Assignment 4

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Finite Element Analysis I

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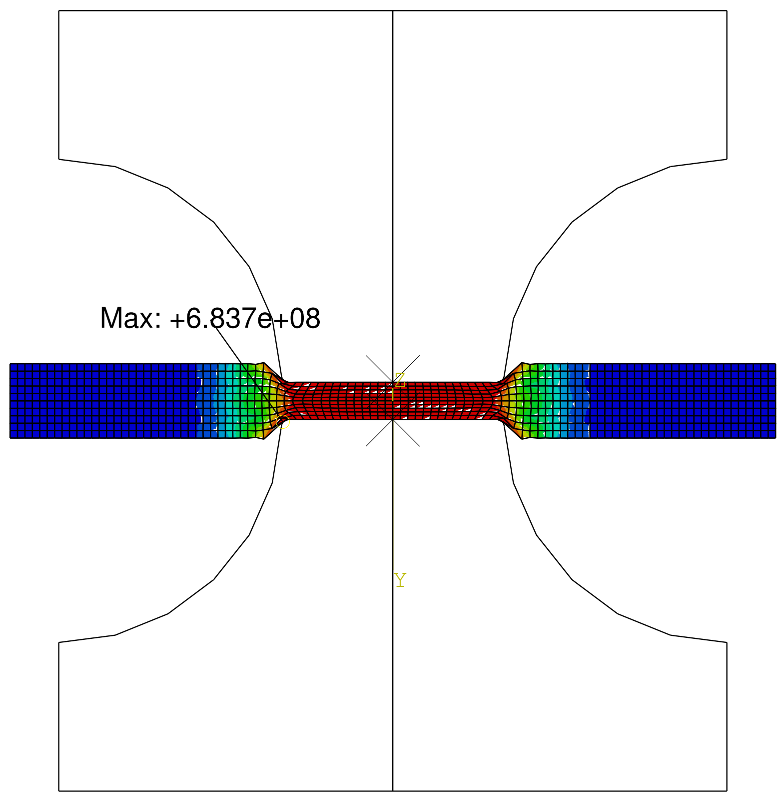

Abstract

In this assignment we examine the behaviour of a metal plate under compression. A rigid press, modelled as an analytical surface, squeezes the plate together. By retrieving the force and displacement values over time, we can determine the plastic behaviour of our specimen. This experimental data is then compared to the analytical solution, which was calculated with given material constants. Several different simulation methods were used, e.g. prohibiting the plate from sliding or allowing friction. The experimental results are overall similar to the analytical ones.

Contents

1 Introduction

The plate is mounted in a setup shown in **??**figure1). The press then compresses the plate to half its original height.

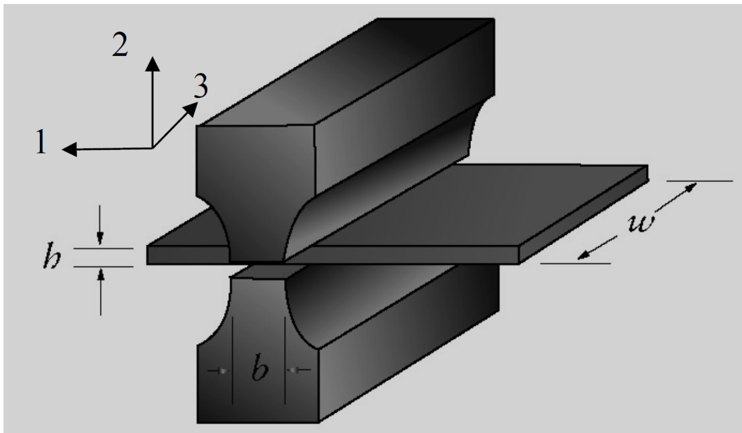

Figure 1: Compression of the aluminum plate

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.

