Computational Mechanics Tools
Assignment 3: Nonlinearity
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Objective

In this assignment, it is desired to calculate stresses on a steel plate with a hole, which is then submitted to axial tensile force. The assignment will be carried out by means of some subcases within two general domains as described below.

Methodology

In order to do so, the steps required in AbaqusNonlinear.pdf will be followed. By doing this, it is first drawn the geometry domain. It is a 30x20x1,5 rectangle with a hole of diameter 5 at 10 distance from left vertical edge and 10 from horizontal edge. Partitions are also made as shown in the *figure 1*.

The material to be imposed will first be elastic with a 2,1e5 [N/mm²] Young Modulus and 0,25 Poisson ratio.

Two steps are assumed:

- Initial (by default).
- Axial: static, general (t=1s, max timesteps=10000, increments=0,005).

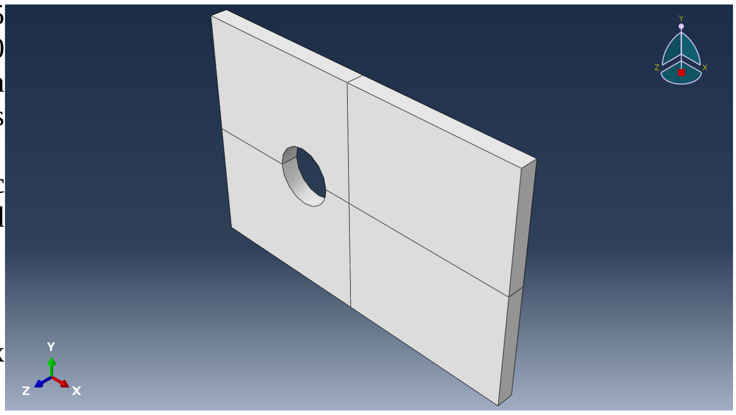

Figure 1. Geometry domain.

Boundary conditions:

- Fixed Y-Z (middle lines of vertical faces).
- Fixed X (vertical edges with ± 0,05mm).

For the meshing, 3D stress, with C3D8R (reduced integration) as element type, 1,75 of global size and 0,03 of curvature deviation factor.

The results will be set at the point located in the *figure 2*.

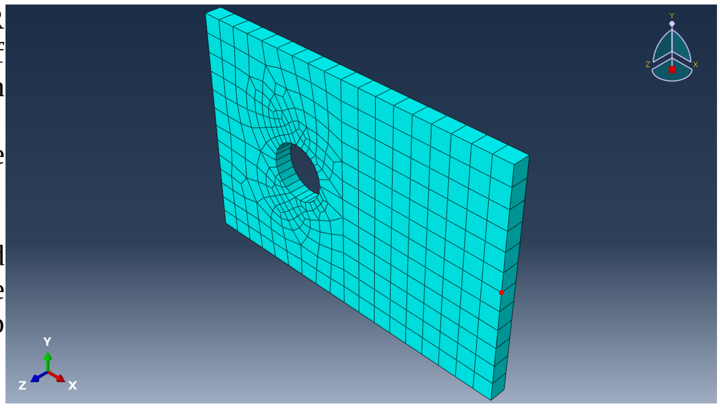

Figure 2. Mesh domain.

In order to carry out with the proposed questions, the comparison between some different materials needs to be done. The setup of this materials is:

Case a:

- Isotropic, perfectly plastic for fy=460 [N/mm²].

Case b:

- Isotropic, with:
  - fy1= 460 [N/mm²] Eps1(plastic strain)=0;
  - fy2= 520[N/mm²] Eps2=5e-03.

Case c:

- Isotropic, with:
  - fy1= 460 [N/mm²] Eps1(plastic strain)=0;
  - fy2= 520[N/mm²] Eps2=2e-03.

So as to give answer to the proposed questions, they are shown below:

Exercise 1:

i. Distribution of Von Mises stresses in the plate.
ii. F-t displacement curve at the point-set.
iii. Compare 3 different cases (a,b and c) in terms of F-t displacement curve.

Exercise 2:

i. Distribution of Von Mises stresses on the deformed shape with an amplification factor of 10.
ii. F-t displacement curve at the point-set.
iii. Compare 3 different cases (case 1, case 2 and elastic case).

Results and conclusions

The distribution of Von Mises is shown below. From the images, it is understood the locations where the plate may collapse first due to the applied loads and boundary conditions.

