Universitat Politecnica de Catalunya
Master in Computational Mechanics CIMNE

Computational Mechanics Tools

Homework 4 – Non-Linearity

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Contents

Details :

In this assignment, we have to perform the stress analysis of some objects on a simulation software and observe and comment on the results obtained from the analysis. This assignment deals with 2 problems to be performed.

Problem 1:

Here, we have to calculate stresses on a steel plate with a hole, which is submitted to axial tensile force. The analysis of the steel plate has been done on ABAQUS CAE. A tutorial has been provided for performing the analysis and following the tutorial the following tasks are to be done.

Task 1: Plot the distribution of Von Mises stresses in the plate.
Task 2: Plot the Force-displacement curve at the point-set.
Task 3: Add the following plastic properties and compare the results.

- Case A: Isotropic, perfectly plastic material, $f_y = 460$
- Case B: Plastic, Isotropic material,
  $f_y = 460$, Plastic Strain = 0, $f_{y2} = 520$, Plastic Strain = 0.005
- Case C: Plastic, Isotropic material,
  $f_y = 460$, Plastic Strain = 0, $f_{y2} = 520$, Plastic Strain = 0.002

Discuss the differences in the Force-displacement curve for the three different cases.

Problem 2:

In this question, we have to model the contact between a fixed pin and a plate, which is pulled at one of its end. The stress analysis is done on ABAQUS CAE only. For this question as well a tutorial has been provided and the following tasks are need to done.

Task 1: Plot the distribution of Von Mises stresses on the deformed shape with an amplification factor of 10. Set scale of stresses between 0 - 460 MPa and make that stresses over this limit are plotted in dark red.
Task 2: Plot the Force-displacement curve for the horizontal reaction at the point-set.
Task 3: Add the following plastic properties to the two materials, one for the plate, and another one for the pin and compare the results with the elastic case.

- Case 1:
  Plate: - Isotropic material,
  $f_y = 460$, Poisson's Ratio = 0, $f_{y2} = 520$, Poisson's Ratio = 0.005
  Pin: - Plastic, Isotropic material,
  $f_y = 900$, Poisson's Ratio = 0, $f_{y2} = 1000$, Poisson's Ratio = 0.002
- Case 2:
  Plate: - Isotropic material,
  $f_y = 460$, Poisson's Ratio = 0, $f_{y2} = 520$, Poisson's Ratio = 0.005
  Pin: - Plastic, Isotropic material,
  $f_y = 320$, Poisson's Ratio = 0, $f_{y2} = 400$, Poisson's Ratio = 0.005

Problem 1 :

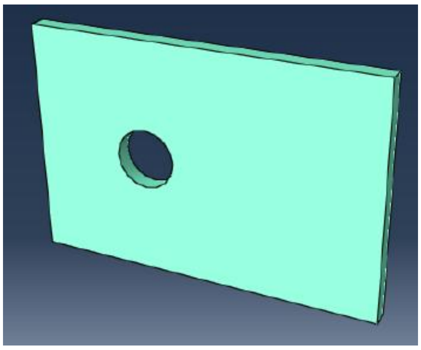
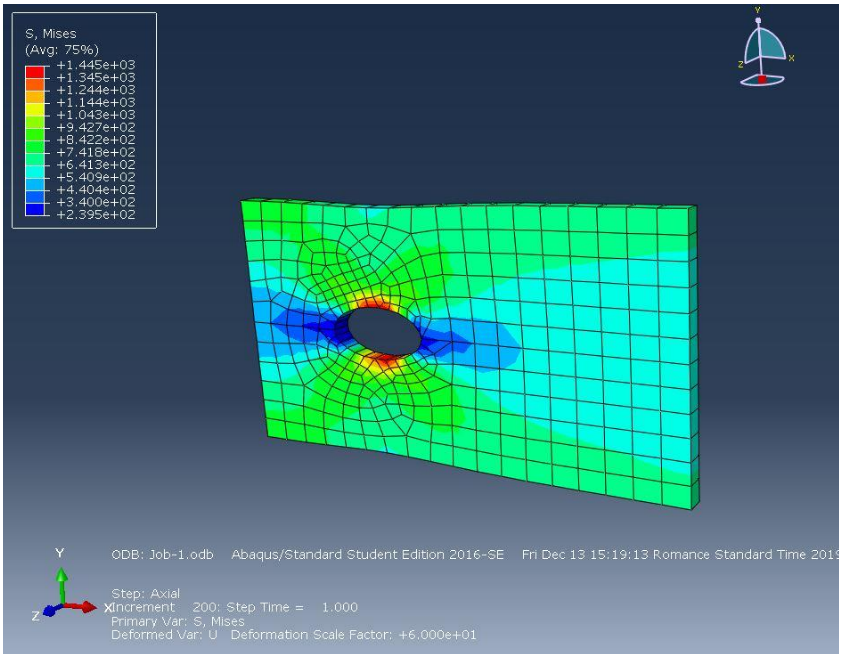


Plate with hole

Task 1:

The distribution of Von Mises stress on the plate with properties as mentioned in the tutorial is shown below.

