24-650 Applied Finite Element Analysis

Homework No 11

Elastic-Plastic, Large Deformation Analysis of a Belleville Washer

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The objective of this assignment was to perform an elastic-plastic, large deformation analysis of a Belleville Washer (inside diameter=12 mm, outside diameter=24.32 mm, thickness=1 mm, uncompressed height H_0 =2.01 mm).

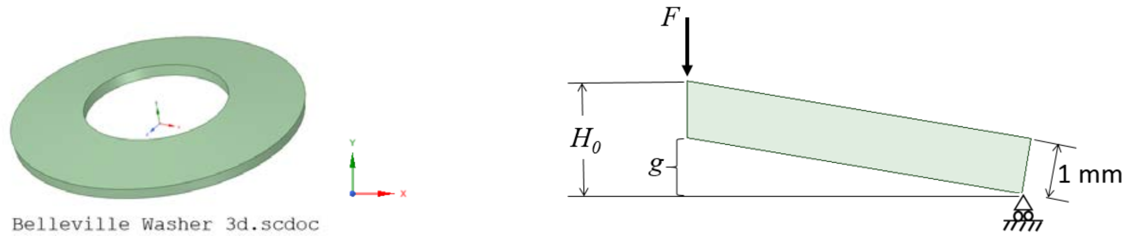

Figure 1: Belleville Washer

1. Setup

The first step was to import the model to Ansys Mechanical in a Static Structural module as a 2D geometry. The 2D behavior was selected as **axisymmetric** and a default mesh (shown in Figure A.1) was used (227 nodes and 60 elements). The material used was Aluminum Alloy and the properties for plasticity are shown below:

- *Bilinear Kinematic with a **yield stress** of **2.8e8 Pa** and a **tangent modulus** of **6.0e10 Pa**.*

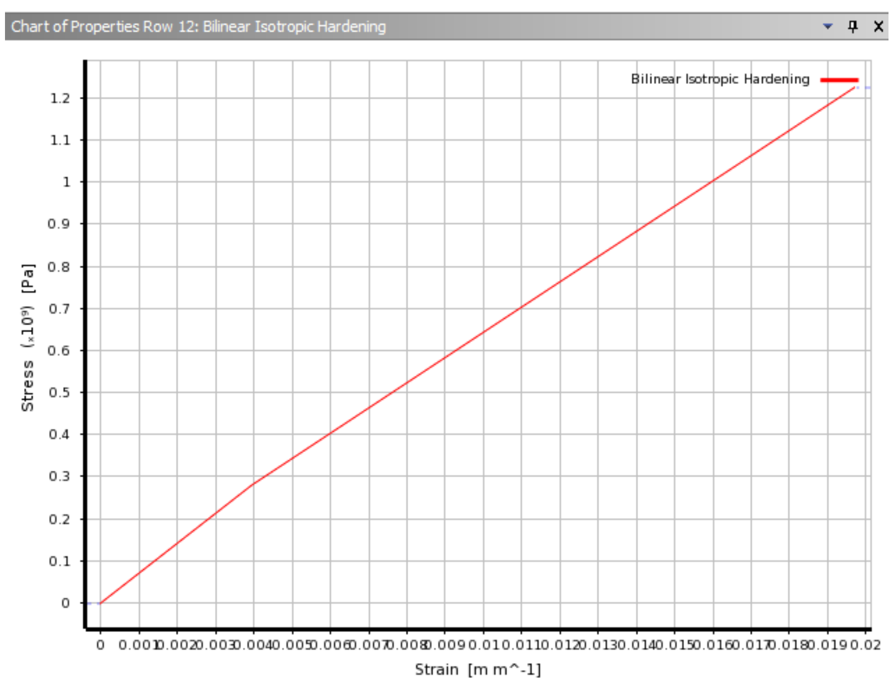

Figure 2: Bilinear Isotropic Hardening, Aluminum Alloy

3 cases were studied applying a load (*F*) that was enough to close the gap *g* (1 mm)

- **Linear elastic analysis:**
    - Loading (Step 1): From 0 s to 1 s. 20 substeps.
    - Unloading (Step 2): From 1 s to 2 s. 2 substeps.
- **Large-deformation, elastic analysis:**
    - Loading (Step 1): From 0 s to 1 s. 20 substeps.
    - Unloading (Step 2): From 1 s to 2 s. 5 substeps.
- **Large-deformation elastic-plastic analysis**
    - Loading (Step 1): From 0 s to 1 s. 20 substeps.
    - Unloading (Step 2): From 1 s to 2 s. 5 substeps.

