COMPUTATIONAL MECHANICS TOOLS
Master of Science in Computational Mechanics/Numerical Methods
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Assignment 3: Nonlinearity

1. Plate with a hole

In this assignment, a plate with a hole has been simulated under tensile force for different considerations of the constitutive equations.

To simulate the tensile force, an axial displacement has been prescribed in the extremes of the plate (0.1mm of elongation). All simulations performed in this problems are quasistatic. That means that the time only plays the role of a load parameter. The load is linear with time. The mesh used in this assignment is very coarse as it is limited to 1000 nodes. For that reason, all analysis presented here are just qualitative and not quantitative as the results may have a big relative error.

Elastic constitutive equation

The first simulation considers the plate as an elastic body with a Young Modulus of 210 GPa and a Poisson ratio of 0.25. The results are the following:

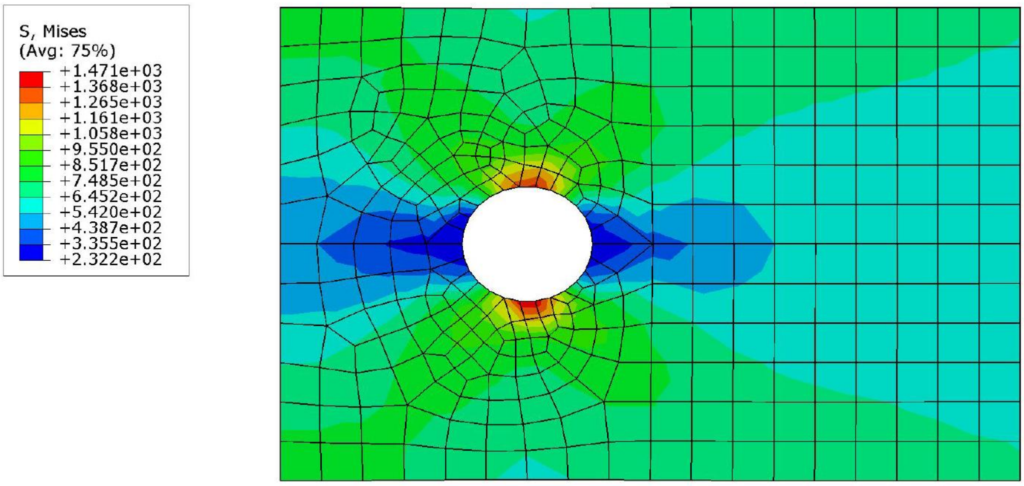

Figure 1: Von Mises Stress distribution in an elastic plate

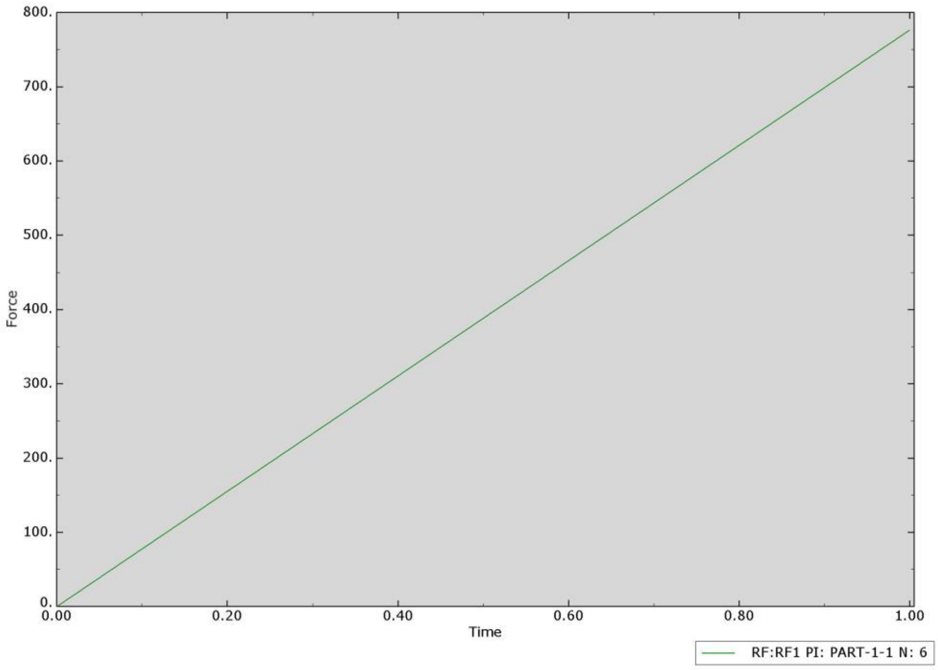

Figure 2: Time vs force on one node in an elastic plate

In this case, as expected the force on one node vs its displacement is linear. It can be seen that, as expected from the linear theory, the stresses are concentrated on the surface of the circumference with a peak value of approximately 1500 MPa.

Elastic-plastic constitutive equation

a) In this case the material has been considered the same as before with the addition of the perfect plastic condition at 460 MPa. That means that any region of the material that reaches the Von Misses equivalent stress will flow without hardening. The results are the following:

