24-650 Applied Finite Element Analysis
Homework No 8
Wrench Design and Nonlinear Contact
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The objective of this assignment was to design a wrench that will torque a given bolt with a minimum factor of safety of 3 (using $\frac{1}{2}S_Y$=700 MPa as the allowable shear stress) when a maximum torque of 120 Nm is applied in a conservative manner.

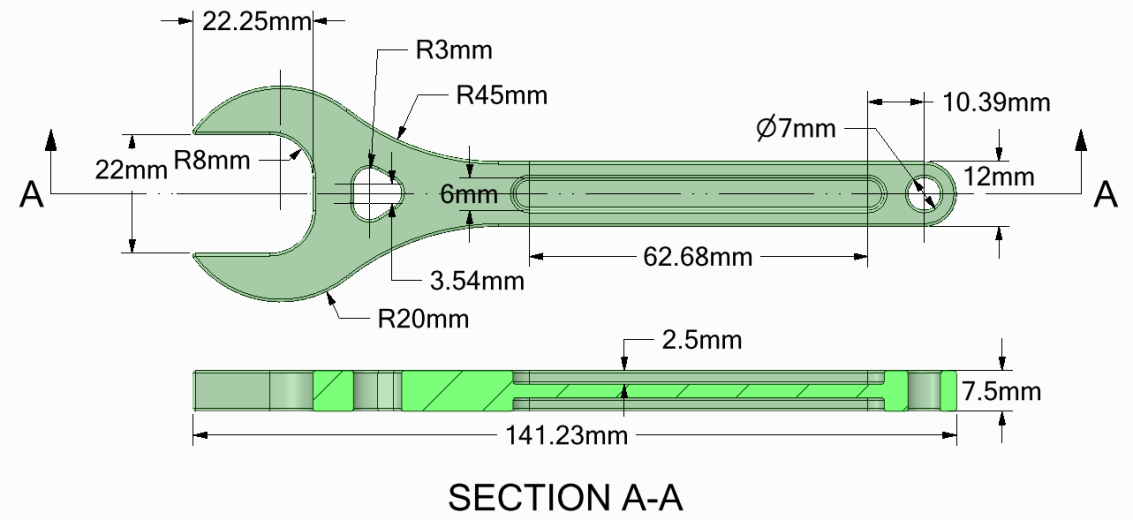

Figure 1: Wrench dimensions

1. Setup

The first step was to design the wrench in SpaceClaim and then import it to Ansys Mechanical in a Static Structural module. The design is shown in Figure 1. The material for the bolt and wrench is steel:

- E=205 GPa
- ν=0.29
- ρ=7,750 Kg/m^3

To check if the design has a minimum factor of safety of 3, a Static Structural simulation was done in Ansys. The features like holes and slots were added at the end to decrease the total weight. The setup is explained below

- The bolt is fully fixed in the area of its threads (shown in Figure A.1)
- The contact between the wrench and the bolt is a “Rough” frictional contact (shown in Figure A.3)
- A bearing load of 940.14 N was applied on the handle (shown in Figure A.1). This is equivalent to a 120 Nm torque applied to the bolt. The force was calculated using the distance between the axis of the bolt and the center of the hole on the handle as shown in Figure 2.

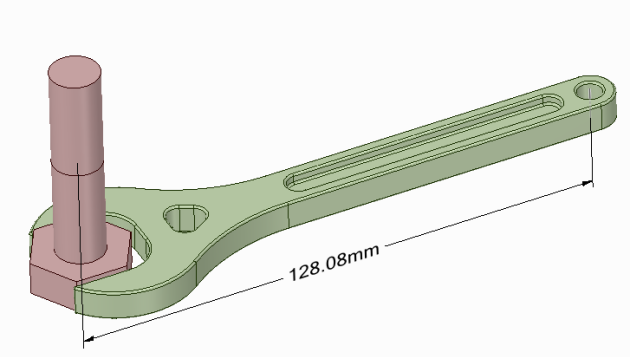

Figure 2: Force distance

The mesh used was a fine one. The mesh consisted of **20,400 nodes** and **11,120 elements**. This is shown in Figure A.2

2. Results and Analysis

After running the simulation, a converged solution was obtained (shown in Figure A.4). The results are presented below.