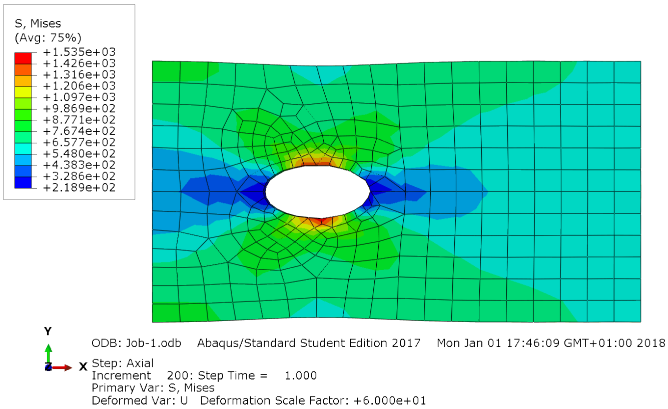

Figure 3. Von Mises plotting in deformed plate (elastic case).

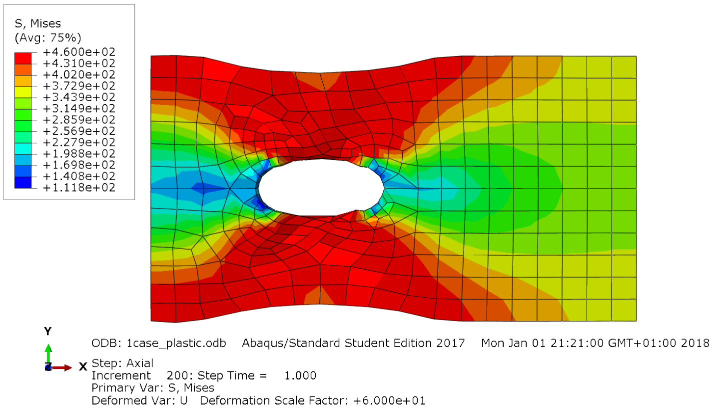

Figure 4. Von Mises plotting in deformed plate (case a).

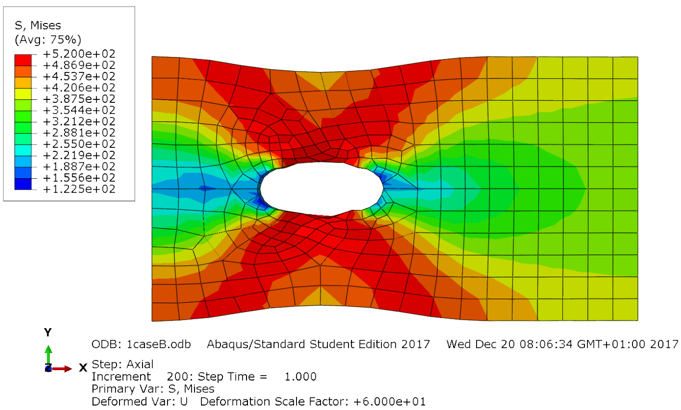

Figure 5. Von Mises plotting in deformed plate (case b).

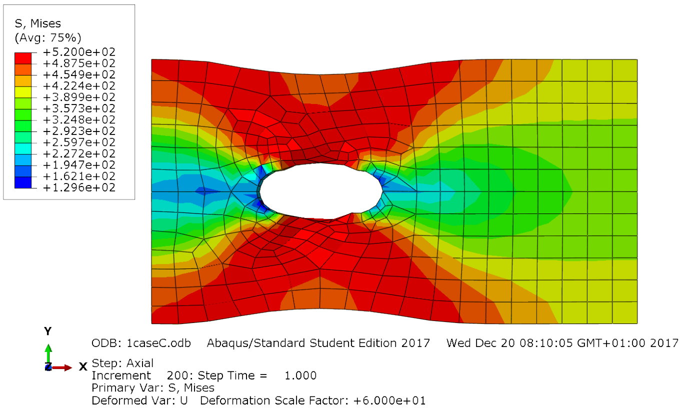

Figure 6. Von Mises plotting in deformed plate (case c).

The next diagram shows the linear behaviour of the plate under elastic conditions. This is the case in which elastic properties E=2,1e5 [N/mm²] and nu=0,25 are applied. The response of the system is proportional to the loads. As domain, boundary conditions and loads are symmetric, so is the solution.

