Mesh Element Size Study for 1D, 2D, and 3D Models

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1 Introduction

This report presents a mesh sensitivity study using 1D, 2D (shell), and 3D (solid) models of a mechanical component. The study investigates the effects of mesh element size on the total deformation, equivalent stress, and computational time. All models were based on an initial 3D geometry, from which corresponding 2D and 1D versions were generated for comparison. In this study, only the maximum values of total deformation and equivalent (von Mises) stress were considered for evaluating convergence and model comparison. Minimum and average values were excluded, as they are typically less critical in structural analysis. The maximum values represent the worst-case mechanical response and are more relevant for assessing design safety and convergence behavior.

Note: Due to file size limitations on the submission platform(Moodle), the ANSYS Workbench archive (*.wbpz) includes only coarser mesh simulations (starting from 3 mm). The results for 1 mm and 2 mm mesh sizes (Design Points DP7 and DP6) were fully computed but removed from the submission file to reduce its size. Nevertheless, their results are fully documented and analyzed in this report.

2 Design Point Results

2.1 1D Model

Table 1: 1D Design Point Results

Name	Mesh Size [mm]	Deformation [mm]	Stress [MPa]	Time [s]
DP 7	1	5.0186	26.632	6
DP 6	2	4.9302	26.632	6
DP 0 (Current)	3	4.8938	26.632	6
DP 4	4	4.8757	26.632	4
DP 3	5	4.8717	26.632	5
DP 2	7	4.0885	20.539	4

2.2 2D Model

Table 2: 2D Design Point Results

Name	Mesh Size [mm]	Deformation [mm]	Stress [MPa]	Time [s]
DP 7	1	4.4182	29.115	24
DP 6	2	4.4317	27.913	10
DP 0 (Current)	3	4.5485	26.936	6
DP 4	4	15.09	346.29	6
DP 3	5	4.6395	26.414	5
DP 2	7	5.2257	27.008	4

2.3 3D Model

Table 3: 3D Design Point Results

Name	Mesh Size [mm]	Deformation [mm]	Stress [MPa]	Time [s]
DP 7	1	4.7347	29.275	272
DP 6	2	4.7345	29.271	44
DP 0 (Current)	3	4.7343	27.742	24
DP 4	4	4.7349	30.239	30
DP 3	5	4.7341	28.224	20
DP 2	7	4.7339	29.389	22