Peak Shear Stress	Minimum Factor of Safety	Weight
230.89 MPa (shown in Figure A.7 and Figure A.8)	3.0318 (shown in Figure A.5 and Figure A.6)	99.31 gr

Table 1: Results

The state of the contact is shown in Figure 4. It can be seen that most of the area is Near (yellow) and just at the end (where the bolt is being pressed by the wrench) the contact is Sliding and Sticking (orange and red). For both faces at the wrench the state is similar but opposite.

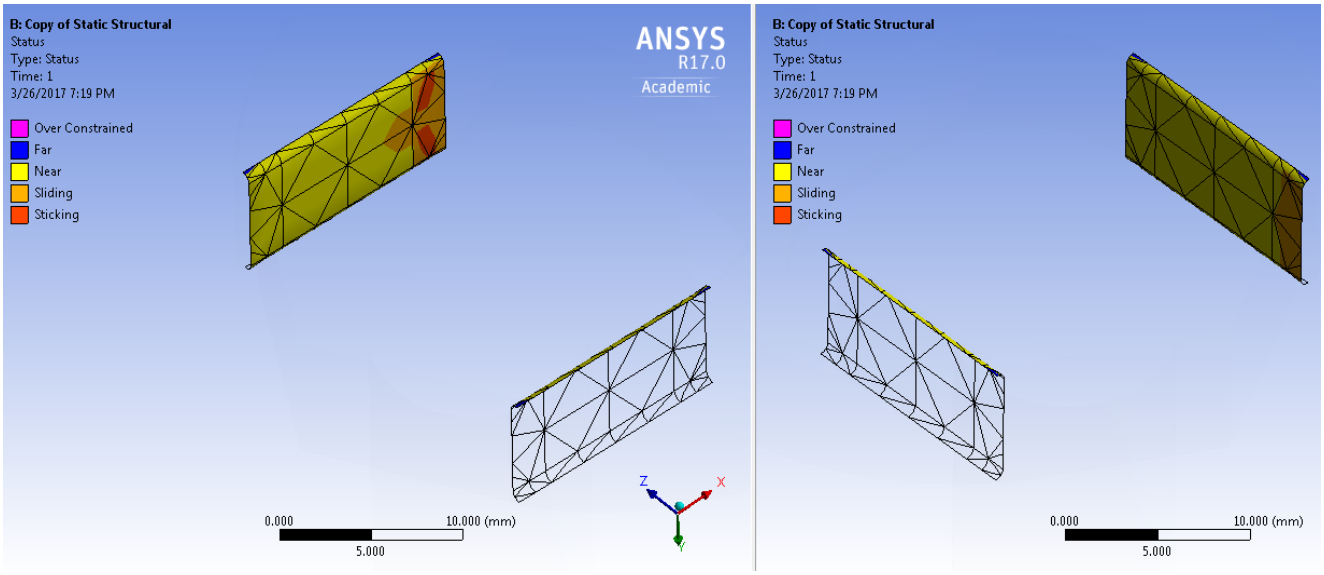

Figure 4: State of the contact

Besides the state of the contact, a total penetration figure is shown below. It can be seen that the max value is 0.00425 mm, which is negligible, so the contact is working properly and reducing the penetration between the surfaces.

