# Finite Element Modeling of an Aluminum Tricycle Frame

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**Introduction**: As a sustainable urban transport system, the tricycle might represent an adaptive mobility vehicle used to transport people and bulk load. In this work we develop a static finite-element analysis to fine-tune the geometry of an aluminum tricycle frame. Stress and deformation distributions are evaluated for assessing the structural characteristics of the tricycle.

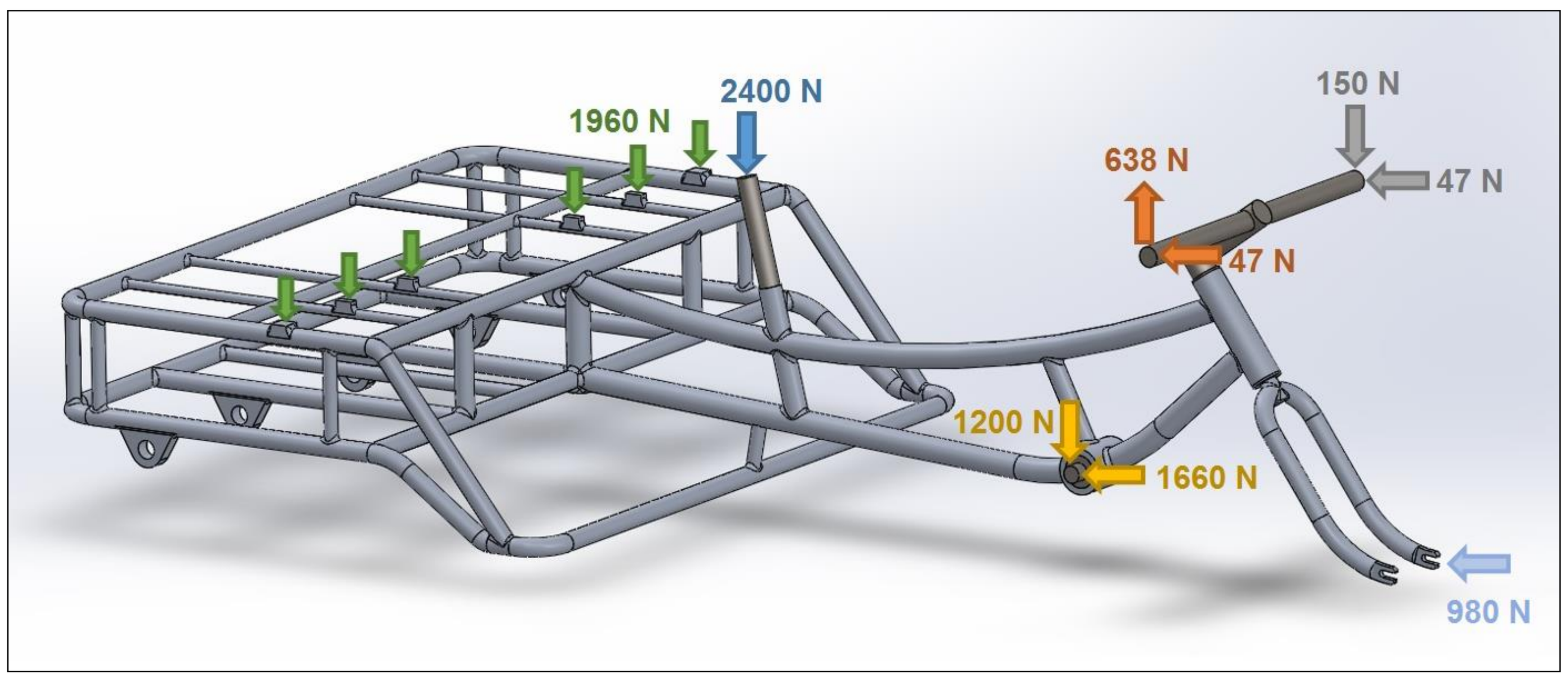


**Figure 1**. Loading values.

**Computational methods**: The tricycle consists of standard bicycle parts with a passenger/load zone on the back side. Only the frame is modeled, with the rest of the parts being used to define the loading conditions. Aluminum 6063-T83 is the material of the frame while bottom bracket and handlebars are made of steel 4130. The SolidWorks CAD of the tricycle is imported in Comsol Multiphysics, then the Structural Mechanics Module is used to define two different 3D FEM models, one applying the Beam interface and the second one the Solid Mechanics (SM) interface.