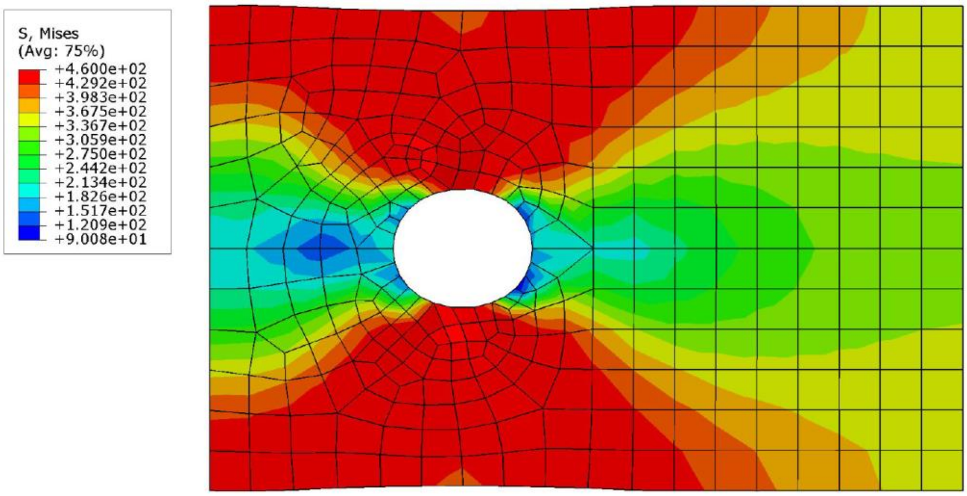

Figure 3: Von Mises stress distribution in a perfect plastic plate

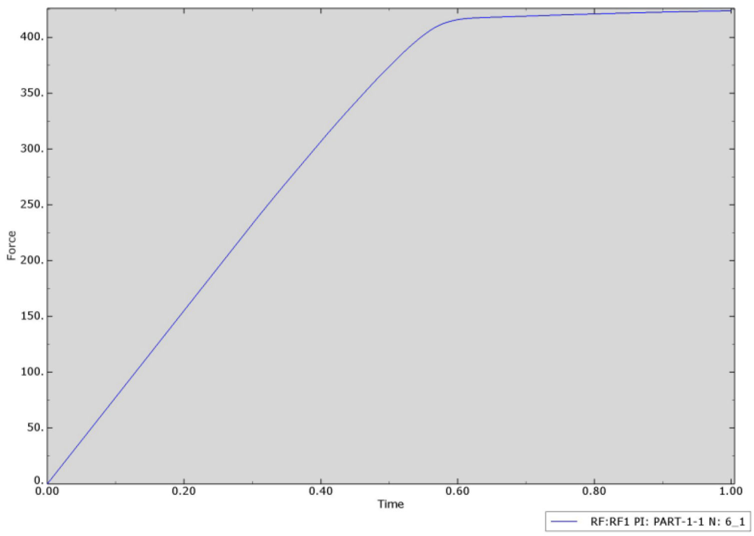

Figure 4: Time vs force on one node in a perfect plastic plate

In this case we can see that the stress distribution has changed significantly as there is not just a concentration of the tensions in the extremes of the circumference but complete regions of the plate show a von Mises stress of 460 MPa. That means that there the material is just flowing. This fact can be checked in the force vs displacement graphic. The force increases linearly until it reaches a certain value which corresponds to the point where the material reaches the plastic condition and it just flows without hardening. For that reason, the maximum force on the node is about half of the elastic case.

