figure A.50)	(Figure A.51)	(Figure A.52)
LC4	20	1083.4	243.08	20.569	0.3167	1083.4
	20	(Figure A.54)	(Figure A.55)	(Figure A.56)	(Figure A.57)	(Figure A.58)
LC1	20 (new	76.792	1.00E+06	N/A	2.344	38.396
	design)	(Figure A.65)	(Figure A.66)	(Figure A.67)	(Figure A.68)	(Figure A.69)
LC2	20 (new	76.792	1.00E+06	N/A	1.9604	41.893
	design)	(Figure A.71)	(Figure A.72)	(Figure A.73)	(Figure A.74)	(Figure A.75)
LC3	20 (new	272.14	22,089	4.5271	0.73492	272.14
	design)	(Figure A.77)	(Figure A.78)	(Figure A.79)	(Figure A.80)	(Figure A.81)
LC4	20 (new	598.71	683.17	7.3188	0.57309	598.71
	design)	(Figure A.83)	(Figure A.84)	(Figure A.85)	(Figure A.86)	(Figure A.87)
			Table	1: Results		

As can be seen in Table 1, for the height of **7.6 cm**, none of the cases failed to meet the design life.

For LC1 and LC2, the fatigue safety factor at the critical location is different. The reason is because the nature of the stresses at the critical location depends if the load is being applied along -Y (LC1) or +Y (LC2), and if it is zero-based or fully reversed. If the load is applied along -Y (LC1) and it is zero-based, the stresses at the critical location are mostly negative (compression). If the load is applied along +Y(LC2) and it is zero-based, the stresses at the critical location are mostly positive (tension). Due to the cracks growing only because of tension stresses, the safety factor for LC2 must be lower than LC1.

If the loading for LC1 and LC2 changes from zero-based to fully reversed, there is not difference between both cases and the fatigue results should be equal.

If the height changes to **20 cm**, the fatigue safety factor obtained for LC1 and LC2 increases to 1.7899 and 1.497 respectively, but the cases LC3 and LC4 fail to meet the design life. For both cases the fatigue safety factor is below 1 and the values of Life are below their expected design life. The **damage** is **116.7** for LC3-20cm and **20.569** for LC4-20cm.

To improve the fatigue safety factor of the hitch when the height is 20 cm, a new design is presented in Figure 3. A rib was added to make the hitch stiffer when the load is applied along the X axis. As can be seen in Table 1, there is a big improvement in the fatigue safety factor for all the cases. Nevertheless, for LC3 and LC4, the part is still failing to meet the design life.



Figure 3: New design for Height:20 cm

## 3. Appendix

Homework No 10



Figure A.1: LC1, Height: 7.6 cm. Boundary Conditions



Figure A.2: LC2, Height: 7.6 cm. Boundary Conditions



Figure A.3: LC3, Height: 7.6 cm. Boundary Conditions



Figure A.4: LC4, Height: 7.6 cm. Boundary Conditions



Figure A.5: Height: 7.6 cm. Surfaces selected for Convergence Tool



Figure A.6: LC1, Height: 7.6 cm. Convergence Tool (5% allowable change)



Figure A.7: LC1, Height: 7.6 cm. Equivalent Stress



Figure A.8: LC1, Height: 7.6 cm. Fatigue Tool: Life



Figure A.9: LC1, Height: 7.6 cm. Fatigue Tool: Damage



Figure A.10: LC1, Height: 7.6 cm. Fatigue Tool: Safety Factor



Figure A.11: LC1, Height: 7.6 cm. Fatigue Tool: Equivalent Alternating Stress



Figure A.12: LC2, Height: 7.6 cm. Convergence Tool (5% allowable change)



Figure A.13: LC2, Height: 7.6 cm. Equivalent Stress



Figure A.14: LC2, Height: 7.6 cm. Fatigue Tool: Life



Figure A.15: LC2, Height: 7.6 cm. Fatigue Tool: Damage



Figure A.16: LC2, Height: 7.6 cm. Fatigue Tool: Safety Factor



Figure A.17: LC2, Height: 7.6 cm. Fatigue Tool: Equivalent Alternating Stress



Figure A.18: LC3, Height: 7.6 cm. Convergence Tool (5% allowable change)



Figure A.19: LC3, Height: 7.6 cm. Equivalent Stress



Figure A.20: LC3, Height: 7.6 cm. Fatigue Tool: Life



Figure A.21: LC3, Height: 7.6 cm. Fatigue Tool: Damage



Figure A.22: LC3, Height: 7.6 cm. Fatigue Tool: Safety Factor



Figure A.23: LC3, Height: 7.6 cm. Fatigue Tool: Equivalent Alternating Stress



Figure A.24: LC4, Height: 7.6 cm. Convergence Tool (5% allowable change)



Figure A.25: LC4, Height: 7.6 cm. Equivalent Stress



Figure A.26: LC4, Height: 7.6 cm. Fatigue Tool: Life



Figure A.27: LC4, Height: 7.6 cm. Fatigue Tool: Damage



Figure A.28: LC4, Height: 7.6 cm. Fatigue Tool: Safety Factor



Figure A.29: LC4, Height: 7.6 cm. Fatigue Tool: Equivalent Alternating Stress



Figure A.30: LC1, Height: 20 cm. Boundary Conditions



Figure A.31: LC2, Height: 20 cm. Boundary Conditions



Figure A.32: LC3, Height: 20 cm. Boundary Conditions



Figure A.33: LC4, Height: 20 cm. Boundary Conditions



Figure A.34: Height: 20 cm. Surfaces selected for Convergence Tool



	Equivalent Stress 2 (MPa)	Change (%)	Nodes	Elements
1	82.245		35017	19442
2	103.9	23.262	58012	35069
3	100.56	-3.2579	123422	79972