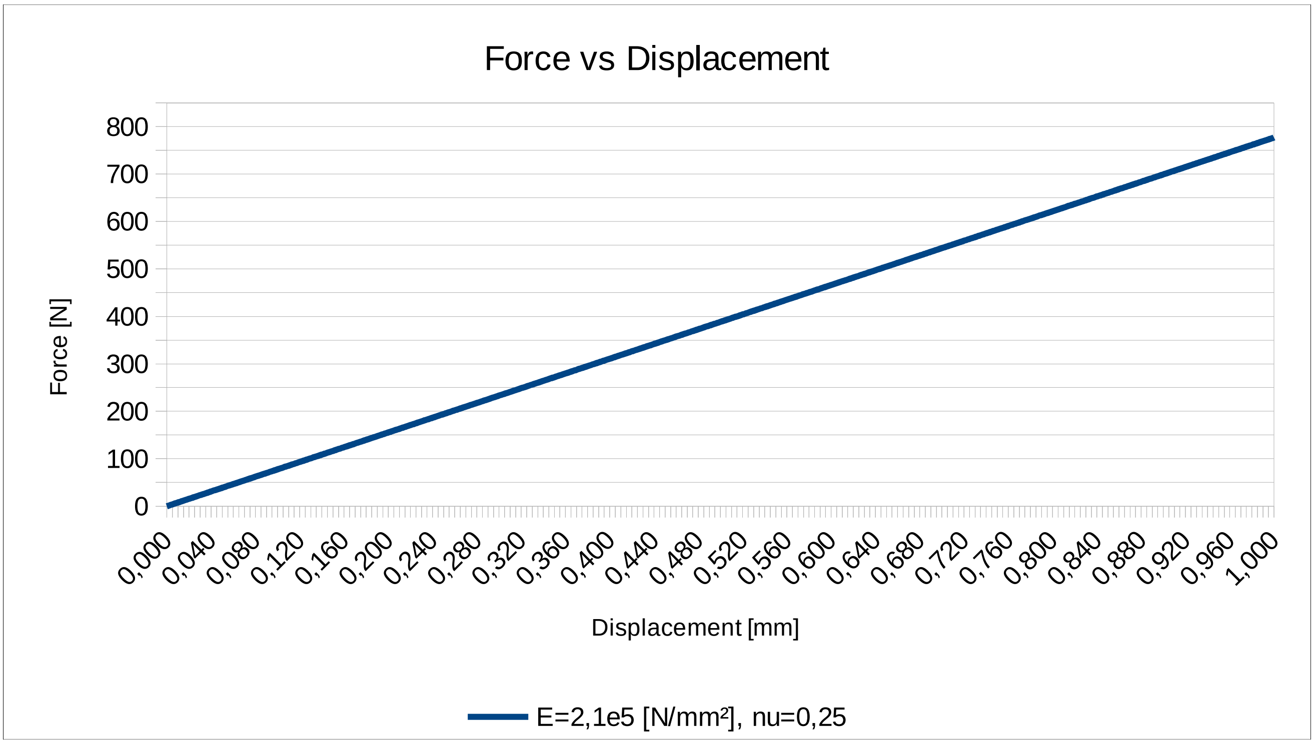

Figure 7. Force vs displacement diagram of perfectly elastic plate.

Then, by adding the forementioned plastic properties, the behaviour of the plate relates as follows. Figure 8 shows almost perfectly plastic behaviour since plastic strain is equal to 0. In cases b (fig. 9) and c (fig. 10), the slope when in plastic regime, shows pretty difference from perfectly plastic behaviour since in these cases plastic strain varies not too much from 0.

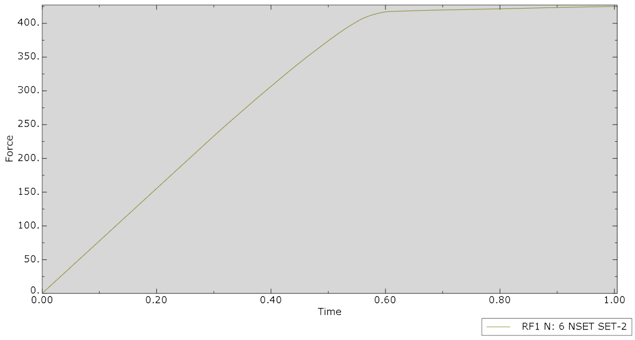

Figure 8. F-t diagram for Isotropic perfectly plastic (a).

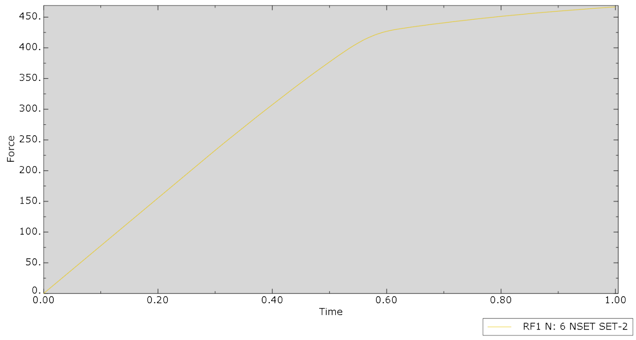

Figure 9. F-t diagram for fy1=460, eps1=0; fy2=520, eps2=5e-3 (b).