b) In this case, the material has supposed to became plastic at 460 MPa as before but from this point it will harden linearly until reach 520 MPa at a plastic strain of $5 \cdot 10^{-3}$.

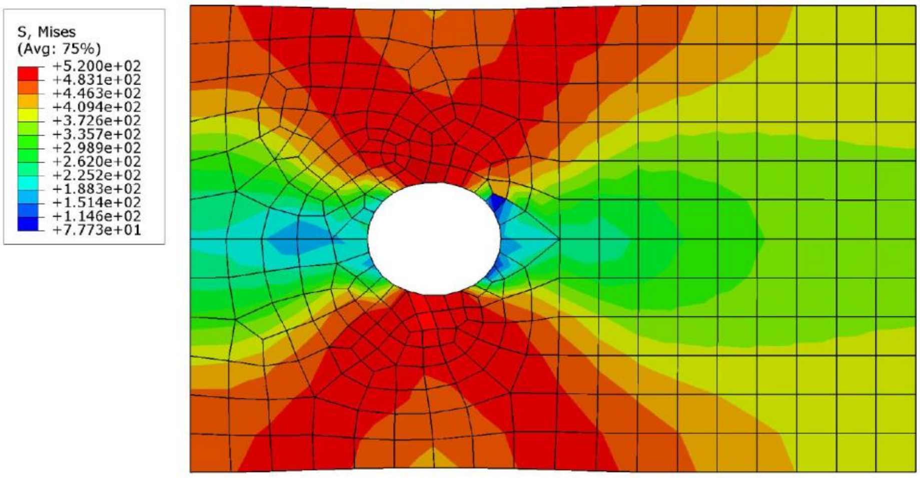

Figure 5: Von Mises stress distribution in plastic case b

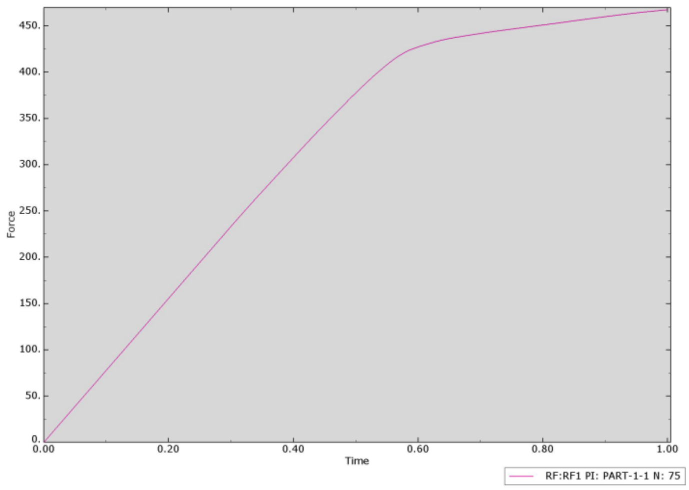

Figure 6: Time vs force on one node in plastic case b

In this case it is seen that the von Misses stress arises in the same region than before but it reaches the peak of 520 MPa instead of 460 MPa. That is due to the fact that the material is hardening until the value of 520 MPa and then it flows as a perfect plastic. However, it can be seen that the region of 520 MPa is narrow. That means that the perfect plastic behaviour will still not be present in the simulation.