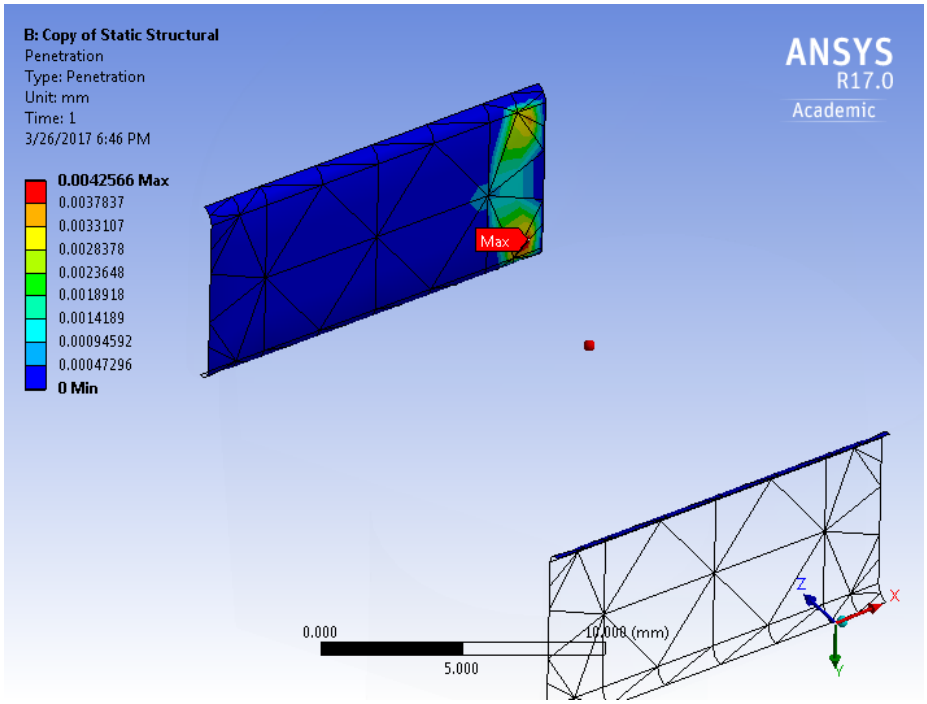

Figure 5: Penetration at the contact

3. Appendix

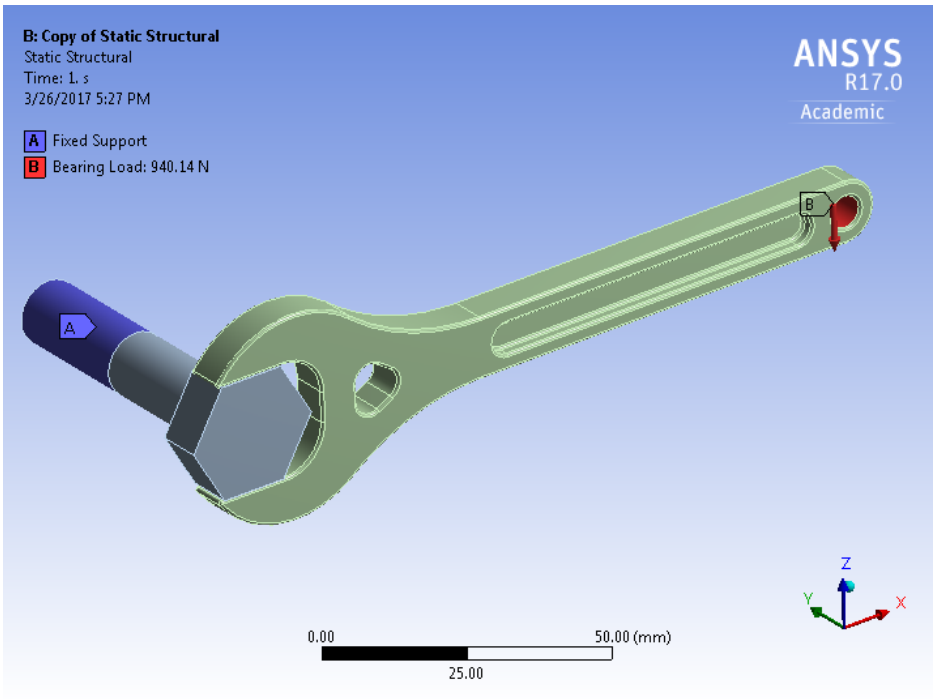

Figure A.1: Boundary Conditions

