Structural Analysis of a Shelf Support Assembly

Numerische Simulation technischer Systeme, SoSe 2025 Heehwan Soul, 885941

1. Objective

The aim of this assignment is to analyze the stress and deformation occurring in a shelf bracket assembly with bolted joints, under a load equivalent to a 50,kg object (approximately 500 N). The geometry was imported from a provided STEP file.

2. Material Definition

The bracket (Träger) and the wall (Wand) are made of **Structural Steel**. For the bolts, a custom material was defined with the following properties:

- Young's Modulus: 2.1×10^{11} Pa (210 000 MPa)
- Poisson's Ratio: 0.3
- Tensile Yield Strength: 5.5×10^{8} Pa (550 MPa)

3. Contact and Boundary Conditions

All contacts were defined as **Frictional** with a coefficient of friction set to 0.15. The back face of the wall was fully fixed. A vertical load of 500 N is applied in the negative Y-direction in the second step.

The bolts were pretensioned with a force of 5.2 kN in Step 1, which remains locked in Step 2. This leads to a two-step loading scenario:

- **Step 1 (0–1s):** Only pretension force is applied (linearly ramped)
- **Step 2 (1–2s):** External force of 500 N is linearly applied

4. Meshing

The mesh was created following the principle: "as coarse as possible, as fine as necessary." For most surfaces, a global element size of 2.5 mm was used, which is sufficient for regions with low stress variation. However, critical regions required local refinements for increased accuracy:

- 2.0 mm element size was applied to the bolts, the force application area of the bracket (Träger), and the contact between the bracket and the wall (Wand). These areas are expected to experience high stress gradients or local deformations due to bolt pretension and external loading.

- 1.0 mm mesh was used for the remaining contact regions to capture contact behavior and stress transmission more accurately.

Finer mesh in these regions ensures better accuracy and convergence in stress results, especially around areas of load transfer and mechanical interaction. Contact regions, in particular, exhibit high stress gradients and nonlinear frictional behavior. Finer elements are essential to accurately resolve contact pressure distribution, capture sticking/slipping transitions, and ensure convergence of the contact algorithm. For the final report submitted via Moodle, the contact mesh size was increased to 1.5 mm to reduce file size, as the original mesh exceeded the upload limit.

5. Results and Evaluation

5.1 Total Deformation

The maximum deformation occurred at the upper central area of the bracket (Träger), near the location where the force is applied.

- Maximum Total Deformation: 0.025 05 mm
- Average: 0.004 09 mm
- Minimum: 0.0 mm (fixed wall)

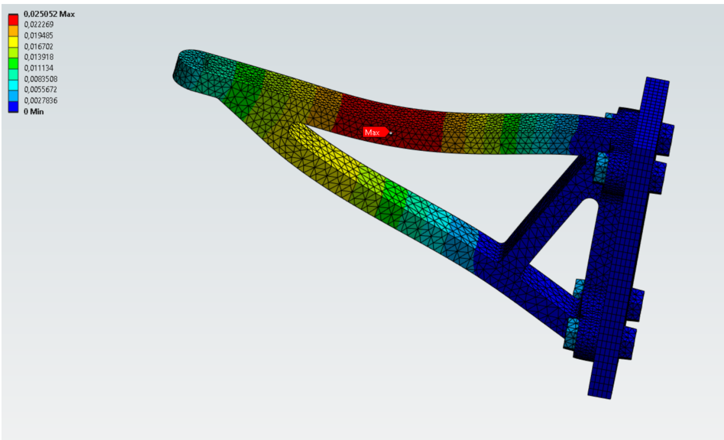

Figure 1: Total deformation – graphical view

5.2 Equivalent (von Mises) Stress

The highest von Mises stress occurred at bolt **Schraube2**. This is due to its proximity to the load application point and asymmetric structural response.