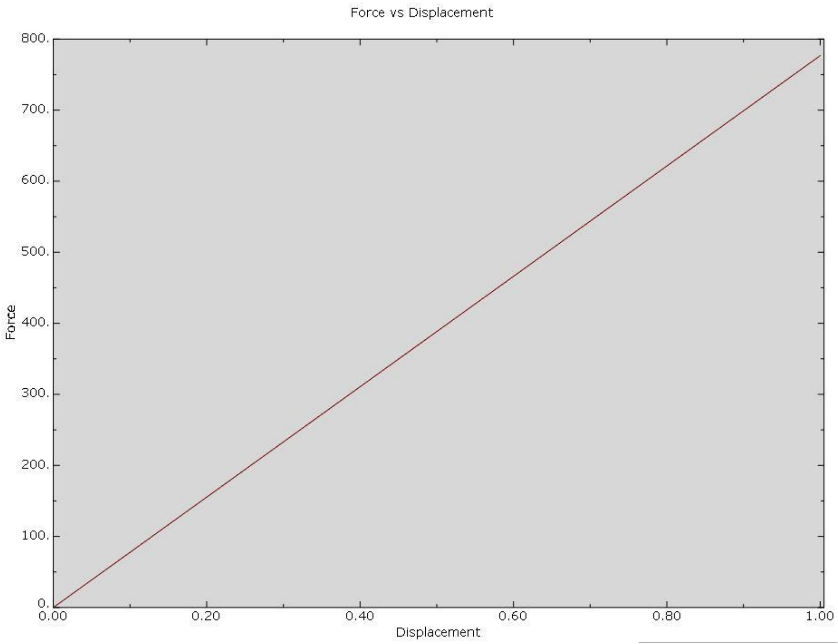


Von Mises stress distribution on plate with elastic properties

Stress concentration is observed around the hole. It is observed that the Von Mises stress ranges from 239.5 MPa to 1445 MPa throughout the plate. The yield limit of 460 MPa for the steel plate has been overpassed in the simulation.

Task 2:

The force - displacement plot for the elastic properties is a straight line showing linearity and no permanent deformation in the limits.



Force vs Displacement plot for Elastic properties

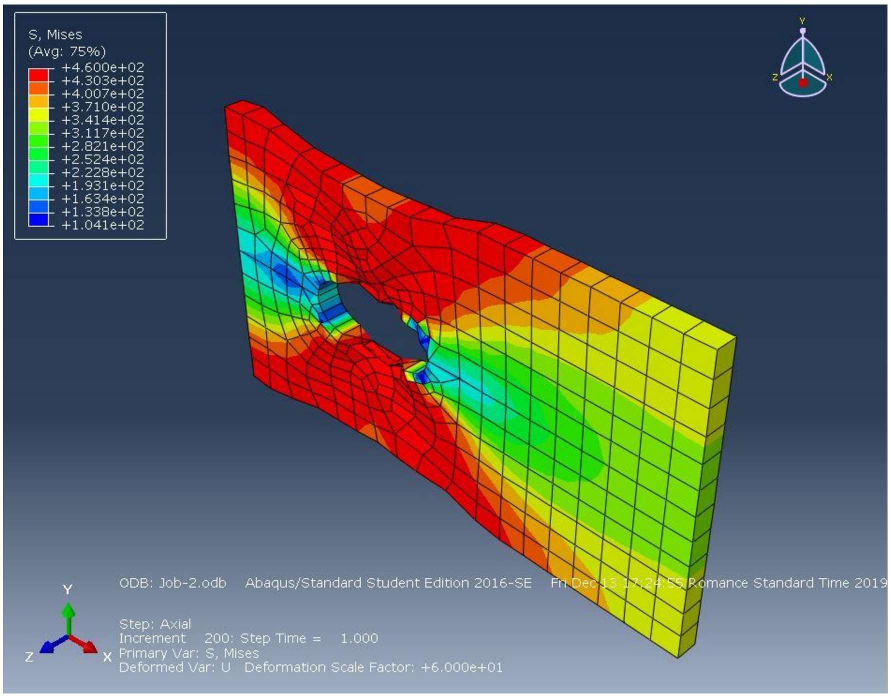
Task 3:

3 different cases are studied here by adding plastic properties.

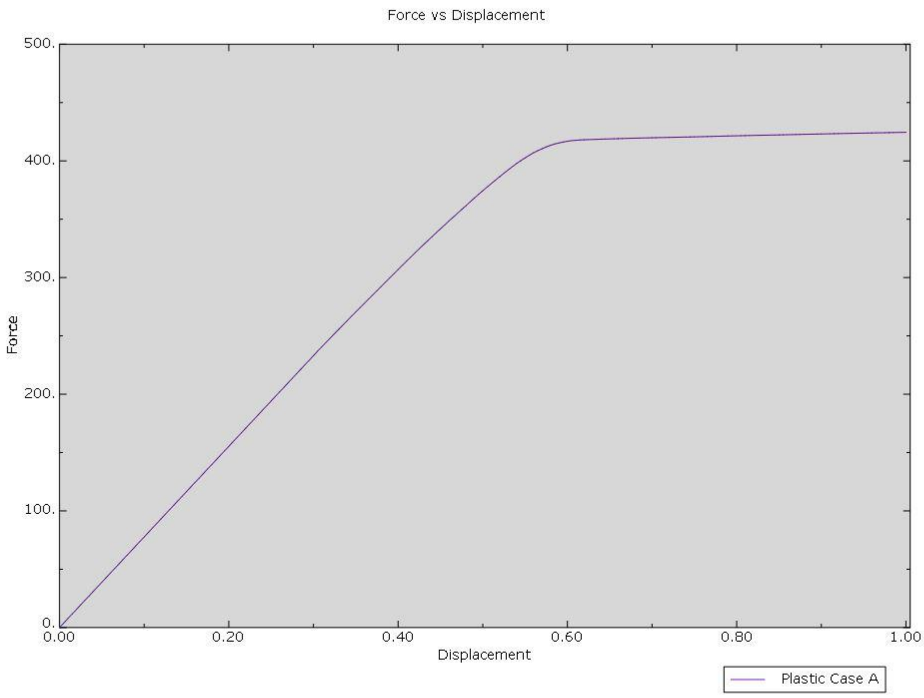
Case A:

Isotropic, perfectly plastic material

$f_y = 460$



Von Mises stress distribution for Plastic Case A



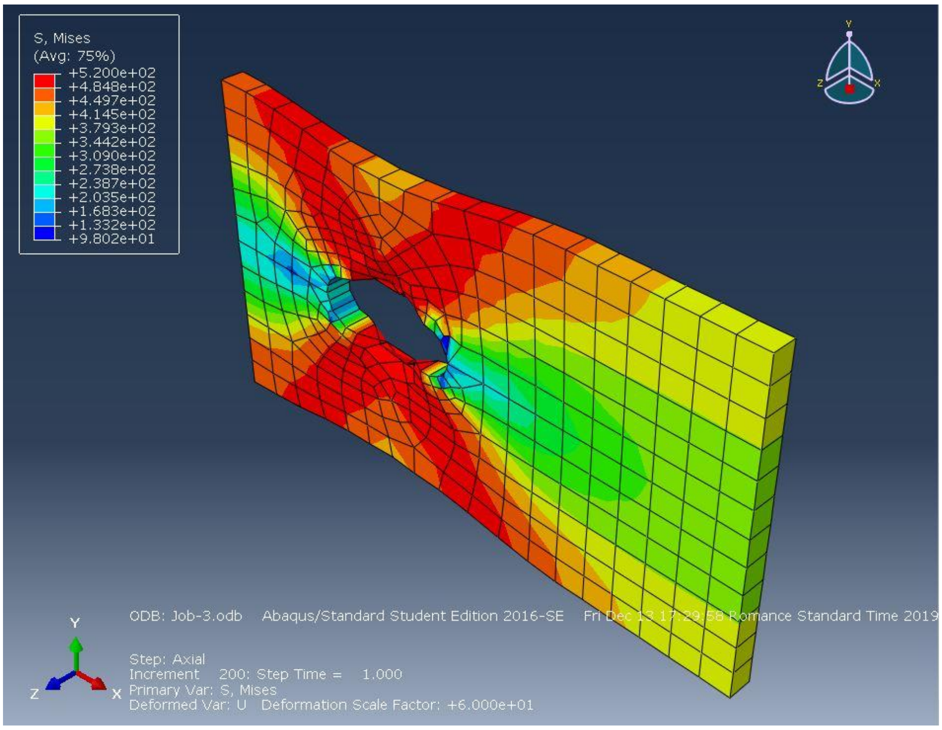
Force vs Displacement plot for Plastic Case A

Case B:

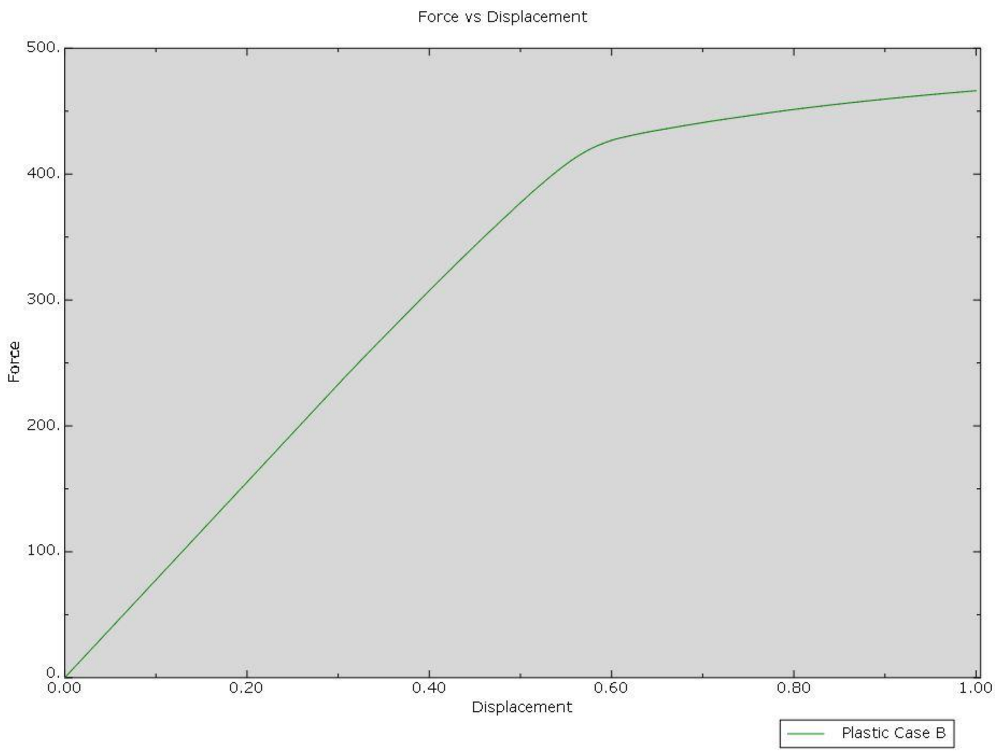
Plastic, Isotropic material,

$f_y = 460$, Plastic Strain = 0

$f_{y2} = 520$, Plastic Strain = 0.005



Von Mises stress distribution for Plastic Case B



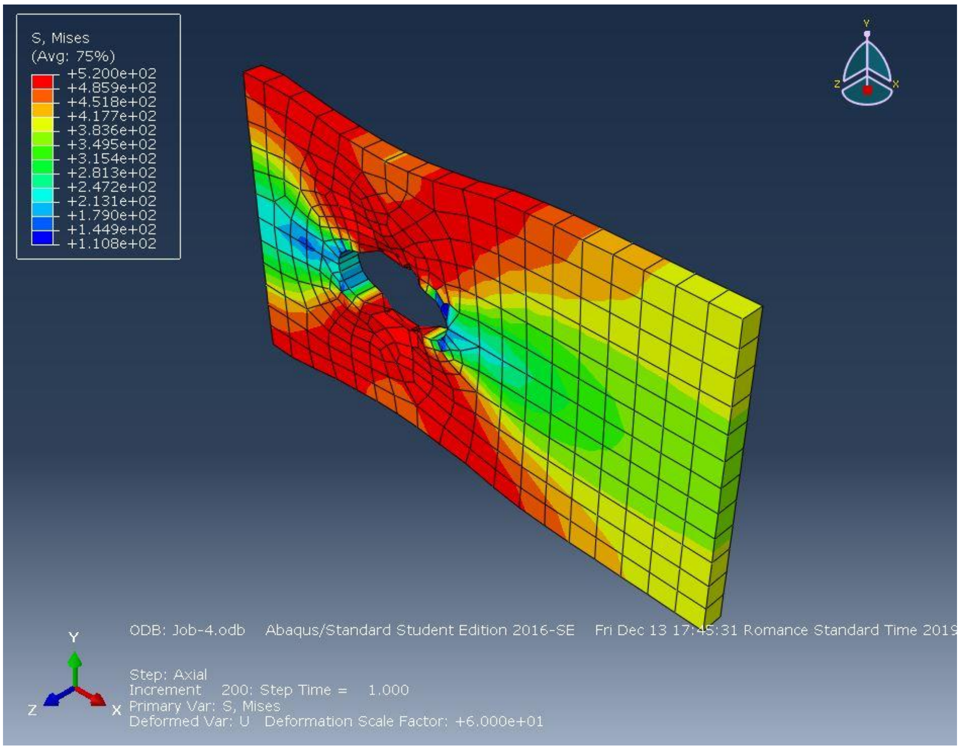
Force vs Displacement plot for Plastic Case B

Case C:

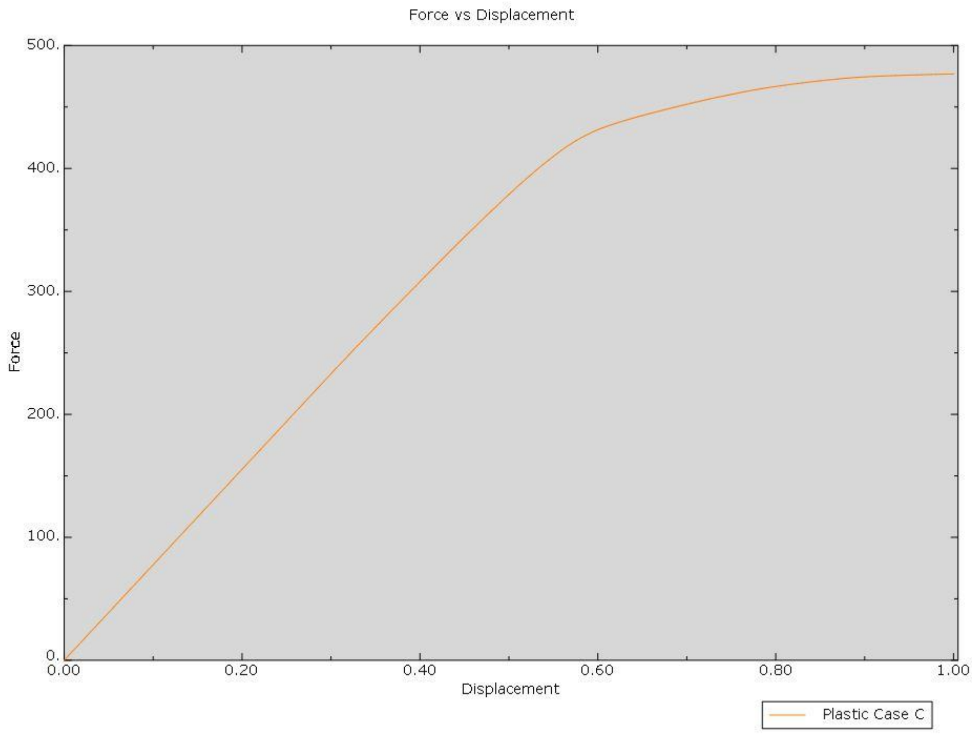
Plastic, Isotropic material,

$f_y = 460$, Plastic Strain = 0

$f_{y2} = 520$, Plastic Strain = 0.002



Von Mises stress distribution for Plastic Case C

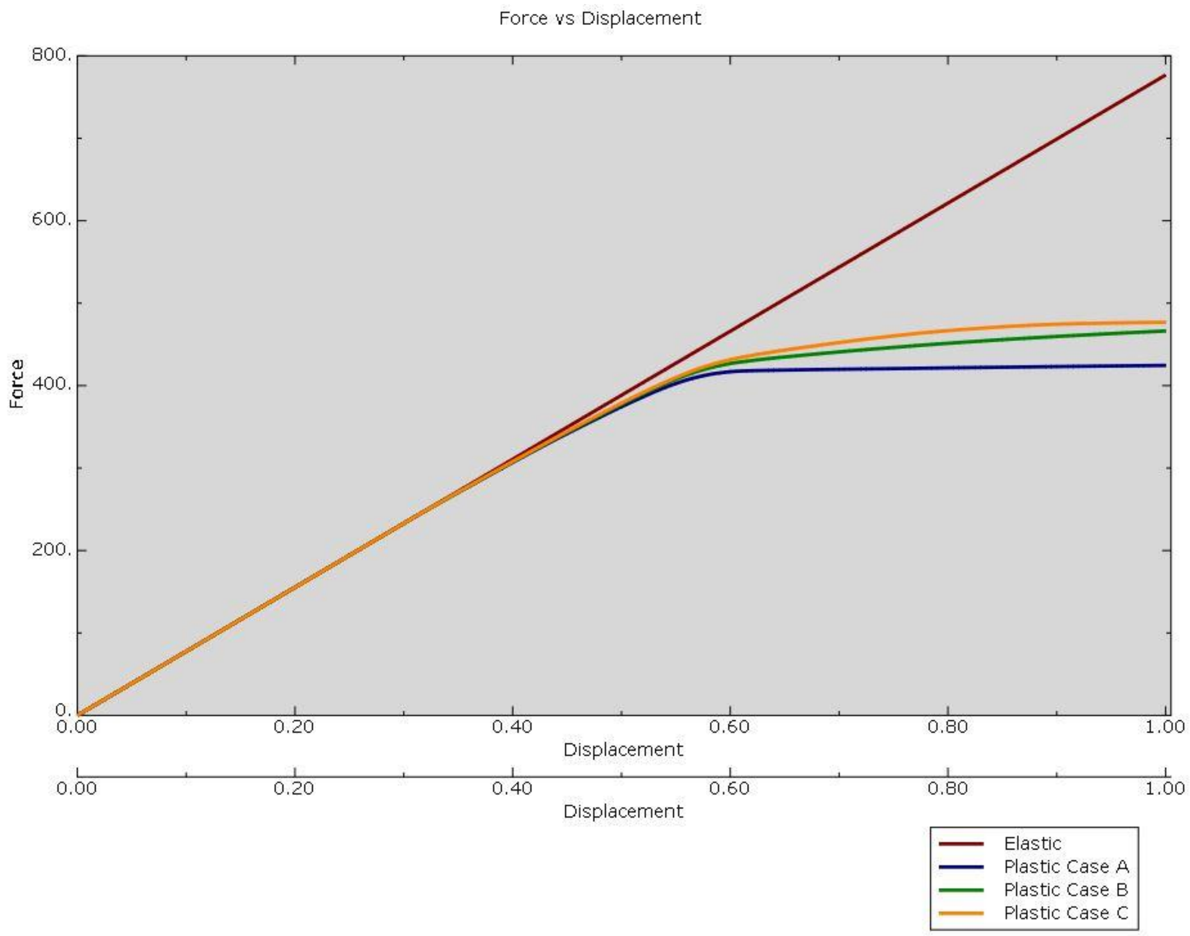


Force vs Displacement plot for Plastic Case C

Comparison of all graphs:

Elastic modulus used in analysis for initial results helped to solve the problem in a single iteration. But this linear assumption becomes weak as the material undergoes permanent deformation. Permanent deformations occur when the Von Mises stress exceeds the Yield stress, and this results in significant plastic or permanent strains. In the analysis of the elastic case, the Yield stress was exceeded by the results. Due to this, it was important to carry out non-linear analysis of the problem as well. In a perfectly plastic model, the yield stress remains constant after the initial yield.

In the graphs shown below, linearity is not achieved when the material is changed from elastic to plastic. Before the Yield stress is reached all the graphs show similar behaviour. The "Elastic" case shows perfectly linear graph. The graph of "Plastic Case A", which is a perfectly plastic case, shows almost horizontal behaviour after yielding as the strain is zero. The "Plastic Case B" and "Plastic Case C" show little bit more slope than perfectly plastic case. Also, it is observed that the reaction force of "Plastic Case C" is the highest and the "Plastic Case A" is lowest, in the plastic material curves.



Force vs Displacement plot for all cases

Problem 2 :

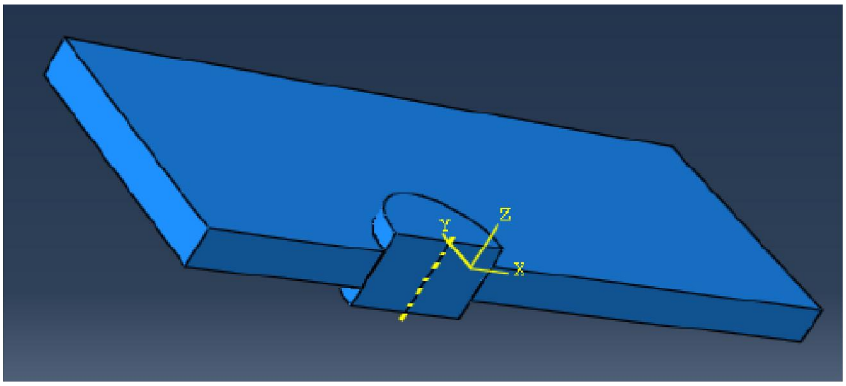
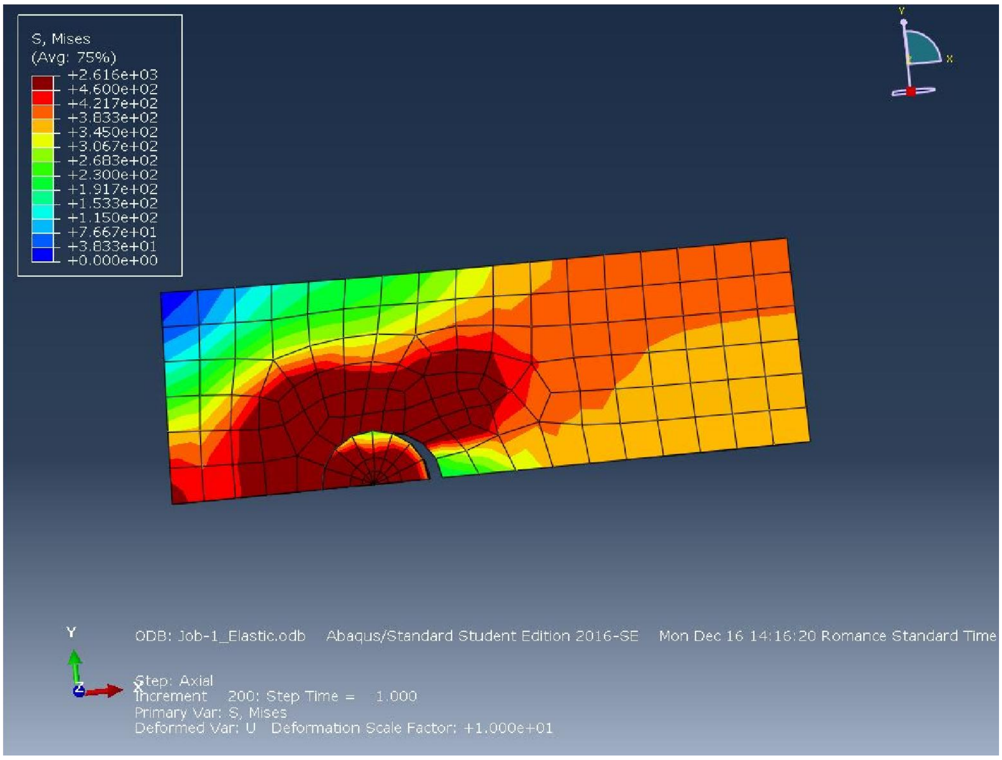