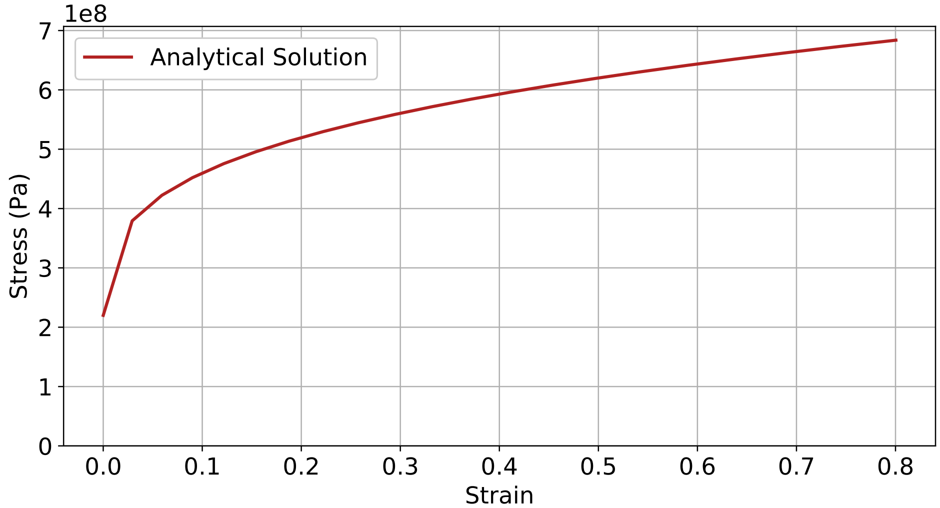

Figure 2: Result of the analytical calculations

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.

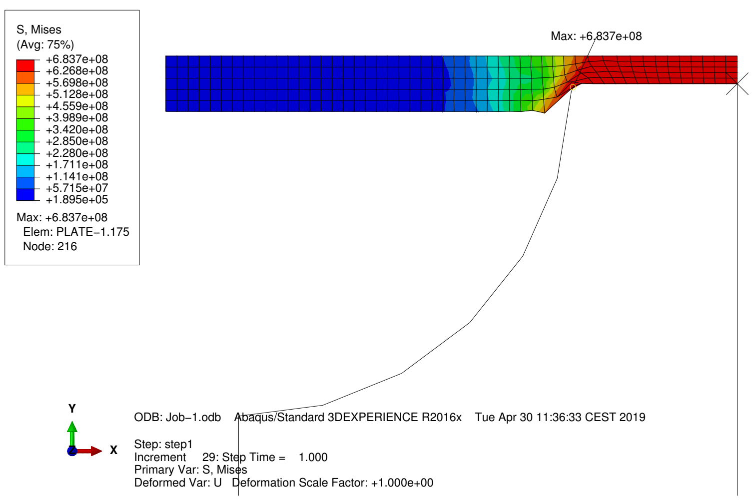

Figure 3: Node to node with no sliding

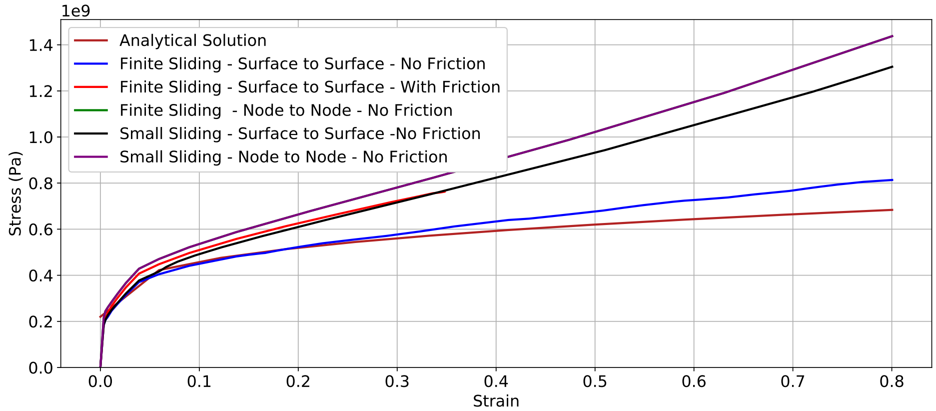

Figure 4: Result of the analytical calculations compared with the results form abacus

3 Results and Discussion

The analytical and the experimental results are similar. Logically the experiment with introduced friction (friciton coefficien 0.2) results in a higher stress/strain ration, as energy of the compression gets lost in friction. during modelling, we ran into troubles with the simulation due to the sharp corner of the press. Thus we introduced a small 1mm fillet to smoothen the process. This worked out fine and the results got better and were calculated more quickly.

The stress/strain ratio calculations which allowed for small sliding show a higher stress per strain ratio.

References

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