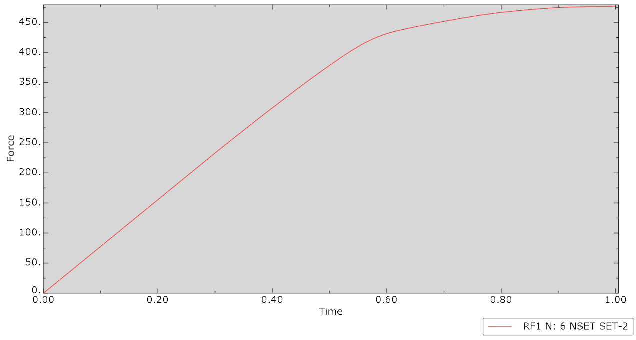

Figure 10. F-t diagram for fy1=460, eps1=0; fy2=520, eps2=2e-3 (c).

Plots all are shown in terms of time, but as it is seen, displacement behaves linearly with time. In order to get the plots in terms of displacement, the reescaling should be done considering the figure shown in the right hand side.

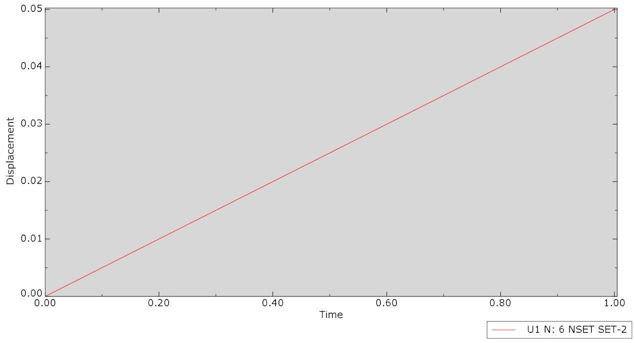

Figure 11. Displacement-time diagram.

The following diagram shows the comparison in behaviour of forementioned cases. It is appreciated that all of them behave similar when in elastic regime. However, in plastic regime, due to changes in plastic strain values, the slope, as this value gets closer to 0, so it does.