2. Results and Analysis

The results are shown in Figure 3.

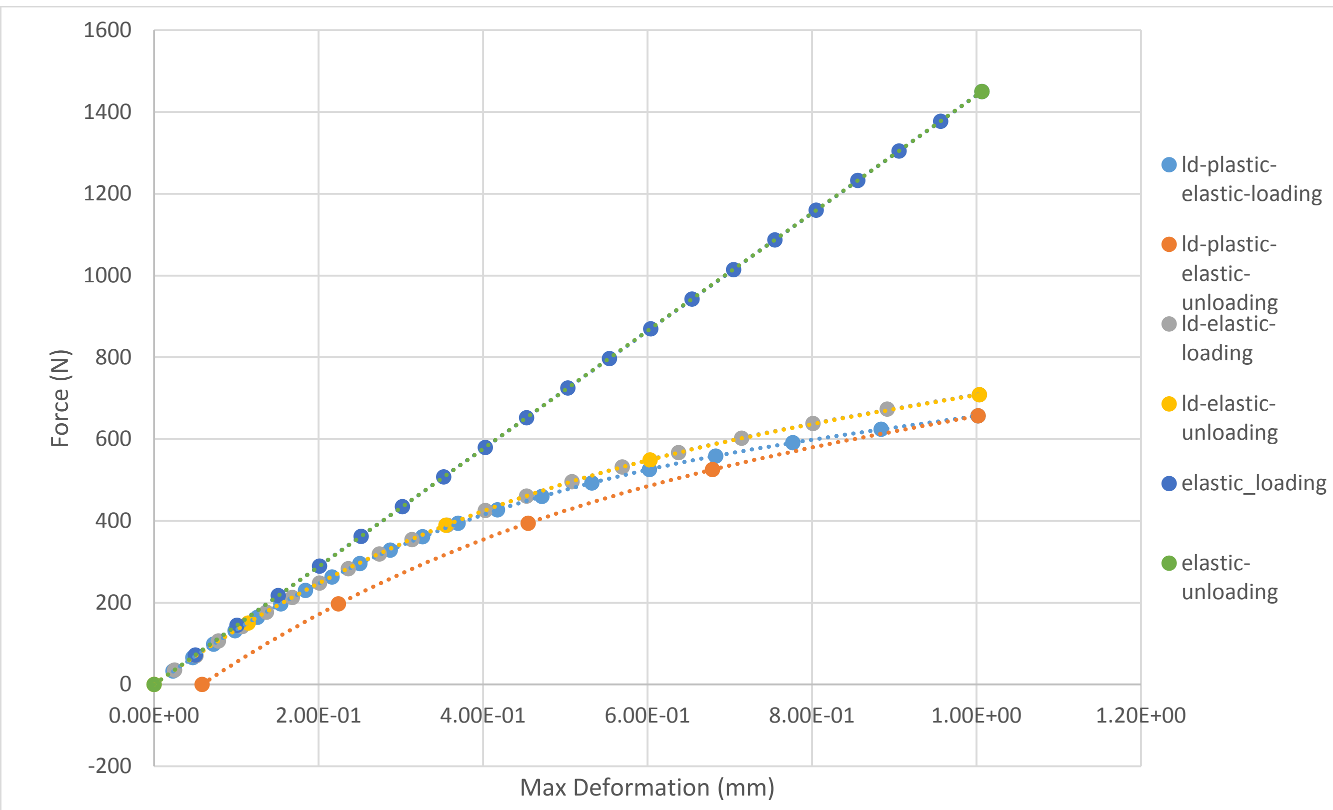

Figure 3: Load-deflection curves

As can be seen in Figure 3, the force needed to close the gap for each analysis is different:

- **Linear elastic analysis:** $F_1=1450\ N$ (Figure A.3)
- **Large-deformation, elastic analysis:** $F_2=709\ N$ (Figure A.5)
- **Large-deformation elastic-plastic analysis:** $F_3=657\ N$ (Figure A.7)

The explanation of this is that the curve stress-strain and the way the solver works are different for all the cases. For the linear elastic analysis, the curve is always linear and the geometry is always considered the same, so the stiffness of the part doesn't change while is being deformed. For the large-deformation, elastic analysis, the solver treats every substep as a new geometry, so the stiffness changes while is being deformed. In that case, the part is less stiff when the gap is smaller, so for the same deformation a lower force is needed. Finally, for the large-deformation, elastic –plastic analysis, a smaller force is needed. The reason of this is that the stresses are above the yield stress of the Aluminum Allow, so a plastic deformation is occurring.