Plate with a fixed pin

Task 1:

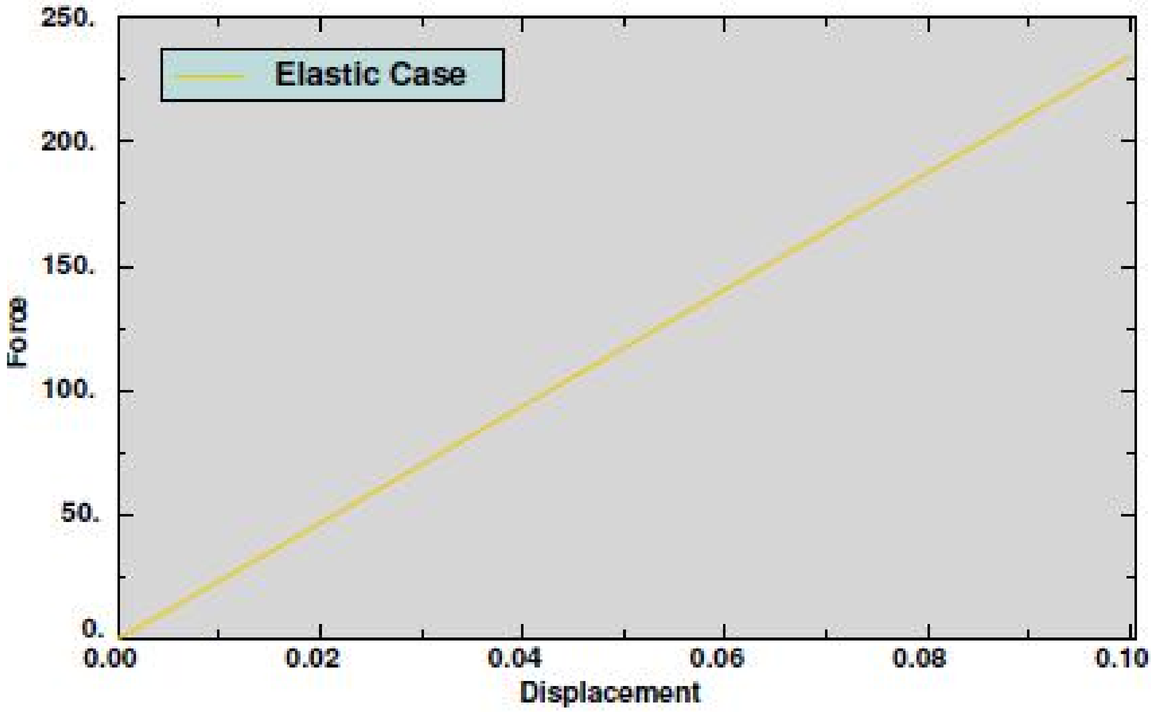
The distribution of Von Mises stress on the assembly as per the properties and constraints mentioned in the tutorial is shown below. The amplification factor is also changed to a uniform value of 10. The scale of the Von Mises stress is set between 0 - 460 *MPa* and the stresses over the maximum limit is plotted in dark red.



Von Mises stress distribution for elastic properties

Task 2:

The Force-displacement curve for the horizontal reaction at the point-set is shown below.