Figure A.35: LC1, Height: 20 cm. Convergence Tool (5% allowable change)



Figure A.36: LC1, Height: 20 cm. Equivalent Stress



Figure A.37: LC1, Height: 20 cm. Fatigue Tool: Life



Figure A.38: LC1, Height: 20 cm. Fatigue Tool: Damage



Figure A.39: LC1, Height: 20 cm. Fatigue Tool: Safety Factor



Figure A.40: LC1, Height: 20 cm. Fatigue Tool: Equivalent Alternating Stress



		Equivalent Stress 2 (MPa)	Change (%)	Nodes	Elements
ſ	1	82.245		35017	19442
	2	103.9	23.262	58012	35069
	3	100.56	-3.2579	123422	79972
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Figure A.41: LC2, Height: 20 cm. Convergence Tool (5% allowable change)



Figure A.42: LC2, Height: 20 cm. Equivalent Stress



Figure A.43: LC2, Height: 20 cm. Fatigue Tool: Life



Figure A.44: LC2, Height: 20 cm. Fatigue Tool: Damage



Figure A.45: LC2, Height: 20 cm. Fatigue Tool: Safety Factor



Figure A.46: LC2, Height: 20 cm. Fatigue Tool: Equivalent Alternating Stress



	Equivalent Stress 2 (MPa)	Change (%)	Nodes	Elements
1	405.32		35017	19442
2	504.98	21.895	57985	34969
3	492.45	-2.5129	171436	113758

Figure A.47: LC3, Height: 20 cm. Convergence Tool (5% allowable change)



Figure A.48: LC3, Height: 20 cm. Equivalent Stress



Figure A.49: LC3, Height: 20 cm. Fatigue Tool: Life



Figure A.50: LC3, Height: 20 cm. Fatigue Tool: Damage



Figure A.51: LC3, Height: 20 cm. Fatigue Tool: Safety Factor



Figure A.52: LC3, Height: 20 cm. Fatigue Tool: Equivalent Alternating Stress



	Equivalent Stress 2 (MPa)	Change (%)	Nodes	Elements
1	891.71		35017	19442
2	1111.	21.895	57985	34969
3	1083.4	-2.5129	171436	113758

Figure A.53: LC4, Height: 20 cm. Convergence Tool (5% allowable change)





Figure A.55: LC4, Height: 20 cm. Fatigue Tool: Life



Figure A.56: LC4, Height: 20 cm. Fatigue Tool: Damage



Figure A.57: LC4, Height: 20 cm. Fatigue Tool: Safety Factor



Figure A.58: LC4, Height: 20 cm. Fatigue Tool: Equivalent Alternating Stress



Figure A.59: LC1, Height: 20 cm (new design). Boundary Conditions



Figure A.60: LC2, Height: 20 cm (new design). Boundary Conditions



Figure A.61: LC3, Height: 20 cm (new design). Boundary Conditions



Figure A.62: LC4, Height: 20 cm (new design). Boundary Conditions



Figure A.63: Height: 20 cm (new design). Surfaces selected for Convergence Tool



Figure A.64: LC1, Height: 20 cm (new design). Convergence Tool (5% allowable change)



Figure A.65: LC1, Height: 20 cm (new design). Equivalent Stress



Figure A.66: LC1, Height: 20 cm (new design). Fatigue Tool: Life



Figure A.67: LC1, Height: 20 cm (new design). Fatigue Tool: Damage



Figure A.68: LC1, Height: 20 cm (new design). Fatigue Tool: Safety Factor



Figure A.69: LC1, Height: 20 cm (new design). Fatigue Tool: Equivalent Alternating Stress



Figure A.70: LC2, Height: 20 cm (new design). Convergence Tool (5% allowable change)



Figure A.71: LC2, Height: 20 cm (new design). Equivalent Stress



Figure A.72: LC2, Height: 20 cm (new design). Fatigue Tool: Life



Figure A.73: LC2, Height: 20 cm (new design). Fatigue Tool: Damage



Figure A.74: LC2, Height: 20 cm (new design). Fatigue Tool: Safety Factor



Figure A.75: LC2, Height: 20 cm (new design). Fatigue Tool: Equivalent Alternating Stress



Figure A.76: LC3, Height: 20 cm (new design). Convergence Tool (5% allowable change)



Figure A.77: LC3, Height: 20 cm (new design). Equivalent Stress



Figure A.78: LC3, Height: 20 cm (new design). Fatigue Tool: Life



Figure A.79: LC3, Height: 20 cm (new design). Fatigue Tool: Damage



Figure A.80: LC3, Height: 20 cm (new design). Fatigue Tool: Safety Factor



Figure A.81: LC3, Height: 20 cm (new design). Fatigue Tool: Equivalent Alternating Stress



Figure A.82: LC4, Height: 20 cm (new design). Convergence Tool (5% allowable change)



Figure A.83: LC4, Height: 20 cm (new design). Equivalent Stress



Figure A.84: LC4, Height: 20 cm (new design). Fatigue Tool: Life



Figure A.85: LC4, Height: 20 cm (new design). Fatigue Tool: Damage



Figure A.86: LC4, Height: 20 cm (new design). Fatigue Tool: Safety Factor



Figure A.87: LC4, Height: 20 cm (new design). Fatigue Tool: Equivalent Alternating Stress