Assignment 6 – Nonlinear Contact and Plasticity of a 4-Point Bend Specimen

The 4-point bend specimen configuration and dimensions are shown in Figure 1. The specimen is notched and made of a soft aluminum alloy: E = 67 GPa, ν = 0.33. Its yield strength, S_y, and ultimate strength, S_u, are 220 MPa and 640 MPa, respectively. The support and load pins are made of machine steel: E = 205 GPa, ν = 0.29. All the pins are 100 mm in length, which means they are longer than the width of the specimen.

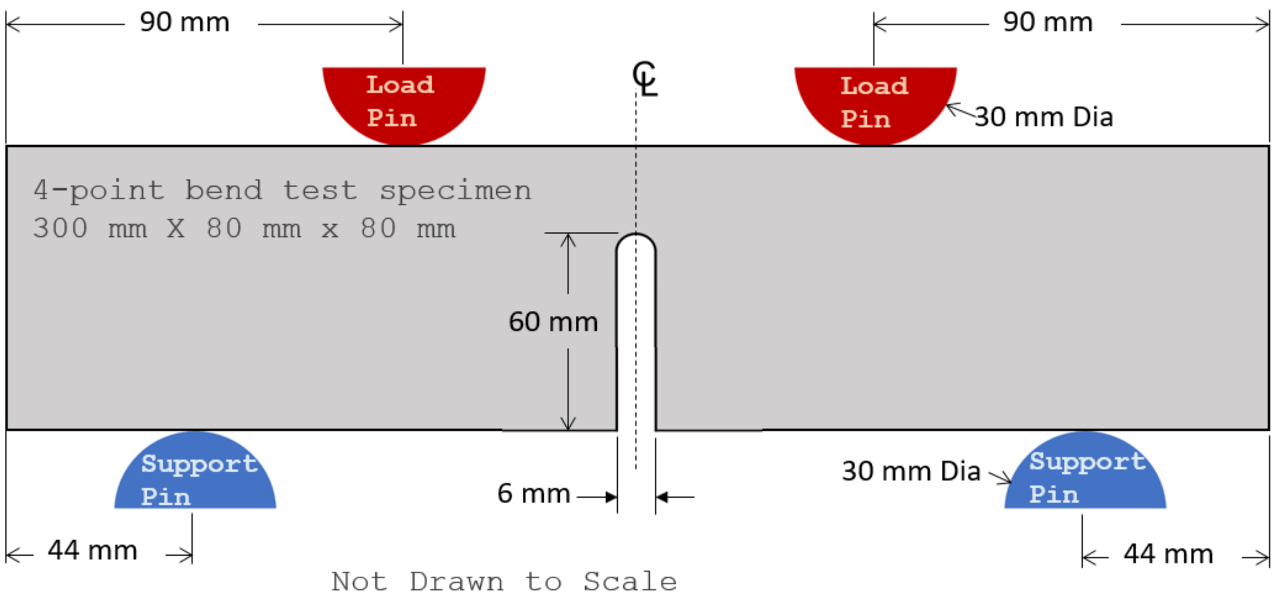

Figure 1

The goals of this assignment are to calculate factors of safety at the notch under a given load for both linear elastic and nonlinear elastic-plastic responses of the specimen. Irrespective of material behavior, the problem is patently nonlinear because of contact between the pins and specimen. It might also be geometric nonlinear if the deformations are significant.

Loads, BCs, and Contact Conditions

As shown in Figure 2, the support pins are fixed on their bottom surfaces. The load pins are constrained against in-plane motion and each load by an imposed deformation: Δ = 1mm. There are clearly 4 contact interfaces between the pins and the specimen. Assume "Frictional" behavior between all contact surfaces with a friction coefficient equal to 0.15.