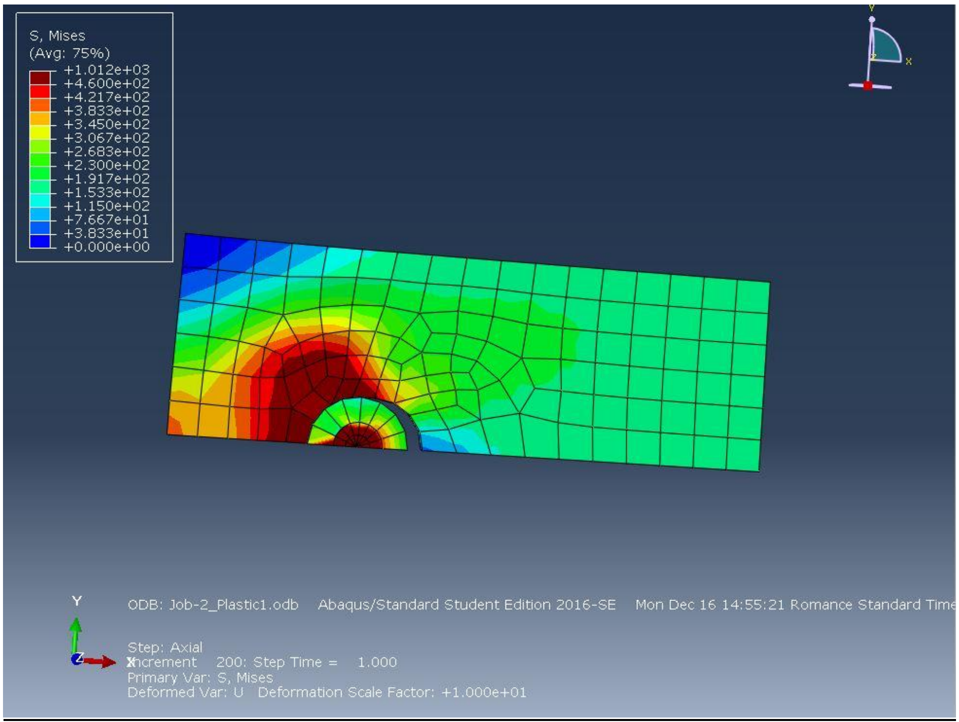


Force vs Displacement plot for Elastic Case

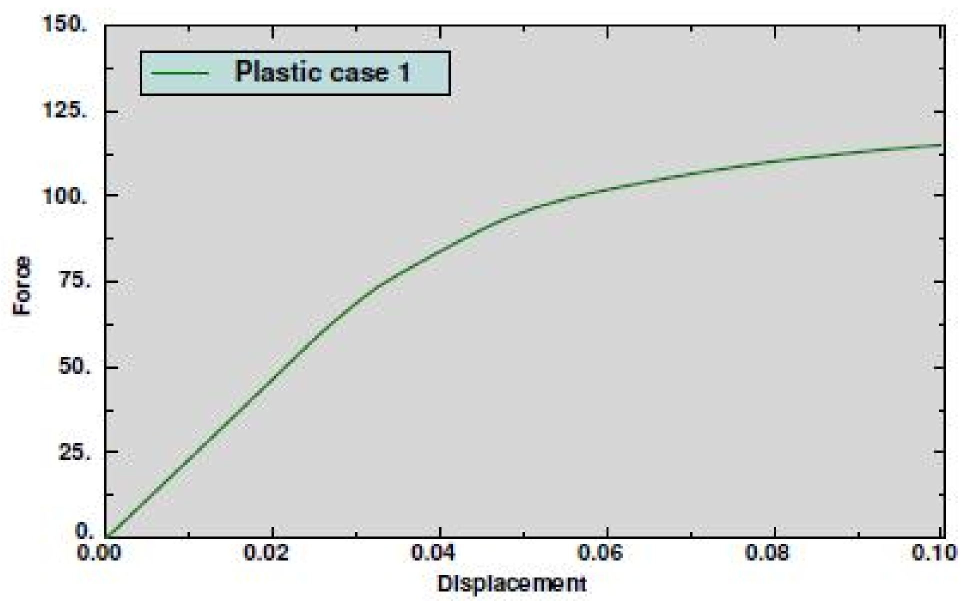
<u>Task 3</u>:
2 cases are studies here by adding plastic properties to the plate and the pin.

Case 1:
The following properties are added to the plate and the pin.
Plate: - Isotropic material,
$f_y = 460$, Poisson's Ratio = 0
$f_{y2} = 520$, Poisson's Ratio = 0.005

Pin: - Plastic, Isotropic material,
$f_y = 900$, Poisson's Ratio = 0
$f_{y2} = 1000$, Poisson's Ratio = 0.002



Von Mises stress distribution for Plastic Case 1



Force vs Displacement plot for Plastic Case 1

Case 2:

The following properties are added to the plate and the pin.