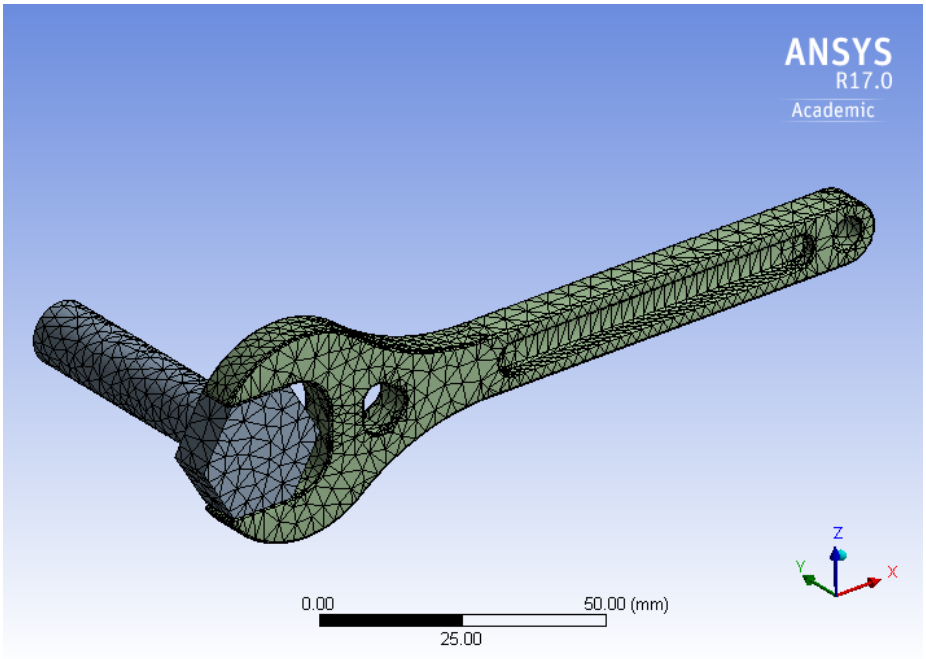

Figure A.2: Fine Mesh

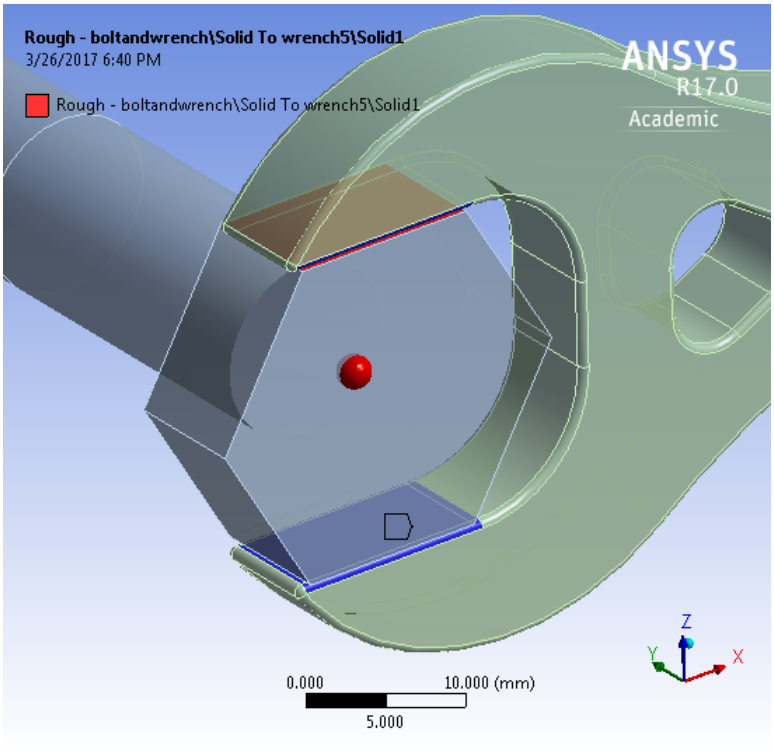

Figure A.3: Rough Frictional Contact.