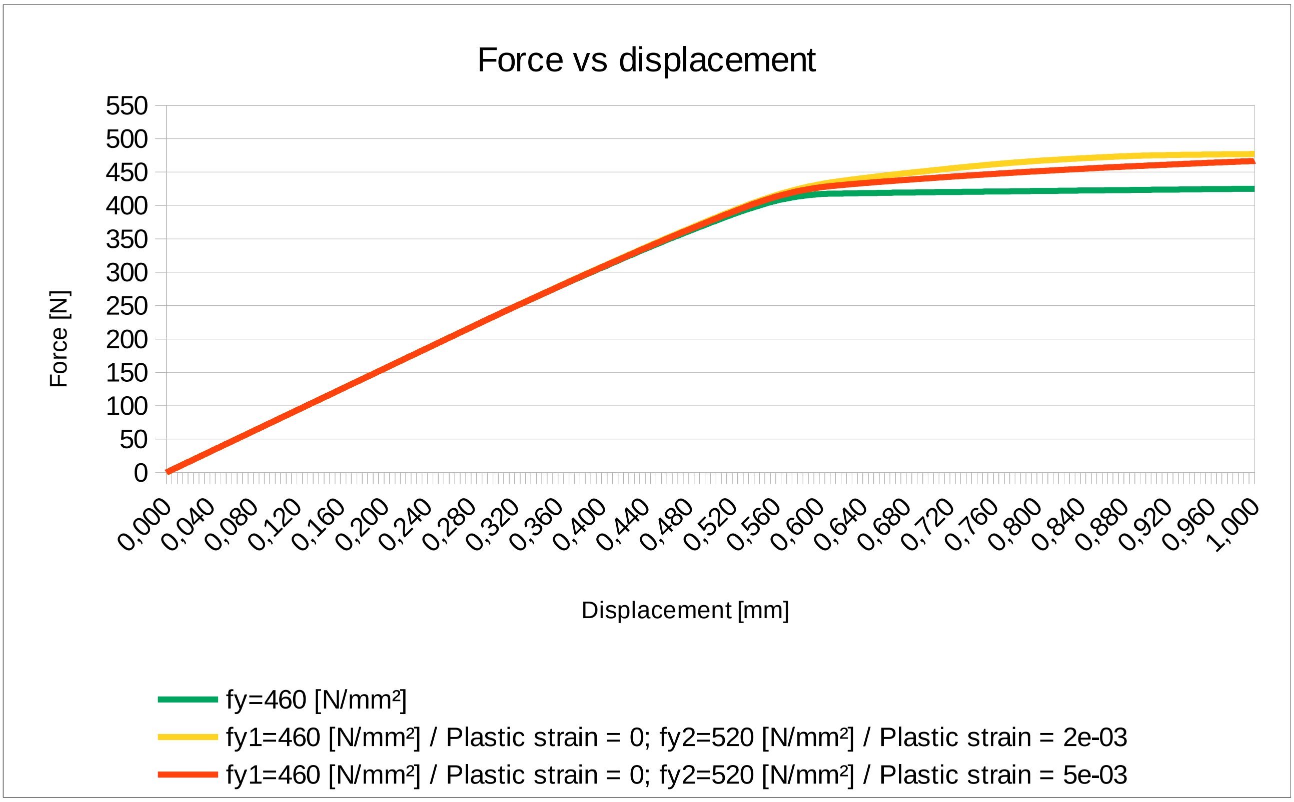

Figure 12. Force vs displacement comparison diagram for cases (a,b and c) .

Objective

For the second case, it is taken profit of half of the first case's geometry. The objective here is to model the contact between a fixed pin and the plate, which is pulled at one of its ends.

For the pin, it is created a new part, 3D deformable solid, revolution (2,5x3 at 180º).

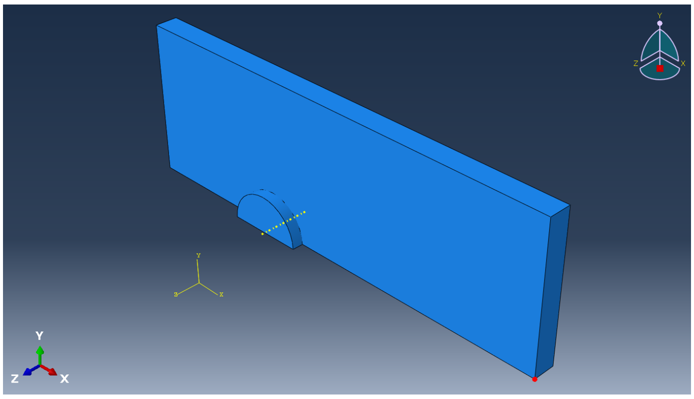

Figure 13. Geometry domain assembly (pin and plate).

Two materials are considered, one for the plate and another one for the pin.

Plate:

Elastic. E=2,1e05 [N/mm²], nu=0,25.

Pin:

Elastic. E=2,1e05 [N/mm²], nu=0,25.

Two steps:

- Initial (by default).
- Axial: Static, general(t=1s, max timesteps=10000, increments=0,005). Geometric nonlinearity: on.

Contact definition (initial step)

Mechanical, tangential behaviour (penalty), friction coefficient = 0,05.

Boundary conditions (second step):

- BC1: Displacement: fixed U1 at central axis of the pin.
- BC2: U1 = 0,1 mm at right face of the plate.
- BC3:
  - Symmetry BC at longitudinal face.
  - U2= 0 and U3 = 0 at longitudinal face.

On the meshing part, for the plate, it is assumed 3D stress, C3D8R (reduced integration) as element type. The global element size is 1,75 with 0,05 as curve deviation factor. The used meshing technique is Hex, sweep.

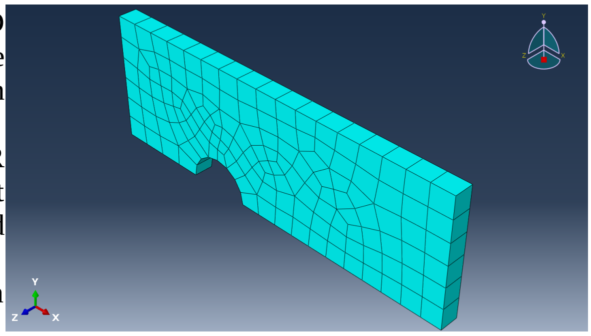

Figure 14. Mesh of the plate.

Whilst, for the pin part, it is assumed 3D stress, C3D8R (reduced integration) as element type. The global element size is 1,00 with 0,05 as curve deviation factor. The used meshing technique is Hex-dominated, sweep.

The calculations are performed in the set point shown in *figure 13*.

For the results, the obtained data will be plotted with an amplification factor = 10. Moreover, the scale of stresses is within the limit 0-460 MPa.