Plate: - Isotropic material,

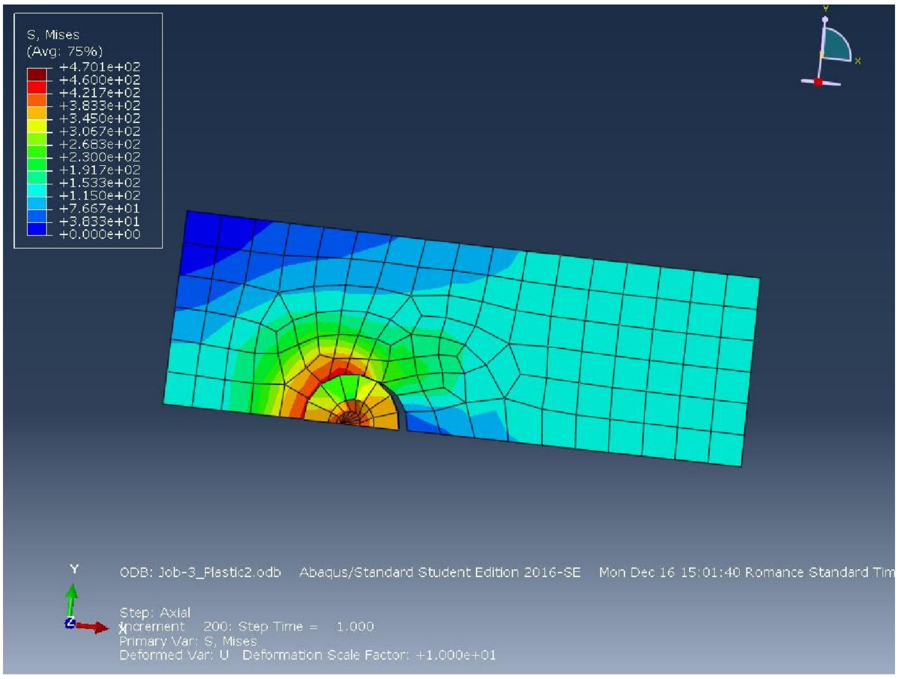
$f_y = 460$, Poisson's Ratio = 0

$f_{y2} = 520$, Poisson's Ratio = 0.005

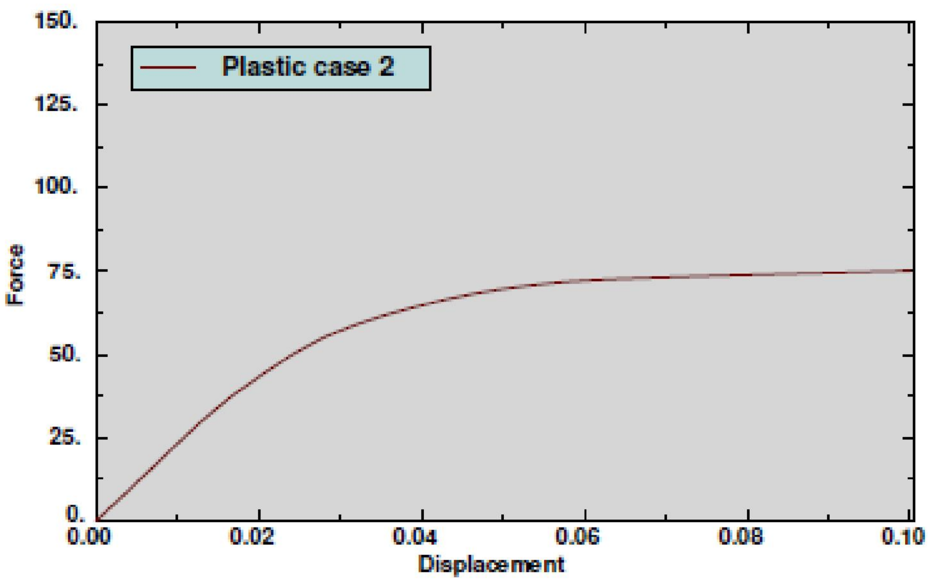
Pin: - Plastic, Isotropic material,

$f_y = 320$, Poisson's Ratio = 0

$f_{y2} = 400$, Poisson's Ratio = 0.005



Von Mises stress distribution for Plastic Case 2



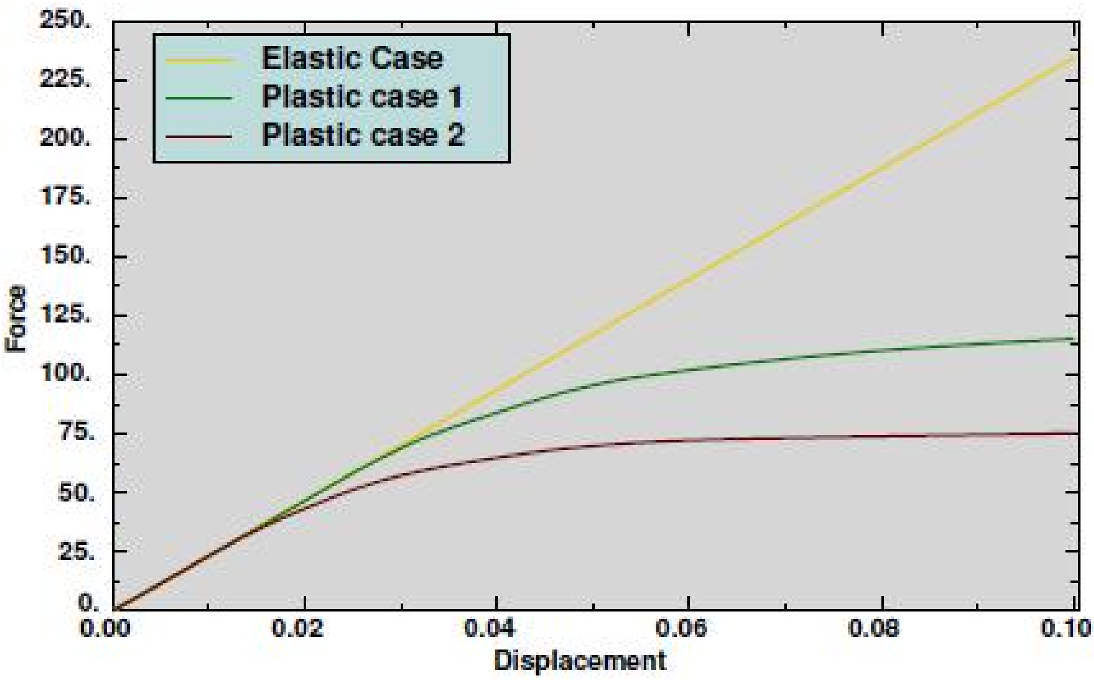
Force vs Displacement plot for Plastic Case 2

Comparison of all graphs:

It is observed that the deformation takes place rapidly in the elastic case, giving very high value of Von Mises stresses compared to the plastic cases. The non-linearity of the graphs in plastic cases indicates the material yielding at that value and takes a permanent deformation. It is also important to note that by reducing the yield stress of the pin, the force required to generate the same displacement of the point-set on the plate is much lower.

Before the Yield stress is reached all the graphs show similar behaviour. The pin of “Plastic Case 2” yields before the other cases which results in this case having the lowest yield stress and lowest reaction force of all the cases. The results of “Plastic Case 1” are in between the other 2 cases. The “Elastic Case” by no doubt shows the highest stresses and hence indicates that non-linear analysis is to be performed.

If you observe the contour plots of “Plastic Case 1” and “Plastic Case 2”, it is seen that in “Plastic Case 1”, as the yielding stress of the pin is higher than that of the plate, the stress is larger than 460 MPa in the region surrounding the pin. But, in “Plastic Case 1”, the stresses in the region surrounding the pin are under 460 MPa as the pin yields before the stresses reach the value of 460 MPa and the deforms afterwards.



Force vs Displacement plot for all cases