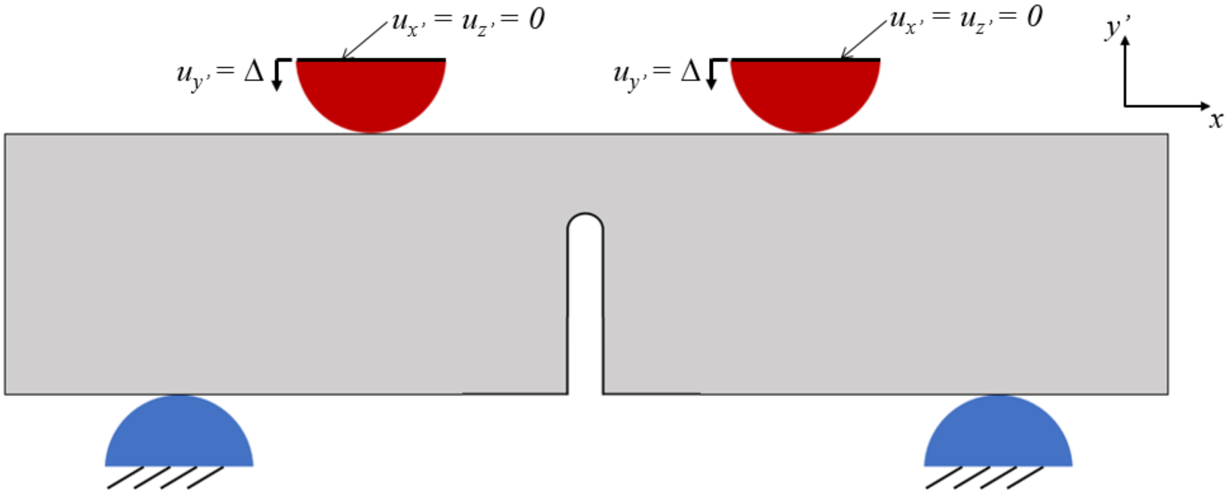

Figure 2

A. Elastic Material Response Analysis

Solve the problem as described above with loads and boundary conditions as shown in Figure 2 and for elastic response of the specimen. This is a nonlinear analysis because of contact. Slow, careful loading will be needed in order to get correct, converged results. Using the Stress Safety tool, calculate the factor of safety, FS_1, at the notch using the Max Tensile Stress theory with the yield strength as the limit stress. Also calculate the factor of safety, FS_2, at the notch using the Equivalent Stress theory with the yield strength as the limit stress value.

B. Elastic-Plastic Material Response Analysis

Again, solve the problem as described above with loads and boundary condition as shown in Figure 2, but this time for elastic-plastic response of the specimen. Use Bilinear Kinematic Hardening with a post yield tangent modulus, E_T, equal to 9.0 GPa. This is a nonlinear analysis because of contact and metal plasticity. Slow, careful loading will be needed to get correct, converged results. Using the Stress Safety tool, calculate the factor of safety, FS_3, at the notch using the Equivalent Stress theory with the ultimate strength as the limit stress value. You should scope the stress tool to only the specimen material. In other words, do not use the stress tool on the machine steel pins. Also report the maximum equivalent plastic strain at the specimen's notch.

Notes and Guidance

1) Write a summary report (no more than 5 pages in Word docx/pdf format, including a title page), showing your assumptions, your analysis approach, how you achieved convergence, your FS_1, FS_2, FS_3, and plastic strain results, and any necessary explanations and conclusions. You may attach extra graphical result displays to your report's appendix (strictly optional).

2) Recommendation: Take maximum advantage of symmetry.

3) Converged nonlinear results are expected. However, to minimize the computation effort, use a default mesh for all parts and set the mesh Refinement to level 2 on the curved surface of the notch. Refer to Figure 3.

4) Referring to lecture notes 19, explain what you did to correctly model contact and to understand and/or minimize over penetration.

5) Is large deformation (nonlinear geometry) analysis required?

6) Part of your grade will be based on your report and approach and part on the accuracy of your result.

7) At the front of your report indicate your results in the following manner. All numbers below are "made up."

Part A: FS_1 = 0.71, FS_2 = 2.10

Part B: FS_3 = 8.2, Max equivalent plastic strain = 0.0023 $^{mm}/_{mm}$

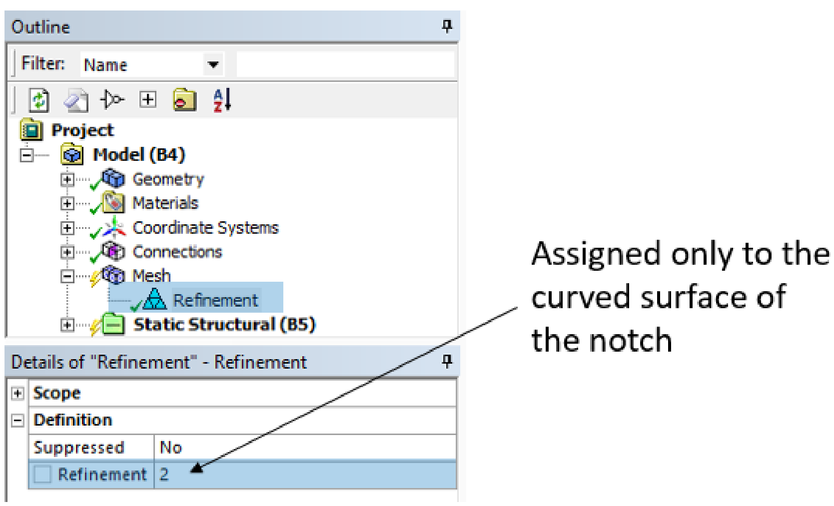

Figure 3