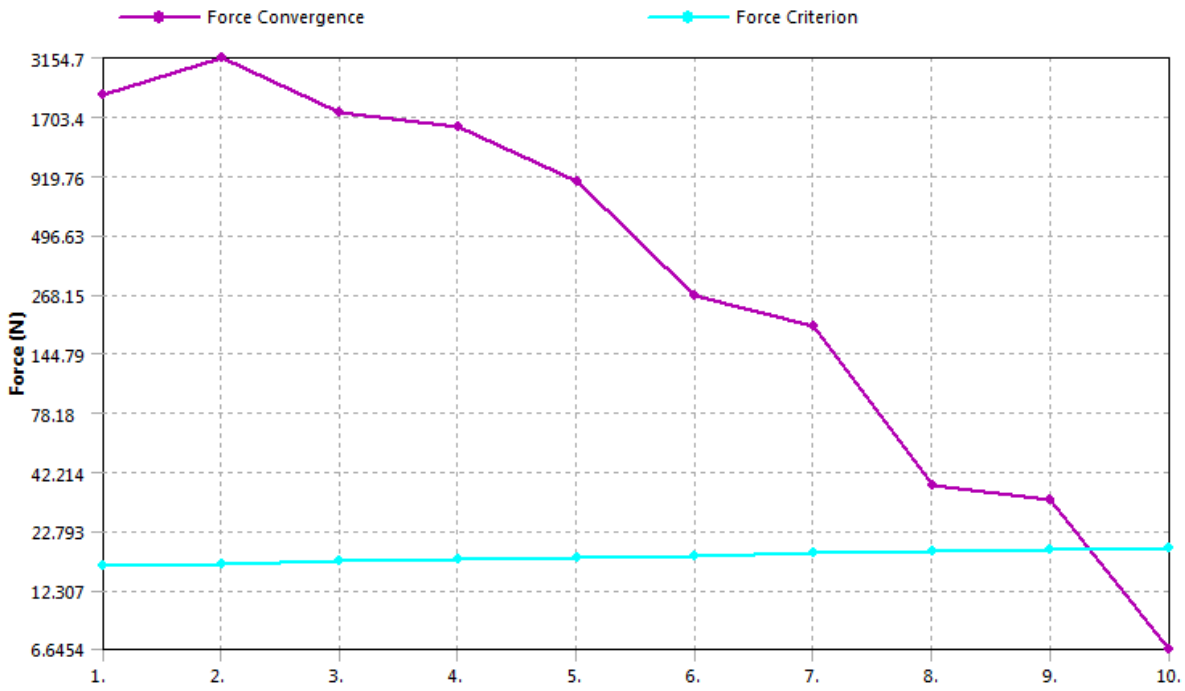

Figure A.4: Force Convergence

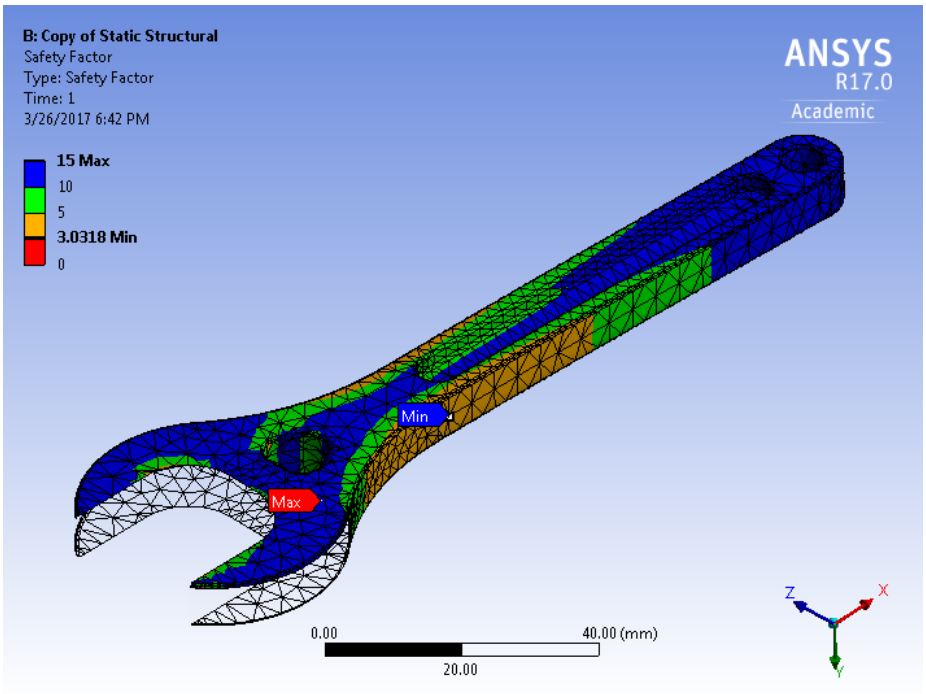