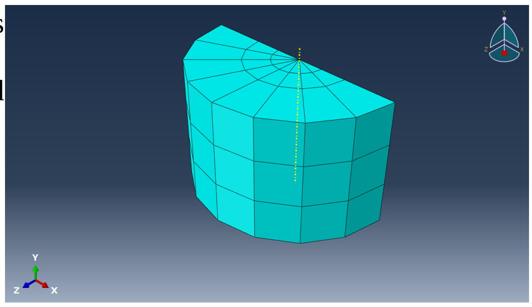

Figure 15. Mesh of the pin.

The remaining calculations so as to answer at the proposed questions are performed with the following data:

- Plate:
  - Isotropic, with:
    - fy1=460 [N/mm²] Eps1(plastic strain)=0;
    - fy2= 520[N/mm²] Eps2=5e-03.
- Pin:
  - Case 1:
    - Plastic, Isotropic, fy1=900 [N/mm²] Eps1(plastic strain)=0;
    - fy2=1000 [N/mm²] Eps2=2e-03.
  - Case 2:
    - Plastic, Isotropic, fy1=320 [N/mm²] Eps1(plastic strain)=0;
    - fy2=400 [N/mm²] Eps2=5e-03.

Results and conclusions

The following map shows the distribution of Von Mises on the deformed shape with an amplification factor of 10. Stresses over 460Mpa are plotted in brown. It is clearly seen the interaction between the pin and the plate and the displacement of the latter.

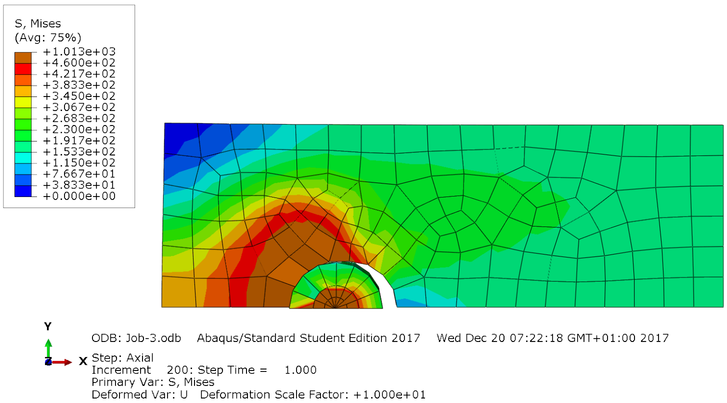

Figure 16. Von Mises plotting of deformed assembly (elastic case).

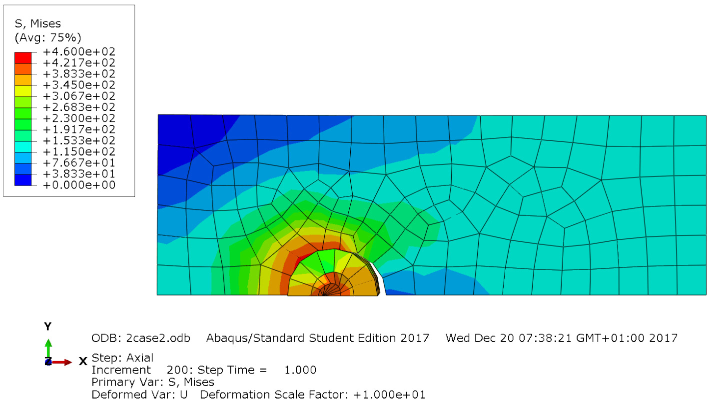

Figure 17. Von Mises plotting of deformed assembly (case 1).

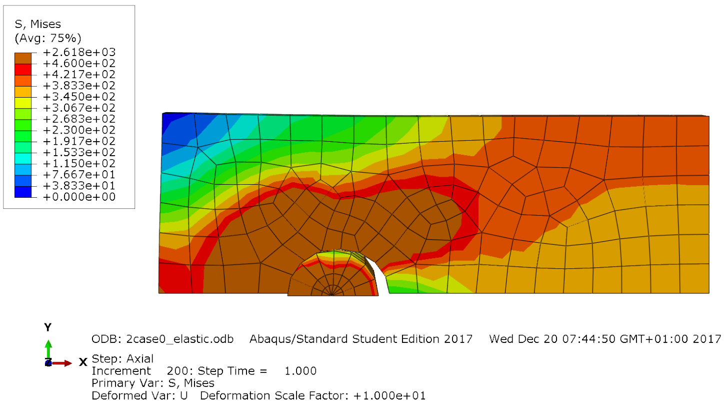

Figure 18. Von Mises plotting of deformed assembly (case 2).