In the force-displacement plot it can be seen that behaviour. The behaviour is linear until the firsts points of the material reach the 460 MPa stress state. This point corresponds with the same as in the case of perfect plastic. The difference is that from this point, the force still increases but with a slower slope as the material presents hardening. However, it does not reach the state of perfect plasticity.

c) Finally, the material has supposed to became plastic at 460 MPa as before but from this point it will harden linearly until reach 520 MPa at a plastic strain of $2 \cdot 10^{-3}$.

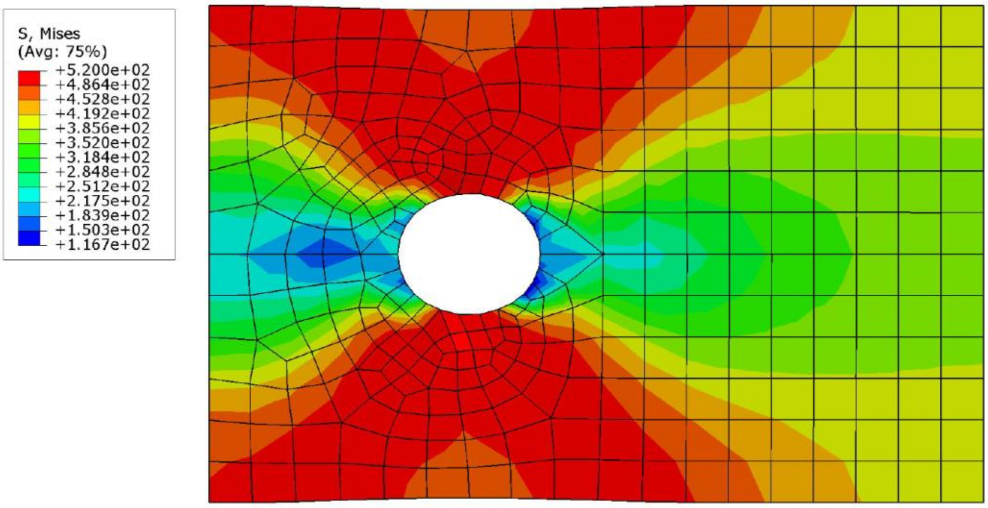

Figure 7:Von Mises stress distribution in plastic case c

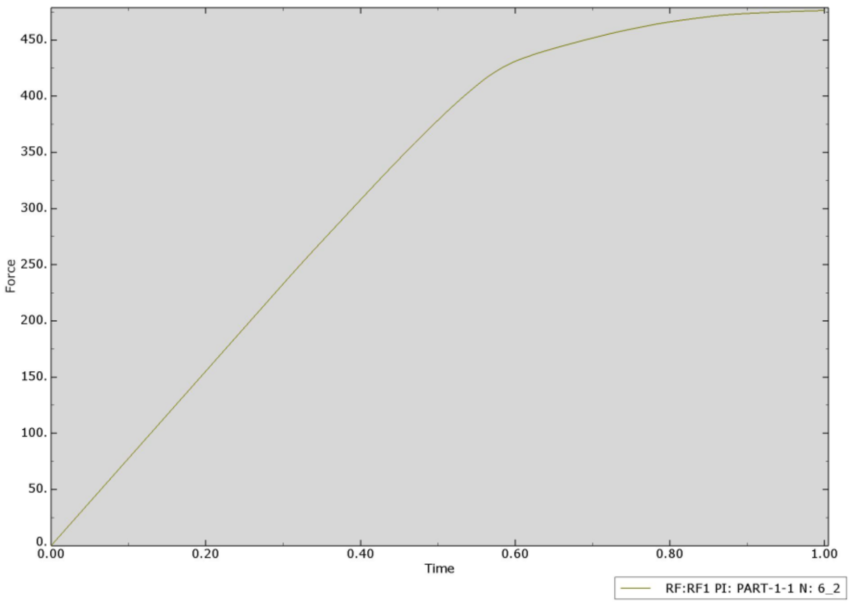

Figure 8: Time vs force on one node in plastic case c

In this case, as the material enters the state of perfect plasticity with a lower strain, this region is wider than in the previous case. This can be checked in the plot. The reduction of the slope is at the same point than before but, near the end of the simulation it reduces even more the slope as an indicator that the material is flowing. The reason why from this point the force still increases a bit is due to the fact that the state of stress of 520 MPa is not the whole section and there is a stress redistribution.

