**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.

A diagram of a metal object

Description automatically generated with medium confidence**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:

**A blue rectangular object with a hole

Description automatically generated**

Figure 3. BCs

**A screenshot of a computer

Description automatically generatedA screenshot of a computer

Description automatically generated**

Force BCs are indicated below:

|  |  |
| --- | --- |
|  |  |
|  |  |

**A blue and green metal object with a red arrow pointing to the center

Description automatically generatedA computer screen shot of a model

Description automatically generatedResults (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:

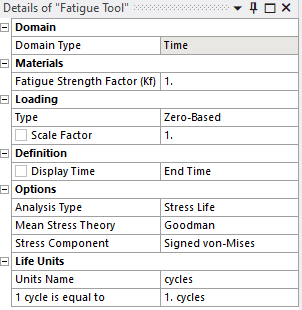
**Mesh convergence study table:**

|  |  |  |  |
| --- | --- | --- | --- |
| **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:

**A screenshot of a computer

Description automatically generated**

(For LC 1 &2) (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)**

A computer generated image of a metal object

Description automatically generated

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.