**Table 1**. Loading cases.

| Loading cases | | | | | | |
|---|---|---|---|---|---|---|
| 1. Acceleration | | √ | √ | √ | | √ |
| 2. Steady Pedalling | | | | | √ | √ |
| 3. Horizontal Impact | √ | | | | | √ |

The two models consider the combination of loading case given in Fig. 1 and Table 1. The frame is constrained from movement in the rear axle, the fork is allowed to slide only along the horizontal X and Y axes and the vertical Z displacement is set to zero on the front axle boundaries. MUMPS (Beam) and SPOOLES (SM) are the solvers. For the SM Model, the frame consists of around $6x10^5$ tetrahedral elements ($3.3x10^6$ DOF in the computations).

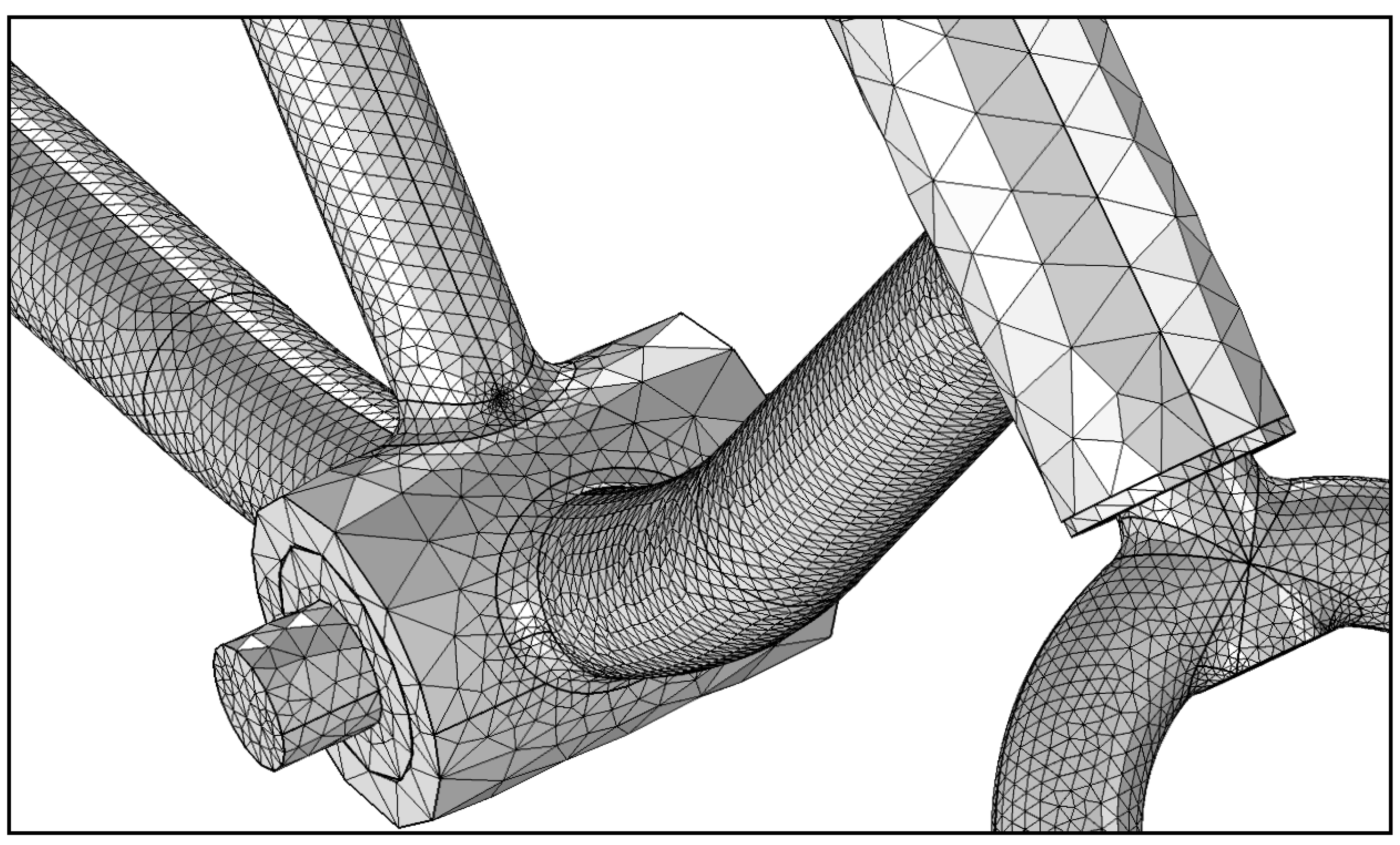

**Figure 2**. A partial view of the mesh (SM Model).

**Results**: In all the loading cases, the simulations show that certain regions of the tricycle might suffer stresses above the tensile yield strength of 214 MPa.