Figure A.5: Safety Factor (using Max Shear Stress)

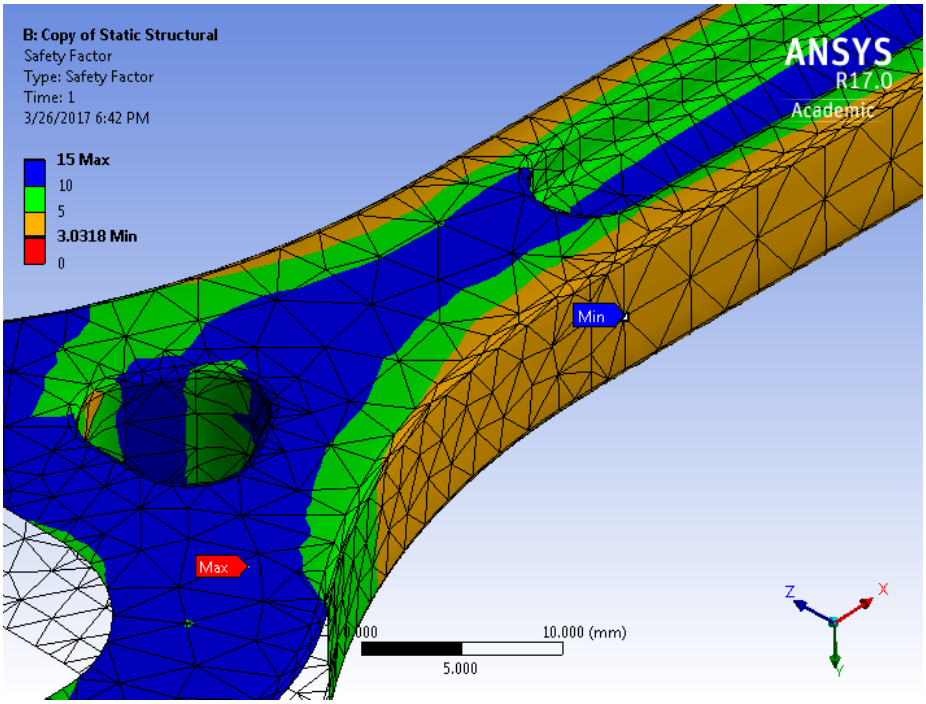

Figure A.6: Safety Factor, Zoom (using Max Shear Stress)