2. Contact problem

In this problem, the plate has been restrained by a pin and a prescribed displacement has been imposed on the right face of the plate.

Elastic constitutive equation

In this first simulation, the plate and pin constitutive equation are linear with the same constants than in the previous problem.

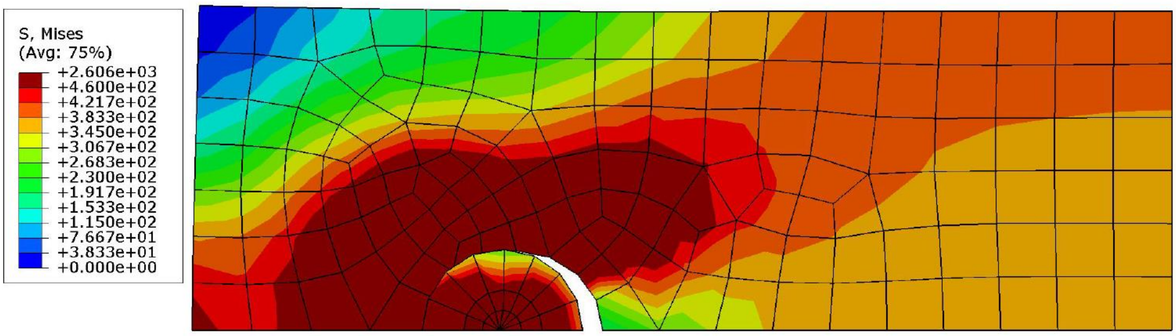

Figure 9: Von Mises stress distribution for elastic constitutive equation

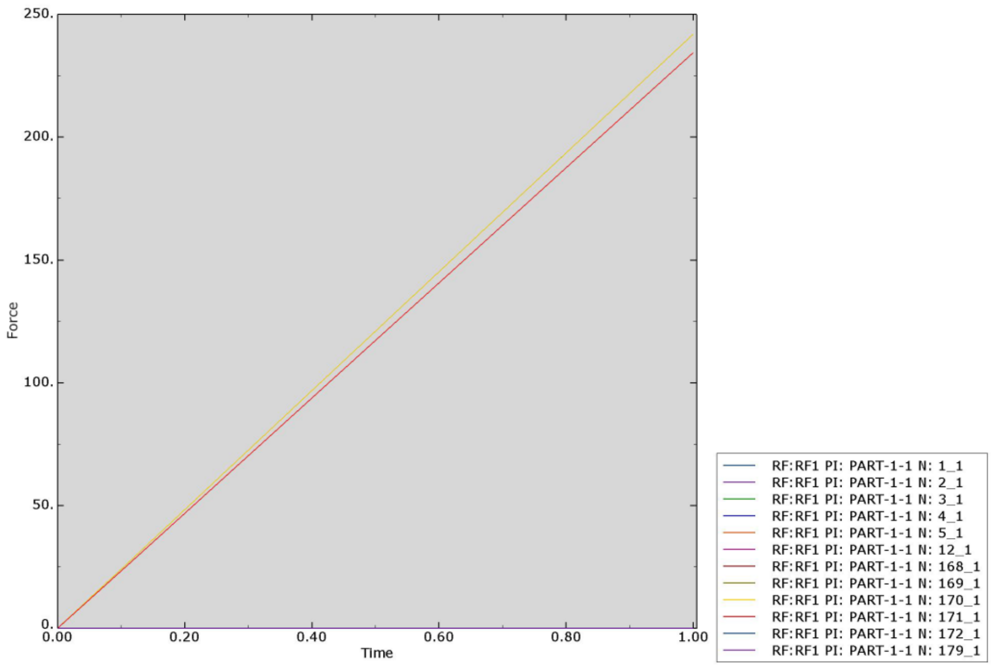

Figure 10: Time vs force for elastic constitutive equation

From the stress distribution it can be seen that there is a high concentration of stresses around the contact zone. As expected, the stress-displacement plot is linear. The reason why the different nodes have quite different loads is because the stress is not uniformly distributed.