- Maximum Stress: 396.77 MPa
- Average: 54.86 MPa
- Minimum: 0.0195 MPa (wall)

- Material Yield Strength (bolt): 550 MPa ⇒ Safety factor ≈ 1.39

The maximum equivalent (von-Mises) stress in the bolt (Schraube2) was 396.77MPa, while the material's tensile yield strength is 550MPa. The safety factor is about 1.39, which means the bolt is strong enough to handle the load. It only stretches slightly and returns to its original shape — it does not bend or get damaged.

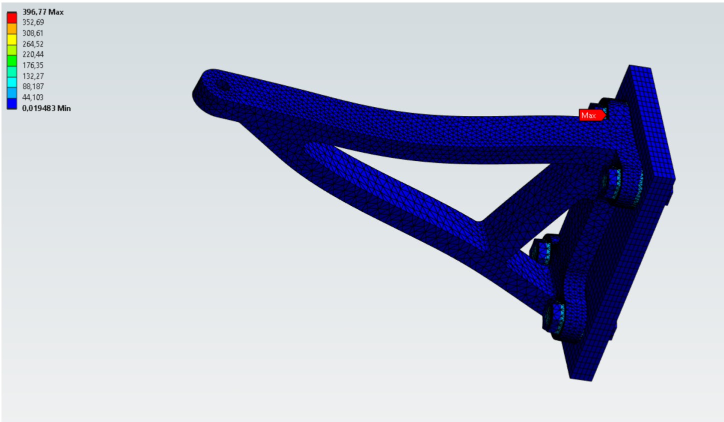

Figure 2: Equivalent von Mises stress – graphical view

5.3 Stress vs. Time

Figure 3: Equivalent stress over time

The graph shows a significant increase in von Mises stress starting from Step 2, when the external load is applied. The response appears linear and stable.

5.4 Deformation vs. Time

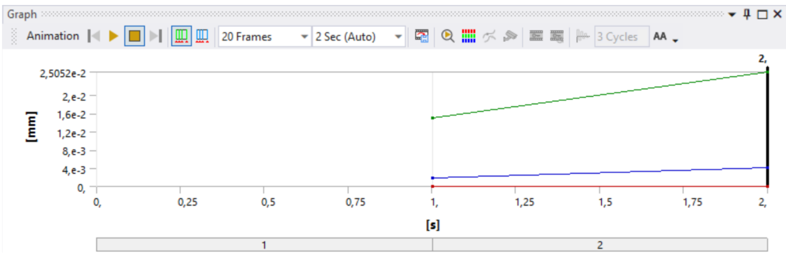

Figure 4: Total deformation over time

The total deformation increases during Step 2 as the external load is applied. The structure behaves in a way that matches what we expect from the material and loading. It doesn't twist, bend, or collapse unexpectedly.

6. Interpretation

The bolts carry most of the load, with the highest stress found at Schraube2. This is because the bolts are the primary connectors between the bracket and the wall, transferring both the pretension and external forces. Among them, Schraube2 is located closest to the force application point, making it the most directly affected by the applied load. The bracket and wall, made of structural steel, experience very low stress levels, far below their yield strength. This confirms that the assembly is structurally safe under the given loading conditions.

Total deformation is small and localized near the upper central area of the bracket, where the external force is applied. This region undergoes the largest deformation due to the bending moment created by the lever arm between the point of load and the wall fixation. The deformation is small and elastic, and no damage is expected. This is supported by the fact that the maximum equivalent stress (396.77MPa) remains well below the material's tensile yield strength (550MPa), and the total deformation is only 0.025mm. These results confirm that the structure stays safely within the elastic range under the given loading conditions.

7. Conclusion

The assembly is mechanically safe under the applied pretension and external load. All stresses remain below the respective yield strengths. The pretension plays a crucial role in maintaining joint integrity, as it ensures tight contact between components and prevents separation or slipping under external loading. This is supported by the simulation results showing low deformation and stress remaining below the yield limit. No yielding is expected in any component, and the structural response is within acceptable limits.