Because of the plastic deformation, after the unloading process, there is a **remaining deformation**. This is shown in Figure A.8 and has a value of **0.058 mm.** The **final height (H_0)** is **0.942 mm.** A contour plot of the equivalent plastic strain is shown in Figure A.9 confirming that a plastic deformation occurred.

3. Appendix

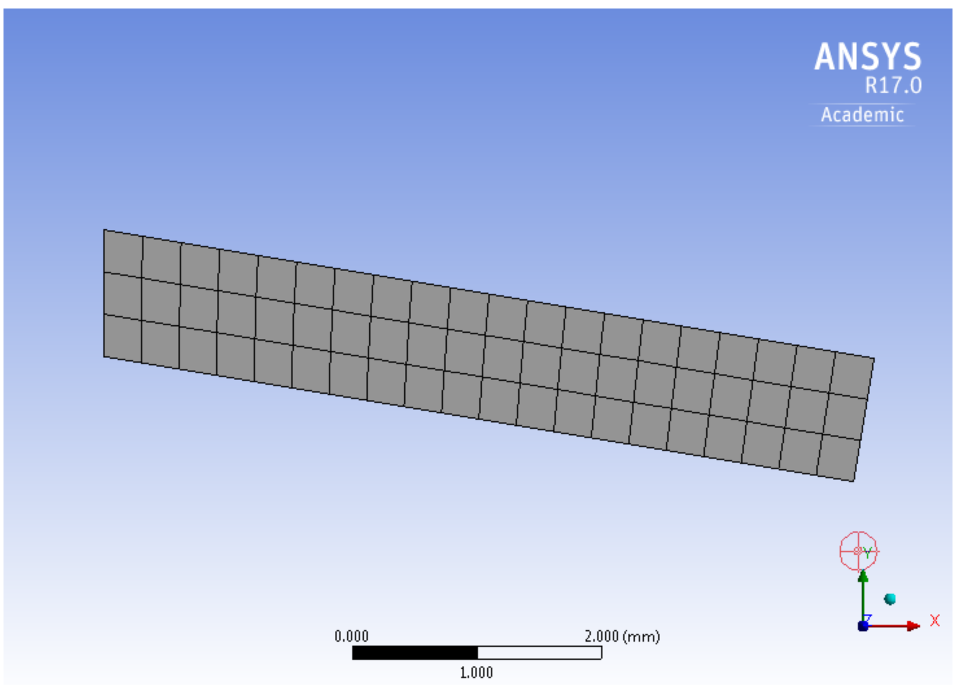

Figure A.1: Default Mesh

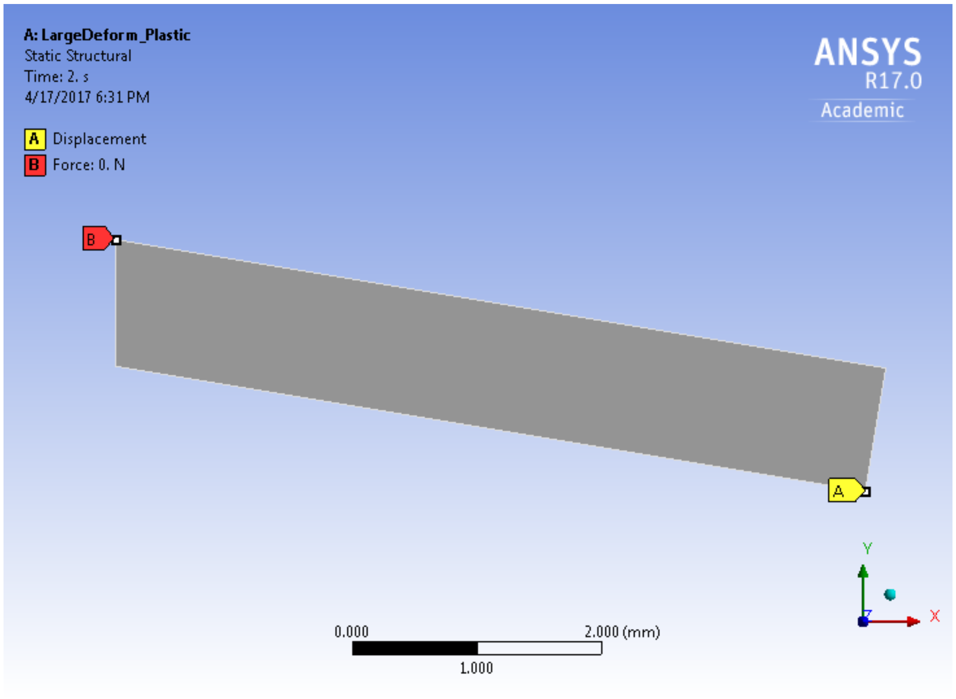

Figure A.2: Boundary Conditions

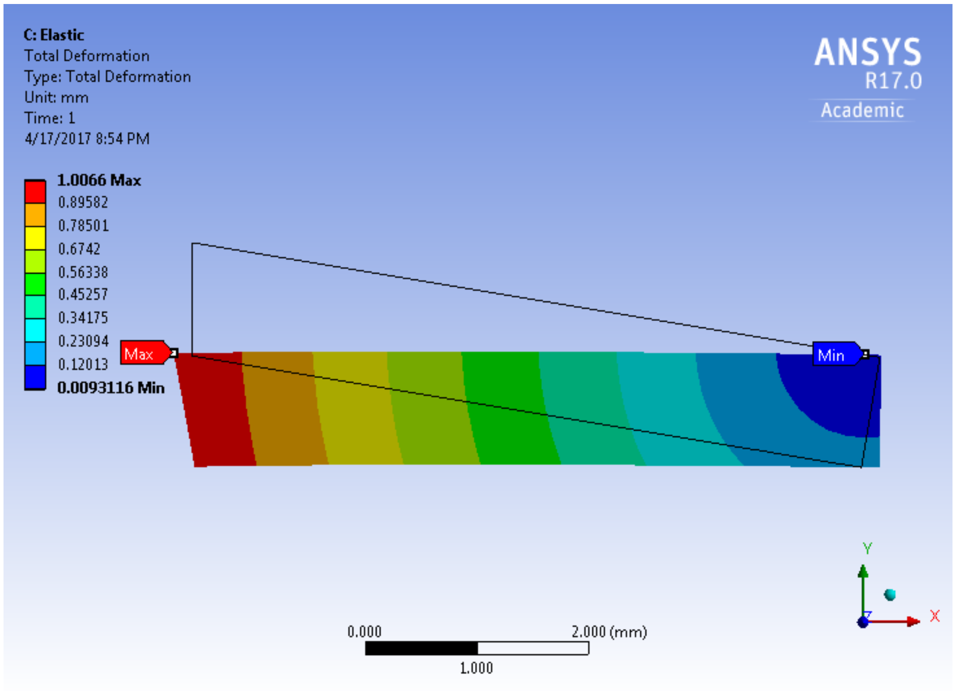

Figure A.3: Linear-elastic- Total Deformation (t=1 s)