The diagram shows the behaviour of the assembly (plate and pin) when applying different materials. As the material has just elastic constants, the assembly behaves proportional to the load applied. However, in the other 2 cases, with similar material conditions for the plate and different ones for pin, it is clearly seen how the slope of the Force-displacement curve changes. In this case, not just the plastic strain has been changed but also the yeld stress giving to the material with higher yeld stress, higher stiffness. This means that the plastic regime appears later.
On the other hand, as mentioned before, as the value of the plastic strain further than 0, the slope of the plastic behaviour tends to increase its order.

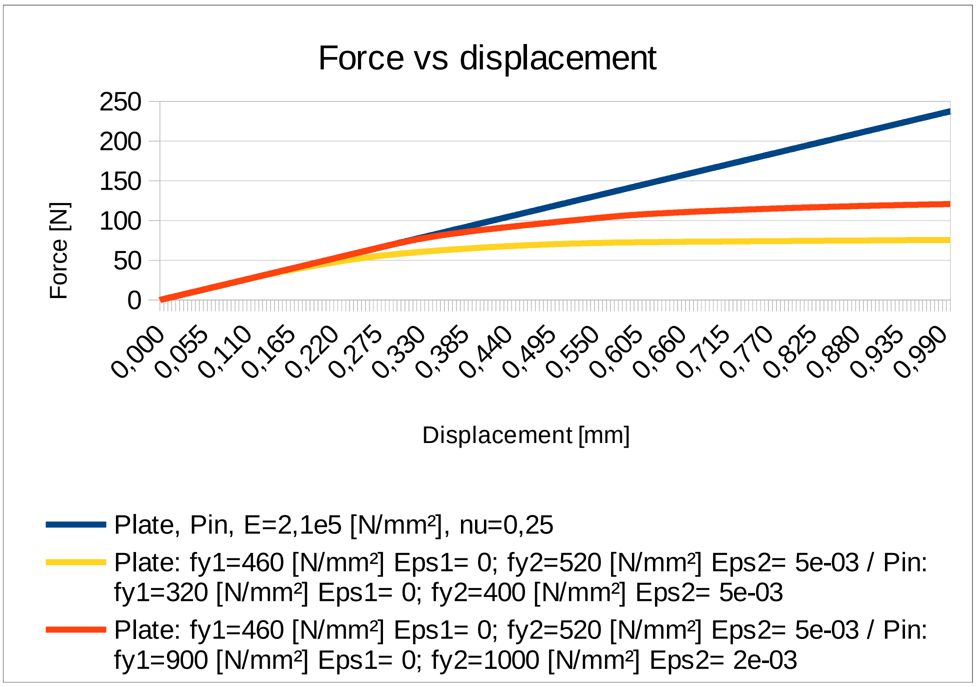

Figure 19. Force vs displacement diagram for cases a,b and c.

Figure 20 and 24 show the same values. This is the perfectly elastic behaviour for the assembly. Comparatively, case 1 and 2 are also displayed so as to show how they perform separatedly.

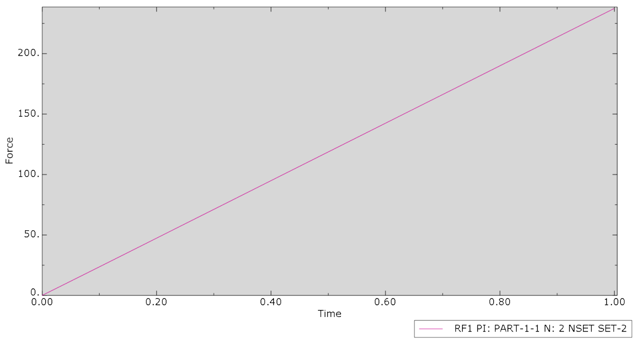

Figure 20. F-t diagram for perfectly elastic.

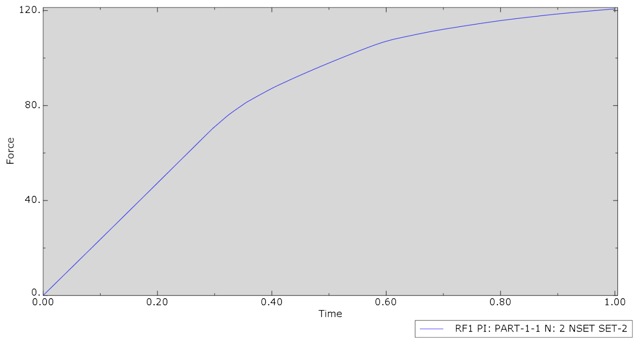

Figure 21. Case 1.