Elastic-plastic constitutive equation

a) The plate will be modelled as was modelled in the section b) of the previous problem. The pin is assumed to begin to yield at 900 MPa and then, linearly to 1000 MPa at a strain of 2e-3.

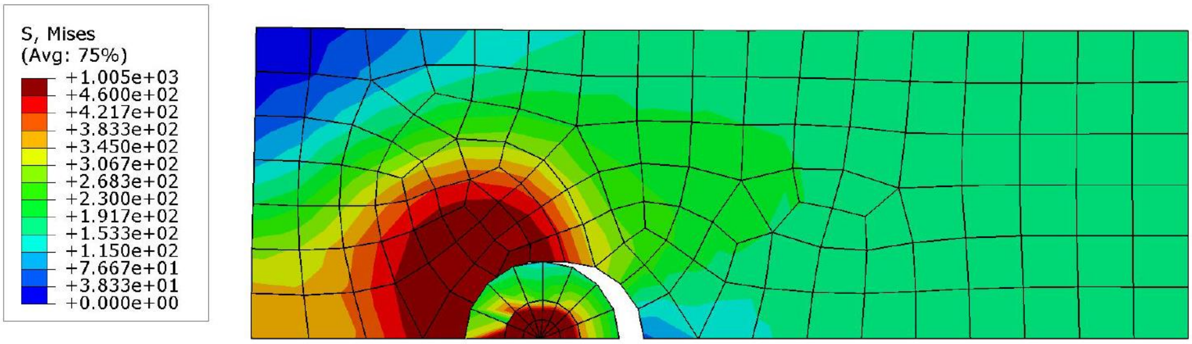

Figure 11:Von Mises stress distribution for case a

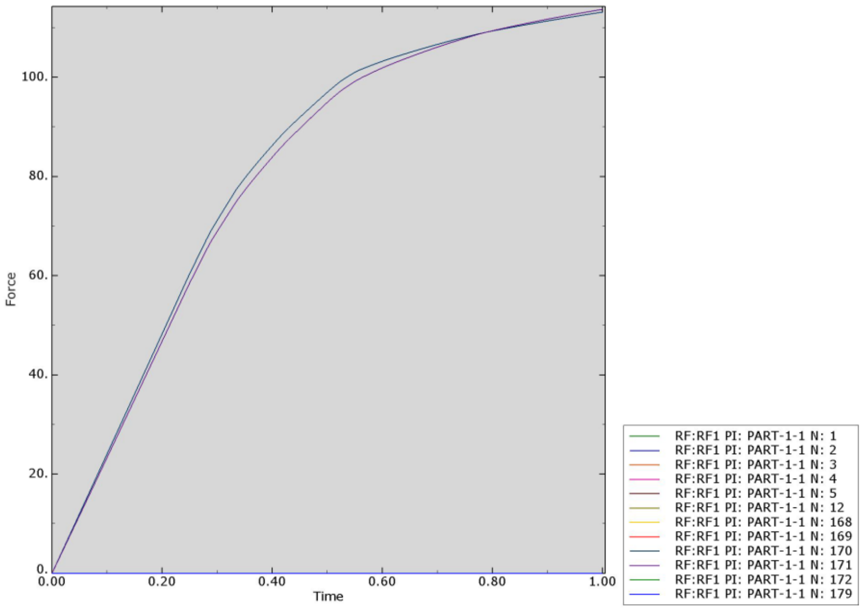

Figure 12: Time vs force for case a

In this case, the stress concentration is much lower because, as can be seen in the plot, the material starts to yield allowing the stresses to redistribute and the force is about the half of the previous elastic case. Also it is noted that the plot has a different behaviour from the problem of the plate with a hole. That is due to the contact behaviour, much more complex than in the previous problem.

b) The plate will be modelled as was modelled in the section b) of the previous problem. The pin is assumed to begin to yield at 320 MPa and then, linearly to 400 MPa at a strain of 5e-3.