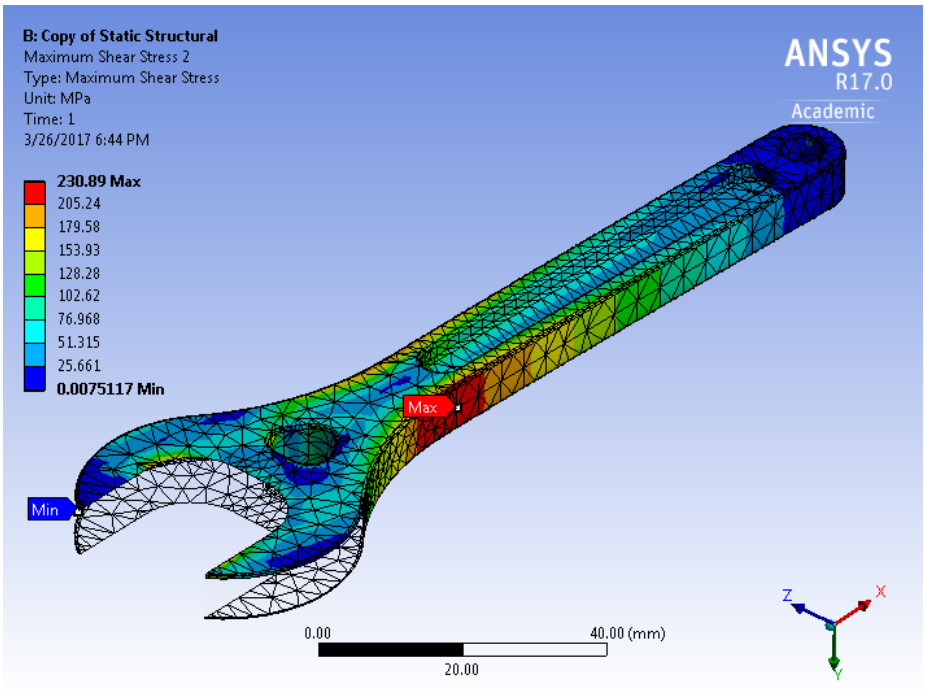

Figure A.7: Maximum Shear Stress

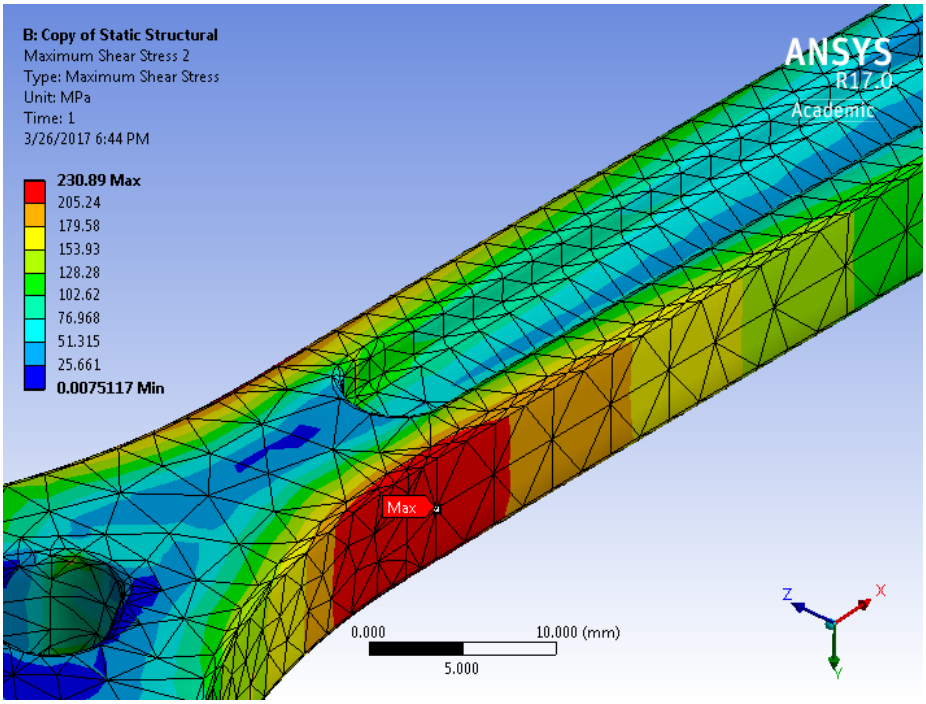

Figure A.8: Maximum Shear Stress, Zoom