3 Simulation Visualizations

3.1 1D Results

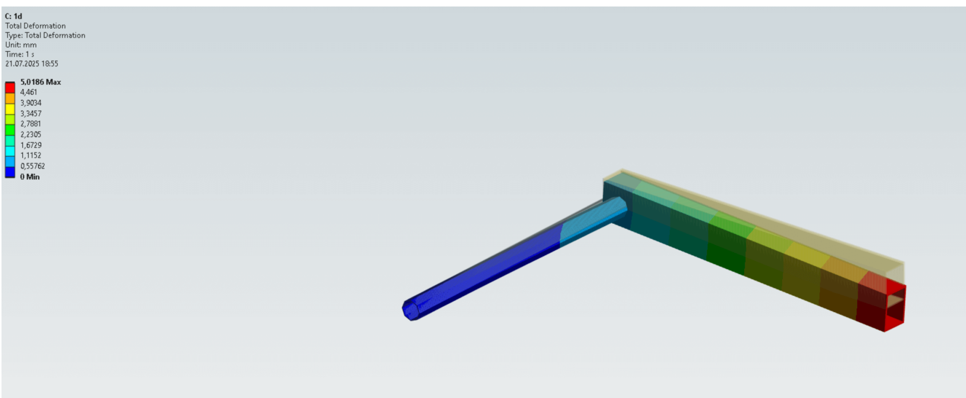

Figure 1: 1D Total Deformation

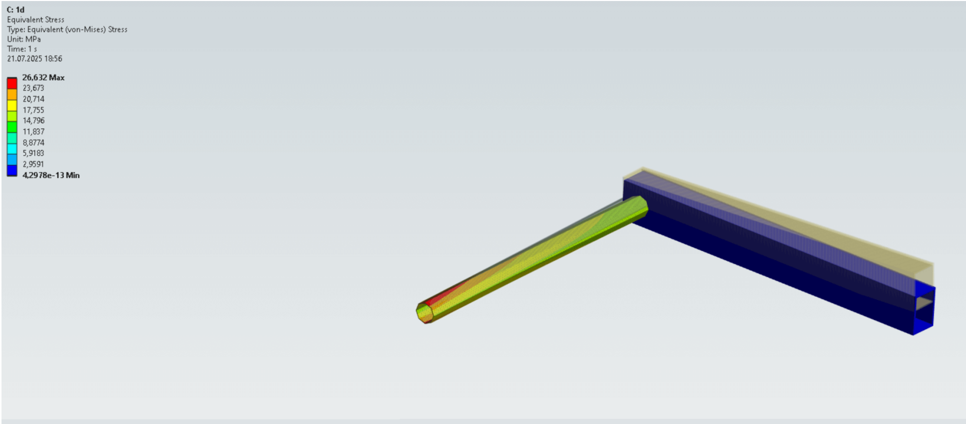

Figure 2: 1D Equivalent Stress

3.2 2D Results

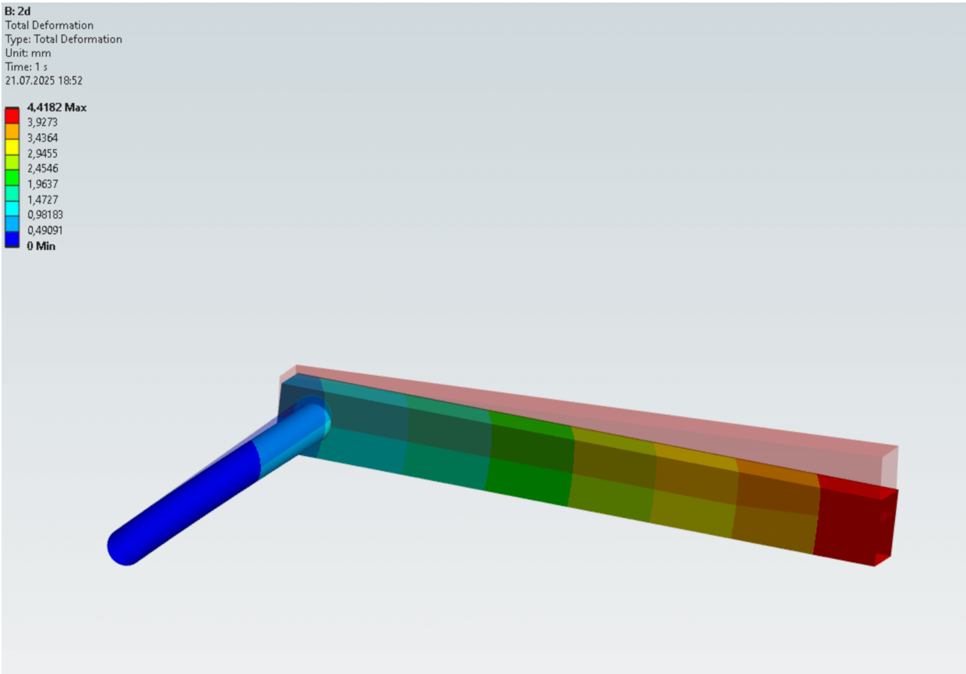

Figure 3: 2D Total Deformation

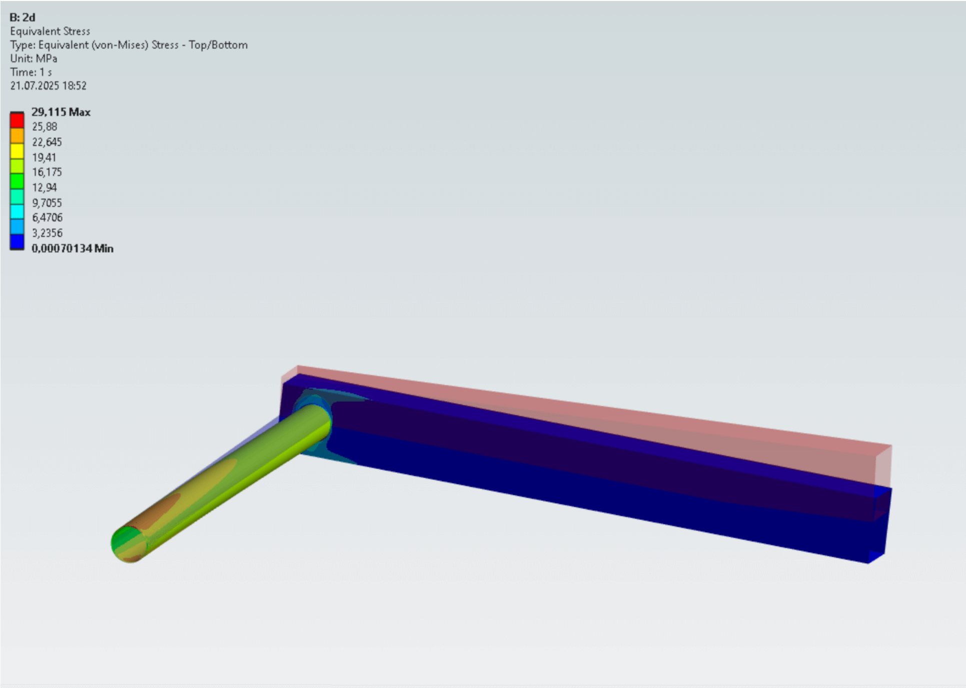

Figure 4: 2D Equivalent Stress

3.3 3D Results

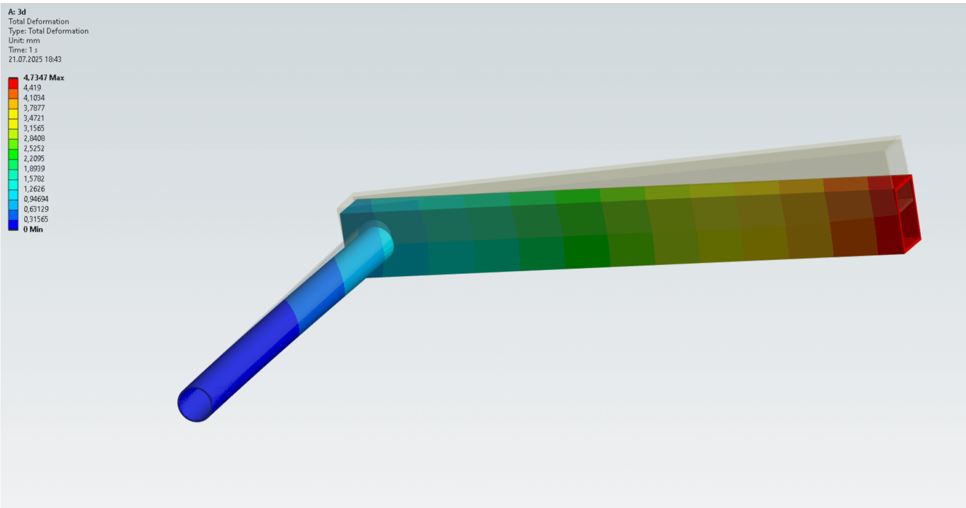

Figure 5: 3D Total Deformation

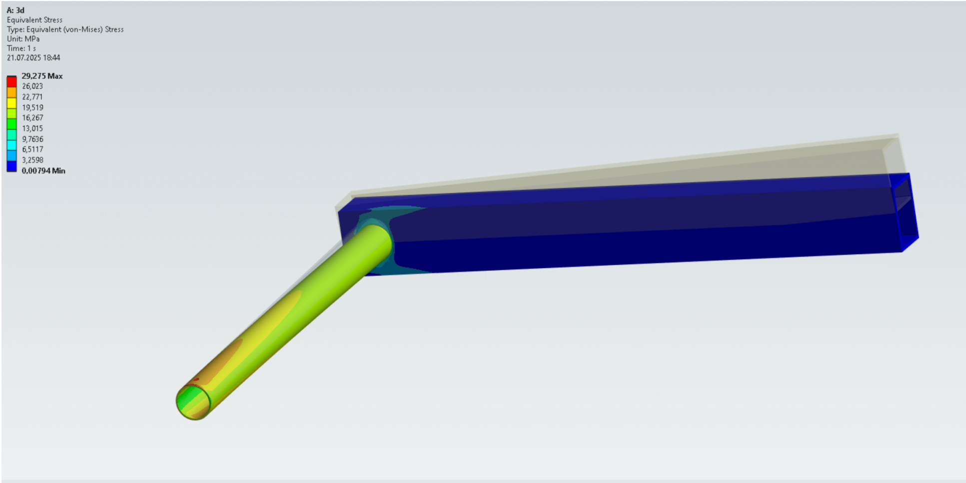

Figure 6: 3D Equivalent Stress

4 Discussion

In this study, convergence behavior was observed at different mesh sizes for each model dimension:

- The 1D model began to converge at a mesh size of approximately 5 mm.
- The 2D shell model showed convergence starting from around 2 mm.
- The 3D solid model exhibited stable results even at 7 mm mesh size, and is expected to maintain accuracy with even larger elements.

The 3D model, which closely resembles the real geometry and boundary conditions, provides stable results even with coarse meshes. In contrast, the simplified nature of the 1D and 2D models requires finer meshes to compensate for the reduced geometric and physical representation. This suggests that higher-dimensional models can deliver reliable results with relatively larger elements due to their inherent modeling accuracy.

5 Conclusion

From the simulation results across different mesh sizes and model types (1D, 2D, 3D), we observe the following:

- Finer mesh sizes tend to yield slightly more accurate deformation and stress results.
- The 3D model shows stable results even with coarser meshes (7 mm), while the 2D model begins to converge around 2 mm and the 1D model around 5 mm.
- One erroneous data point was observed in the 2D model (DP4), which may indicate a local meshing or solver issue.

Among the models, the 3D simulation is considered the most accurate, as it closely replicates the actual geometry and boundary conditions. The 1D and 2D models exhibit a deviation of approximately 0.3 mm in total deformation when compared to the 3D results.

As expected, the computational time increases as the mesh size becomes finer. In the 1D model, the solution time remains constant at approximately 6 seconds, even down to a mesh size of 1 mm. For the 2D model, the runtime starts increasing from a mesh size of 2 mm. In the 3D model, computation time also increases from 2 mm, but grows dramatically at 1 mm, indicating a steep rise in computational demand for very fine meshes in higher-dimensional simulations.

When comparing computational time, the 3D model requires the most resources, followed by the 2D and then the 1D models. The difference in simulation time is substantial — especially for fine mesh sizes in 3D — which can become a limiting factor in practical applications.

Therefore, if computational resources are limited and a deviation of about 0.3 mm is tolerable in the engineering context, using the 2D or even the 1D model can be a reasonable and efficient alternative.