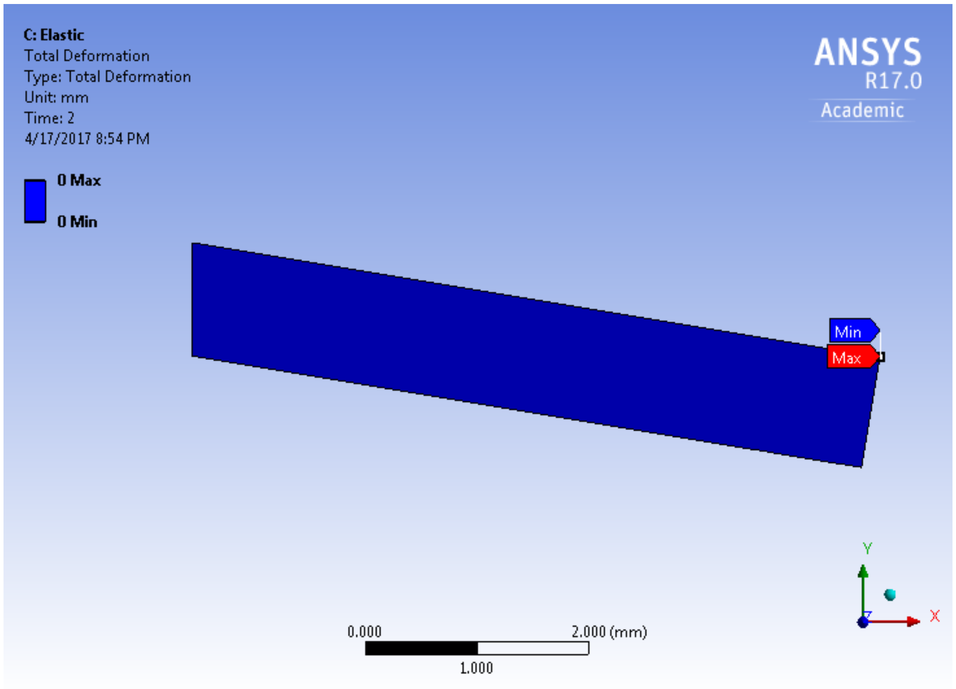

Figure A.4: Linear-elastic- Total Deformation (t=2 s)

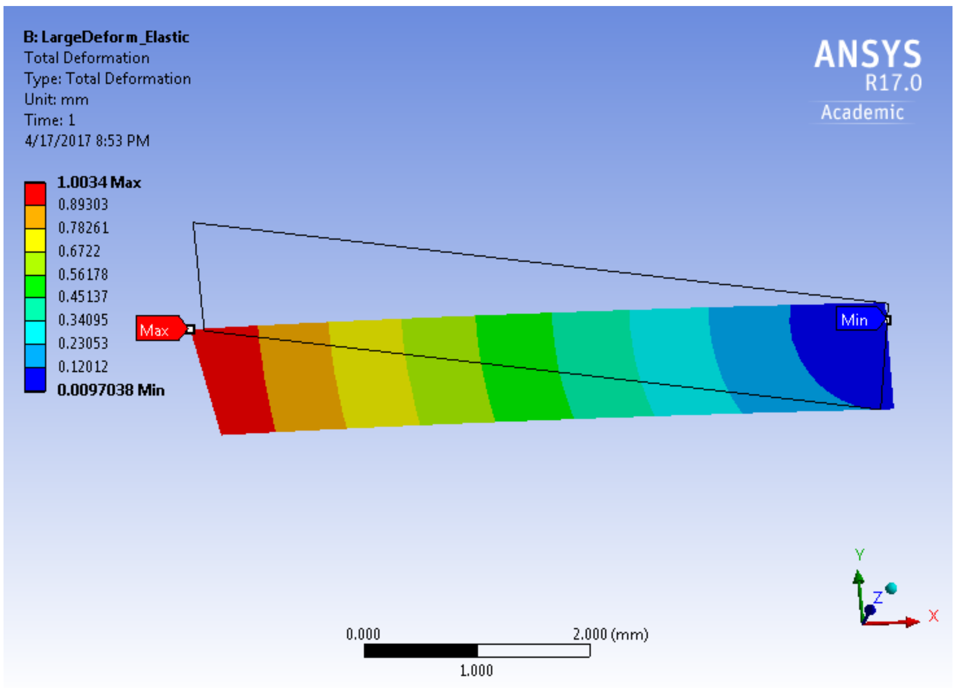

Figure A.5: Large Deformation, Linear-elastic- Total Deformation (t=1 s)