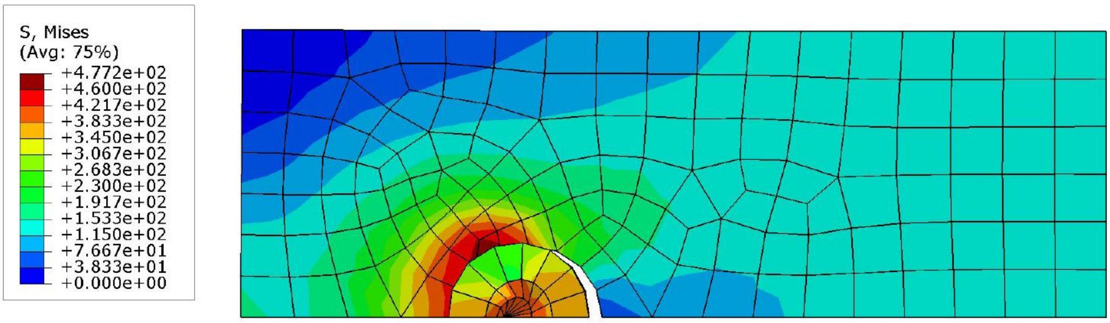

Figure 13:Von Mises stress distribution for case b

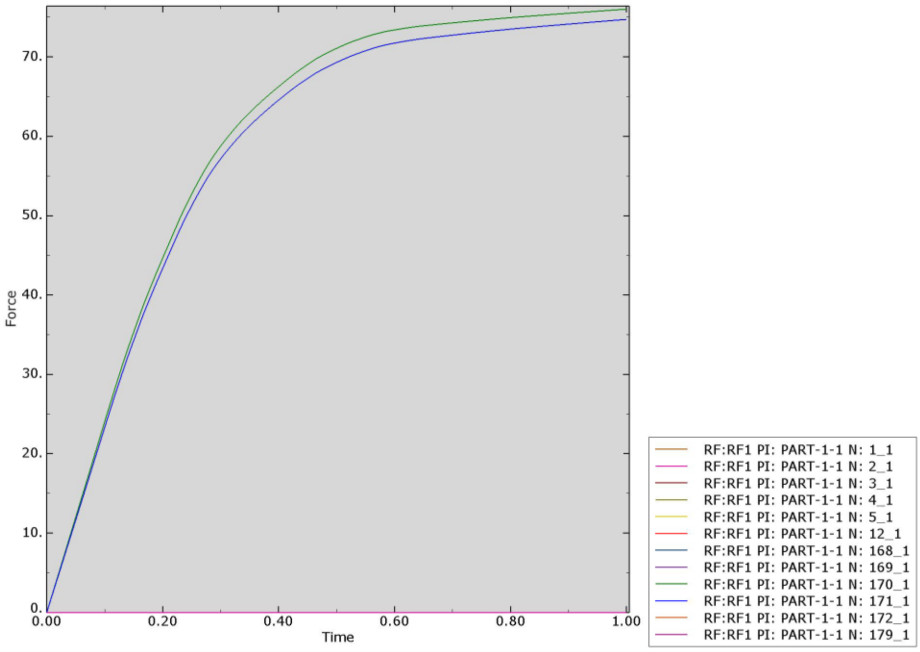

Figure 14: Time vs force for case b

The behaviour of the problem in this case presents similitudes with the previous one with the difference that the stresses and forces are even lower because the pin now presents a higher deformation. This implies that the contact surface between the pin and the plate is larger so the stress concentration on the plate is lower.

Conclusions

In this report it has been studied the use of a commercial FEM software to study the plasticity behaviour and the contact tools. The limitation in the number of nodes has not allowed to obtain accurate results but it has been enough to study the effects from a qualitatively point of view.