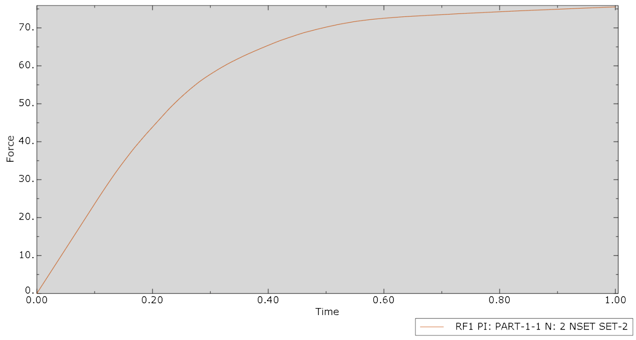

Figure 22. Case 2.

Plots all are shown in terms of time, but as it is seen, displacement behaves linearly with time. In order to get the plots in terms of displacement, the reescaling should be done considering the figure shown in the right hand side.

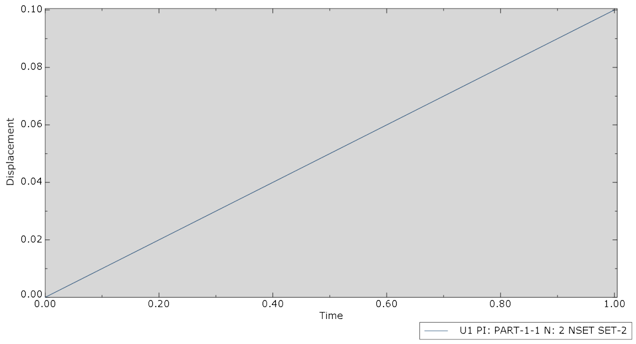

Figure 23. Displacement-time diagram.

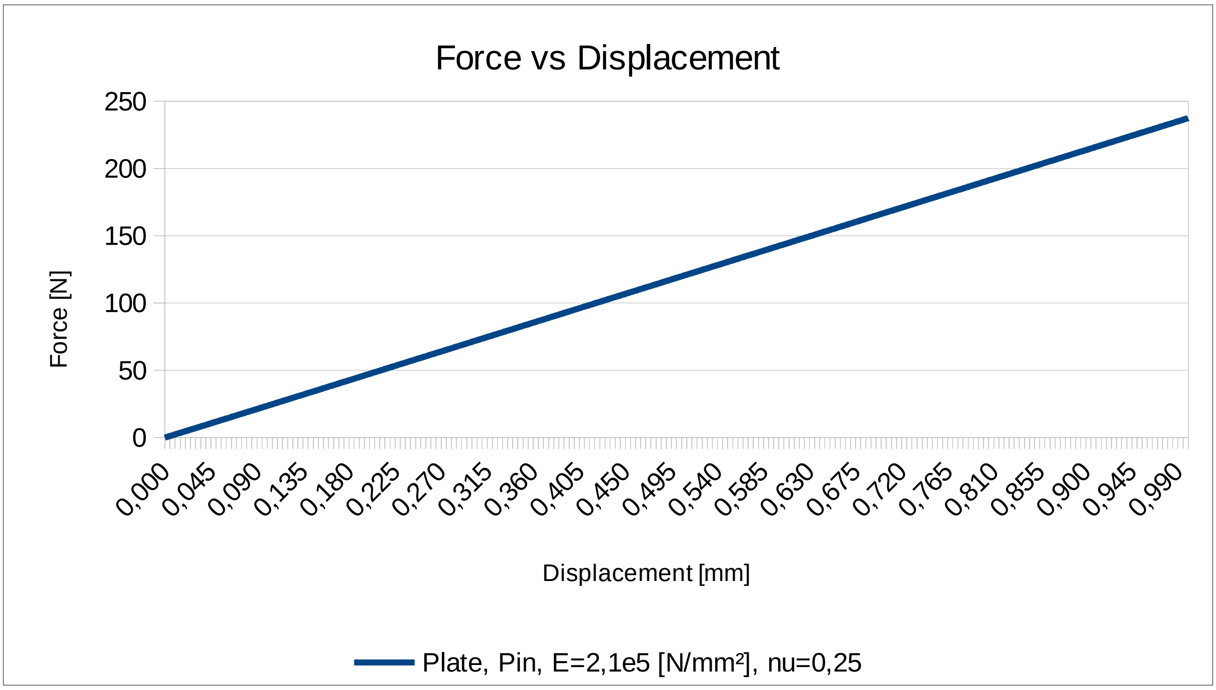

Figure 24. Force vs displacement for perfectly elastic case.