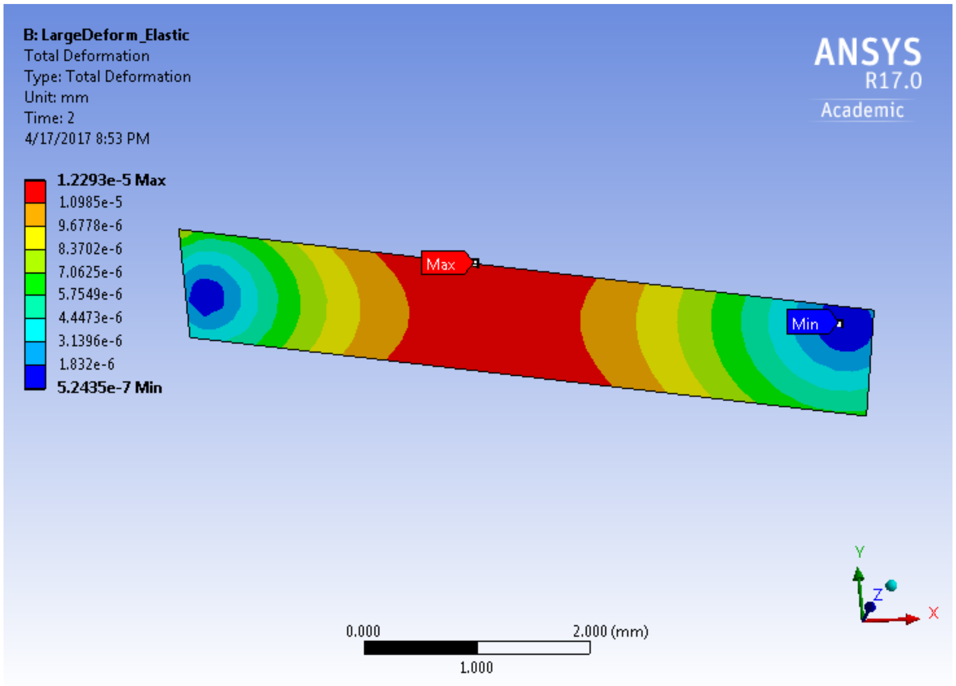

Figure A.6: Large Deformation, Linear-elastic- Total Deformation (t=2 s)

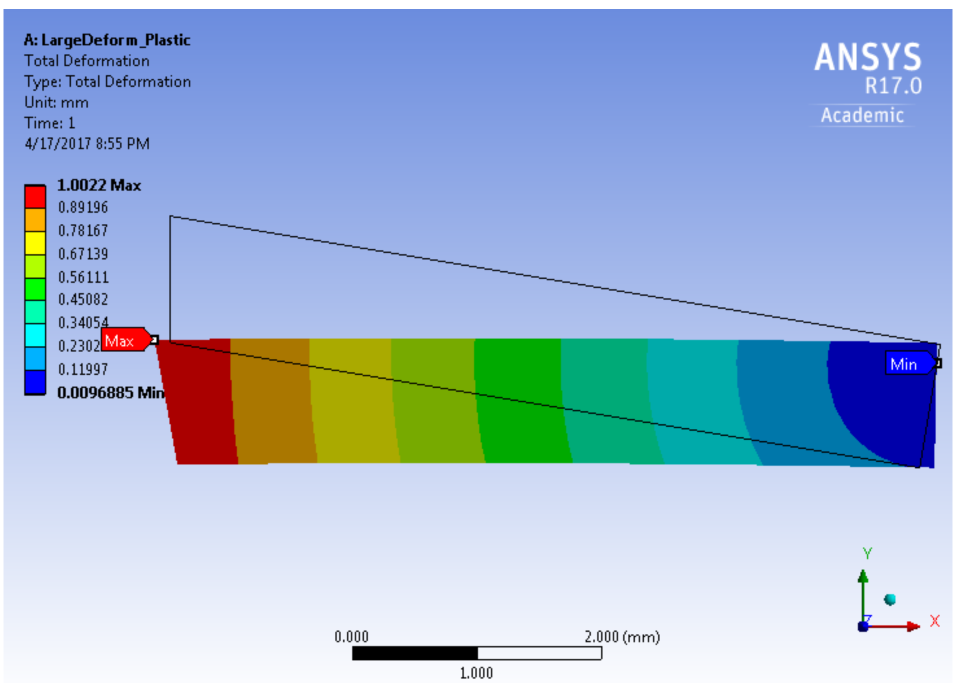

Figure A.7: Large Deformation, elastic-plastic- Total Deformation (t=1 s)

