Assignment 4

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Finite Element Analysis I

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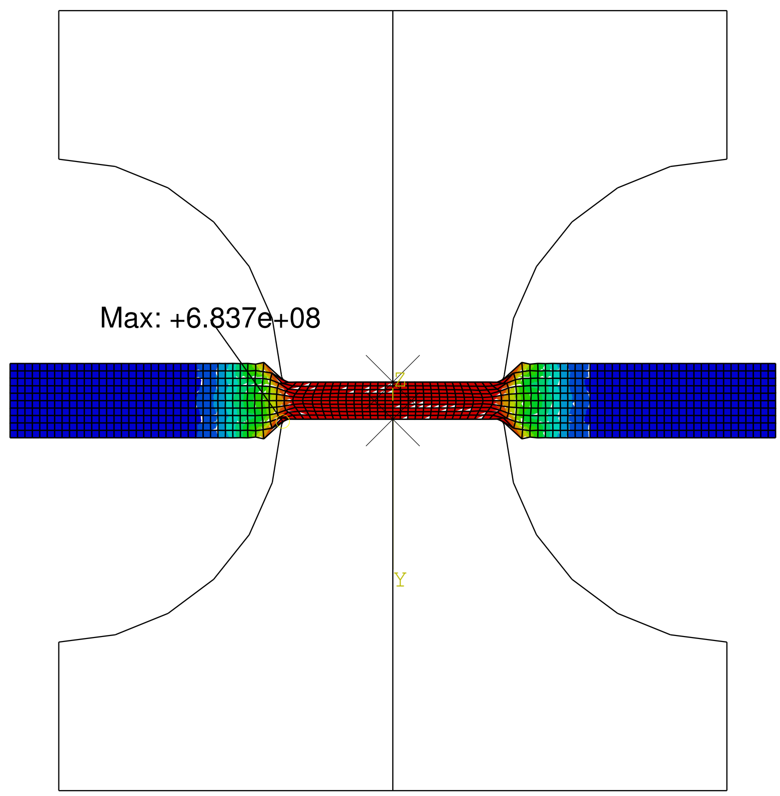

Abstract

In this assignment we examine the behaviour of a beam after being subjected to an impulse. The goal is to extract the resonance frequency of the beam with the given dimensions and material coefficients.

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1 Introduction

Measuring the uniaxial true stress/strain relation is the most fundamental task before any plastic analysis can be made. It defines the strain hardening of a material and determines the general stress-strain relation when plastic deformation is taking place. Plane strain test is a method of choice to obtain this information.

During plane strain compression test, a narrow band of the material is compressed by narrow plates (see Figure). The constraints on each side of the plate prevent deformations of the material in the width dimension.

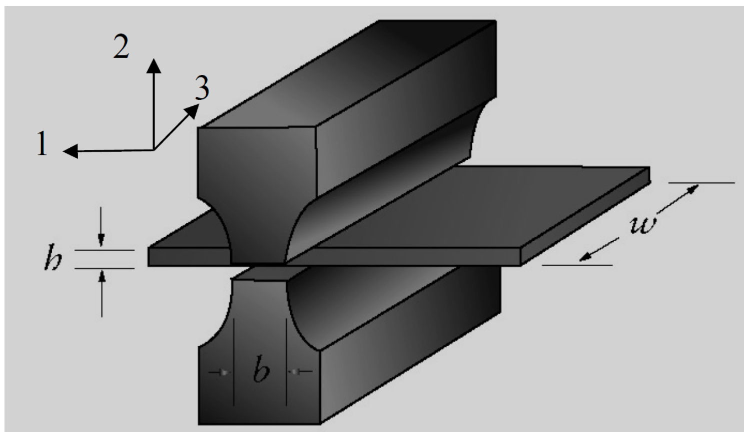

Figure 1: Compression of the aluminum plate

2 Methods

2.1 Analytical solution

In order to ensure the validity of the plane strain assumption, the following relationships have to be fulfilled:

$$w > 5h,\ w > 5b,\ 2h < b < 4h \tag{1}$$

The variables in (1) are the same as in Figure 1

With thouse constraints we assume the following proportions for our model in the analytical solution and later with abaqus:

$$w = 0.2m, b = 0.03m, h = 0.01m \tag{2}$$

In our situation, the true stress and true strain are given by:

$$\varepsilon_1 = -\varepsilon_2,\ \varepsilon_2 = ln(\frac{h}{h_x}),\ \varepsilon_3 = 0,\ \sigma_1 = 0,\ \sigma_2 = \frac{P}{wb},\ \sigma_3 = \frac{\sigma_2}{2} \tag{3}$$

And the equivalent (Mises) stress and strain are defined as:

$$\bar{\varepsilon} = \frac{2}{\sqrt{3}}\varepsilon_2,\ \bar{\sigma} = \frac{\sqrt{3}}{2}\sigma_2 \tag{4}$$

Plastic deformation of aluminium. In this case, the stress-strain relation is given by:

$$\bar{\varepsilon} = \begin{cases} \frac{\bar{\sigma}}{E} & ,\bar{\sigma} < \sigma_0 \\ \frac{\sigma_0}{E} + \frac{\sigma_0}{B}(\frac{\bar{\sigma}}{\sigma_0} - 1)^n & ,\bar{\sigma} >= \sigma_0 \end{cases} \tag{5}$$

Where:

E = 70 GPa
σ_0 = 220 MPa
B = 3 GPa
n = 3.2
v = 0.3

Using our values for $\bar{\sigma} >= \sigma_0$ in equation 5:

$$\frac{2}{\sqrt{3}}ln(\frac{200 \cdot 10^{-3}m}{h_x}) = \frac{220 \cdot 10^6 Pa}{70 \cdot 10^9 Pa} + \frac{220 \cdot 10^6 Pa}{3 \cdot 10^9 Pa}(\frac{\bar{\sigma}}{220 \cdot 10^6 Pa} - 1)^{3.2} \tag{6}$$

Or more simple:

$$(\sqrt[n]{(\bar{\varepsilon} - \frac{\sigma_0}{E})\frac{B}{\sigma_0}} + 1)\sigma_0 = \bar{\sigma} \tag{7}$$

In the end we used the calculated vales for the platisity in abaqus.