**Table 2**. Maximum values for von Mises stress and displacement.

| Load. case | von Mises stress ($N/m^2$) Beam | von Mises stress ($N/m^2$) SM | displacement (m) Beam | displacement (m) SM |
|---|---|---|---|---|
| 1 | 1.13E9 | 7,08E8 | 0.082 | 0,018 |
| 2 | 1.24E9 | 1,10E9 | 0.087 | 0,021 |
| 3 | 1.07E9 | 6,47E8 | 0.075 | 0,010 |

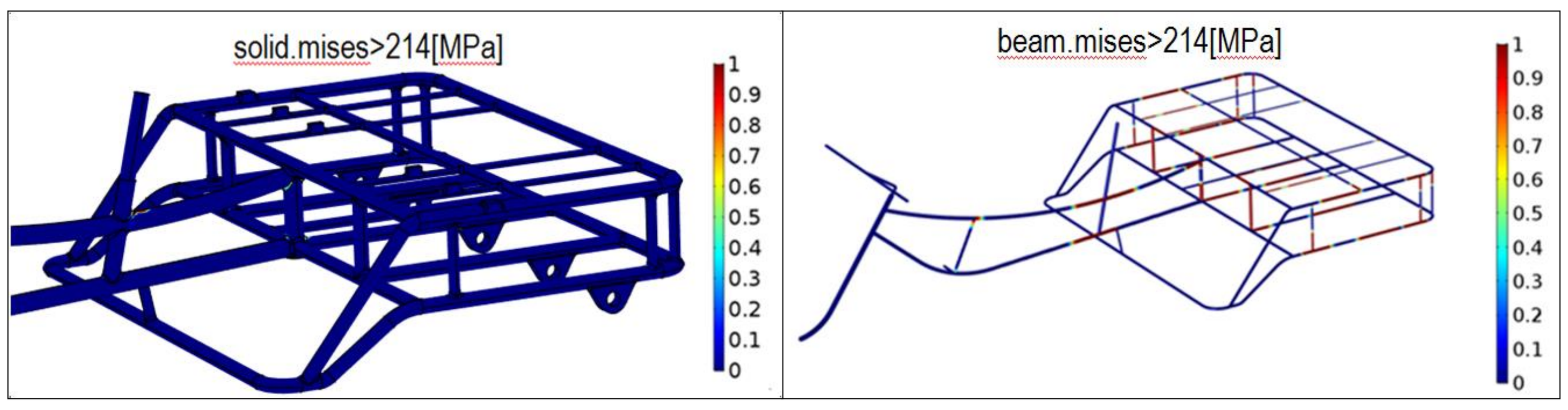


**Figure 3**. Elastic limit: steady pedalling case, SM model on the left, Beam model on the right.

By assuming the fatigue strength value as the materials' resistance after $500x10^6$ fully reversing load cycles (around 69 MPa for Al 6063), the following plots show areas (in red) of the frame and fork which are stressed above this value for the steady state pedalling load (Fig. 4) and acceleration (Fig. 5) cases.