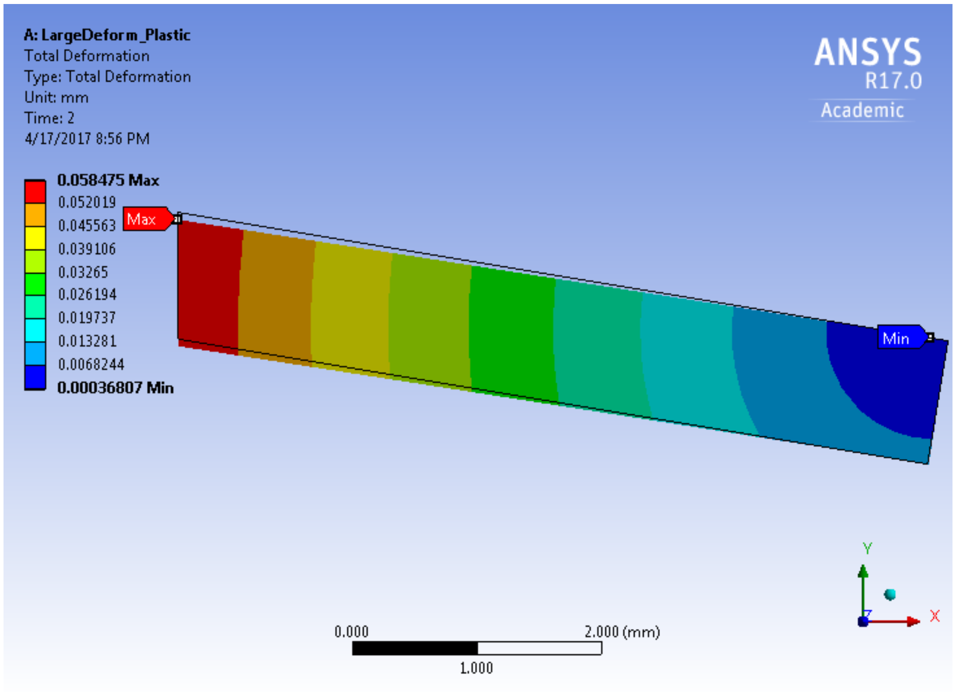

Figure A.8: Large Deformation, elastic-plastic- Total Deformation (t=2 s)

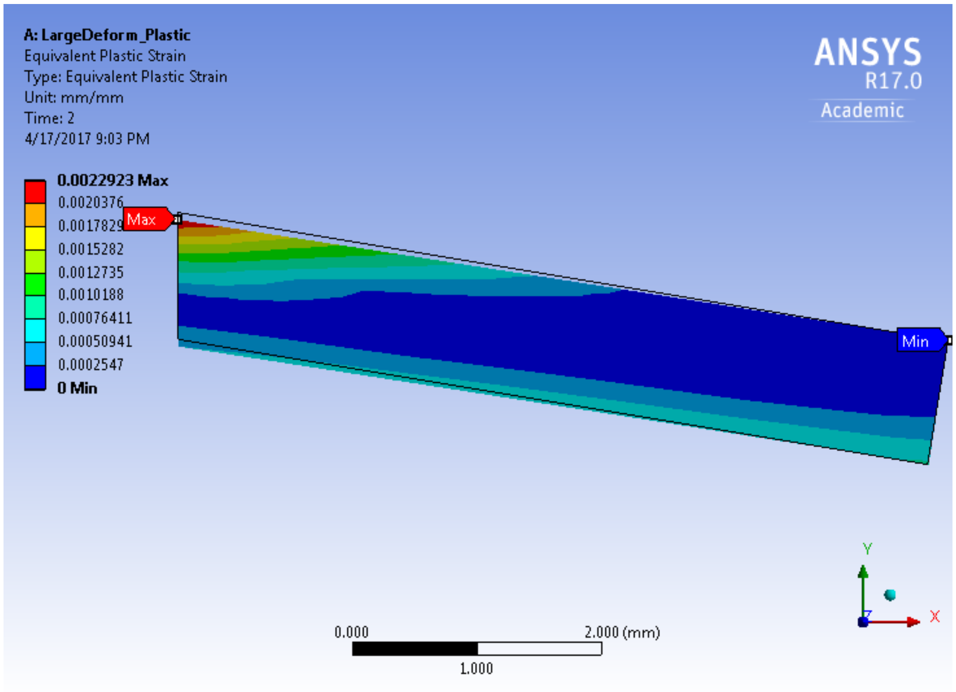

Figure A.9: Large Deformation, elastic-plastic- Equivalent Plastic Strain (t=2 s)