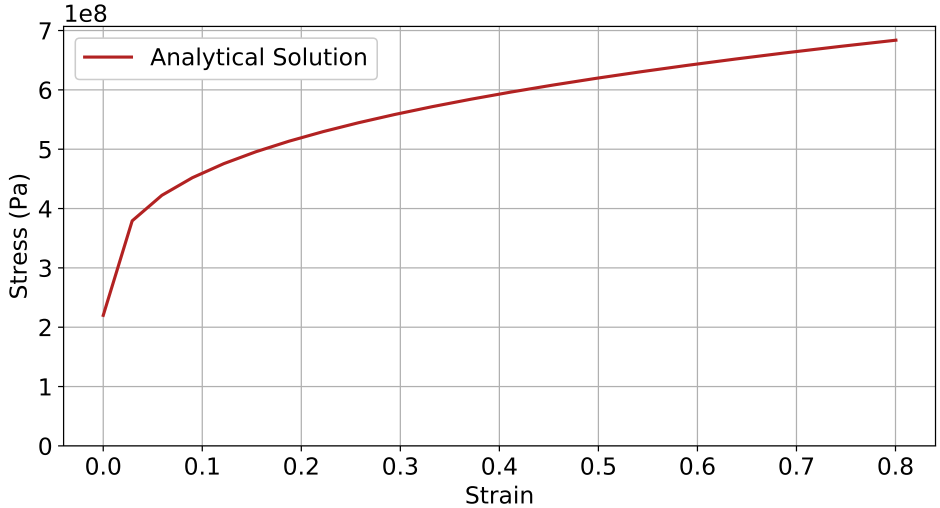

Figure 2: Result of the analytical calculations

2.2 Plain Stress Compression Test in Abacus

We created a model with CPS4R mesh type. Based on the last assignments, the reduced integration gave us the best result, so we stick with that.

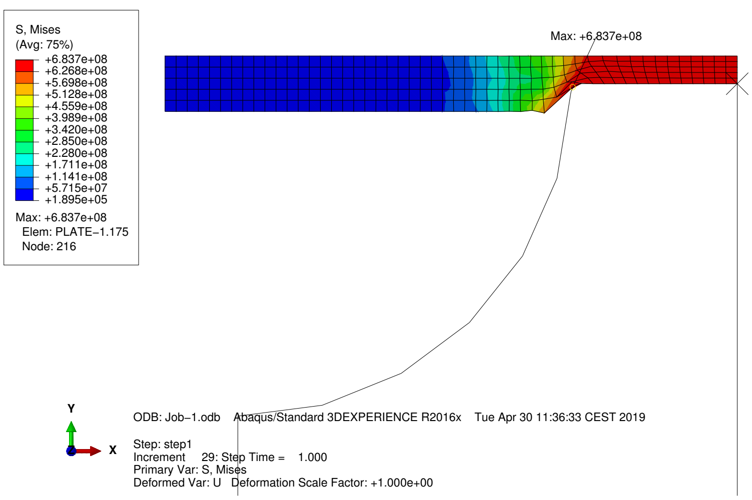

Figure 3: Node to node with no sliding

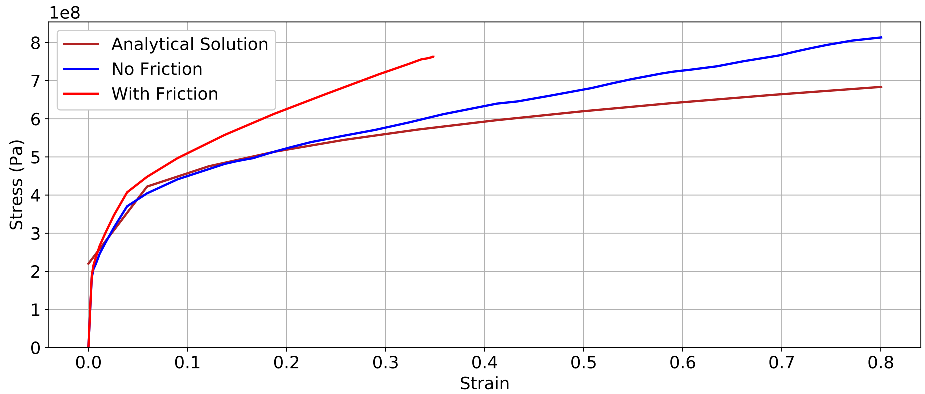

Figure 4: Result of the analytical calculations compared with the results form abacus

3 Results and Discussion

In the submodel with the 1mm fillet, we observe an evenly distributed stress pattern. Also, the maximum value for stress has decreased by about 50 MPa. From a mechanical point of view, the round corner offers a smoother distribution of internal stresses because the lines of forces in a material are not interrupted. However, the maximum stress is still the yield stress of our material, we still expect it to deform.

References

[1] Michel Goossens, Frank Mittelbach, and Alexander Samarin. *The LaTeX Companion*. Addison-Wesley, Reading, Massachusetts, 1993.