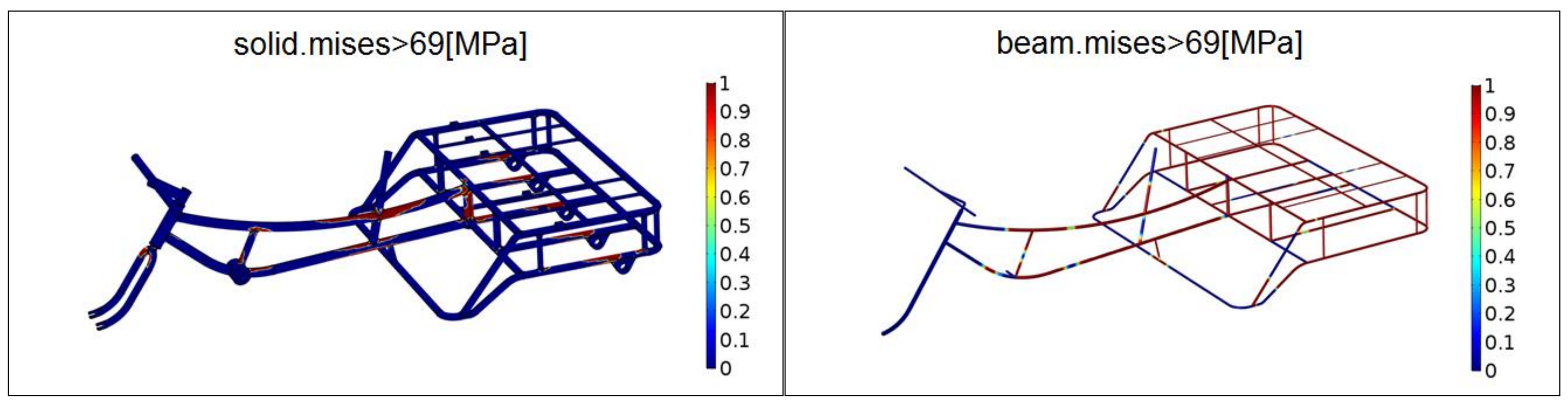


**Figure 4**. Fatigue strength: steady pedaling case, SM model on the right, Beam model on the left.

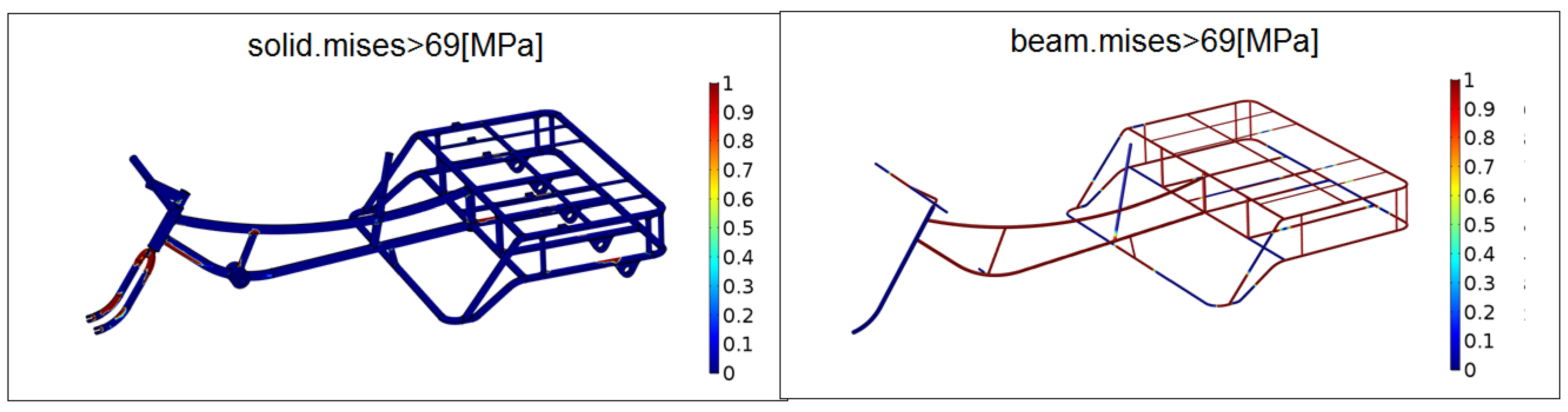


**Figure 5**. Fatigue strength: acceleration case, SM model on the right, Beam model on left.

**Conclusions**:

- Certain regions of the frame will not withstand the loads, needing to fine-tune the frame geometry.
- Further fatigue and impact simulations are suggested in order improve the design of the tricycle.
- The FEM simulations provide useful insights in defining the structural performance of the tricycle, gathering knowledge for future studies.

**References**:

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Gosz M.R., Finite Element Method: Applications in Solids, Structures, and Heat Transfer, Taylor and Francis -CRC Press, Boca Raton (FL), USA (2005).

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