Homework 2 Non-linear Modelling (AE4ASM505), TU Delft

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This is an individual assignment where a report needs to be written to address the required tasks. Automatic similarity check is in the system. Make sure all parts of the report are clearly visible for grading, unreadable parts will be considered as undone. Submit your ancillary files together with the report in Brightspace under Assignments. (Note: External links to your files will not be opened. You must submit the files themselves. Do not submit a zip file)

1 Problem statement

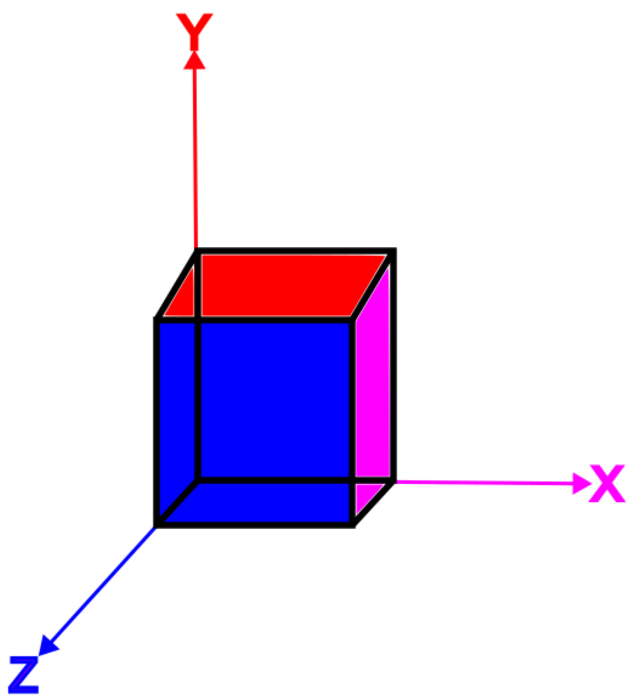

Figure 1: Cube of isotropic material, aligned with coordinate system.

A cube of homogeneous isotropic material, shown in fig. 1, is being deformed cyclically along the global coordinate axes, with displacement control. The cube edge length is $L = 0.7$ m. The cyclic loading is sinusoidal with a mean of 0, with amplitudes in meter per loading axis defined by: $A_x = 0.45$ (tension),

$A_y = -0.2$ (compression) and $A_z = 0$. Due to these loading cycles, the cube undergoes repeated tension and compression. The total number of loading cycles is $N = 10$. Use a Poisson's ratio $\nu = 0$ for the material.

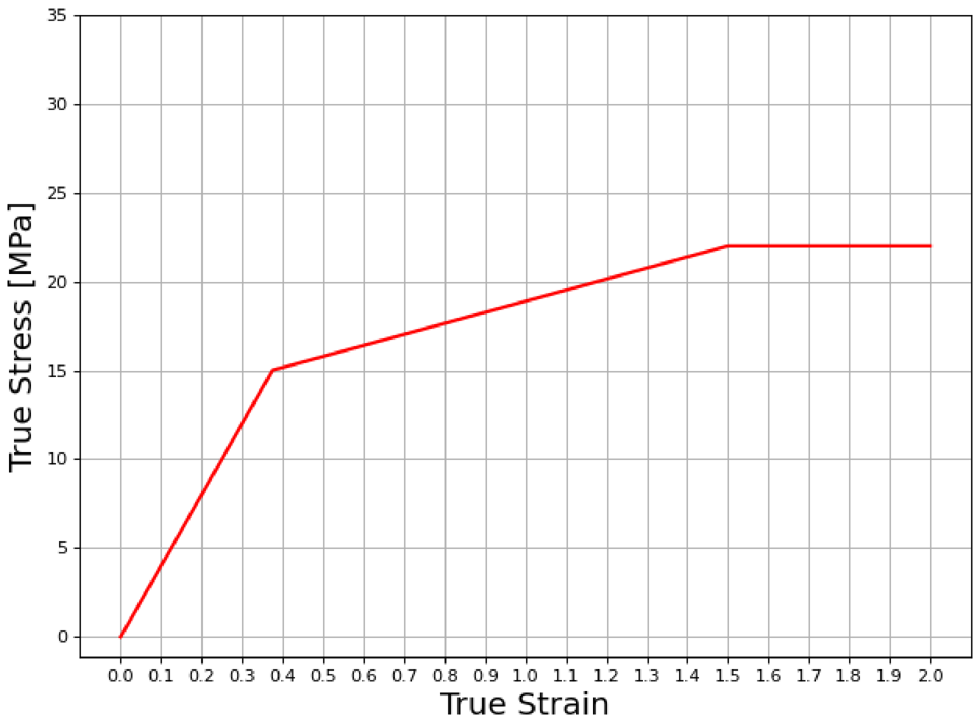

Figure 2: Material stress strain response.

The stress strain response of the material is shown in fig. 2 and summarized in table 1.

Strain	Stress [MPa]
0	0
0.375	15
1.5	22
>1.5	22

Table 1: Material stress strain response.

2 Tasks

Answer the following tasks in the report. Include any program that you make to help address these tasks in an appendix to the report.

2.1 Deformation gradient amplitude

Compute the deformation gradient at the maximum loading amplitude for the given cyclic loading. Use the total Lagrangian formulation. Show your calculations and report the matrix.

2.2 Nominal total strain amplitude

Compute the nominal total strain tensor using small strain assumptions (i.e., the linear strain) at the maximum positive amplitude of loading. Show your calculations and report the final nominal strain tensor in the principal coordinate system.

2.3 True total strain amplitude

Compute the true total strain tensor using small strain assumptions at the maximum positive amplitude of loading, and at the maximum negative amplitude of loading. Show your calculations and report the final true strain tensor in the principal coordinate system. (Tip: use this forumla for compressive strain conversion $\epsilon_t = -\ln(1 - \epsilon_n)$)

2.4 Forward Euler integration

Use the forward Euler integration algorithm from the lecture notes to compute the true stress response to the true total strains imposed on the material cube. Make a plot for each principal true stress component versus the signed true Von Mises strain[1]. You can compute the sign of the true total Von Mises strain from the sign of the true hydrostatic strain. Include the three plots in the report, with the stress strain relationships clearly visible.

2.5 Strain along the Z direction

Explain why the strain along the Z direction occurs (remember that the Poisson ratio of the material is 0), and explain what needs to change in the stress strain response of the material for the strain along the Z direction to converge to 0 as the number of loading cycles increases.

2.6 Signed Von Mises stress

Make a plot of the signed true Von Mises stress versus the signed true total Von Mises strain, for the material stress strain response given in the problem statement. You can compute the sign of the true Von Mises stress from the sign of the true hydrostatic stress. What needs to change in the true stress - true strain input curve (fig. 2) of the material for the signed true Von Mises stress versus the signed true total Von Mises strain response to become linear eventually after the cyclic loading?

2.7 Influence of Poisson ratio

What would happen to the stress response in the Z direction if the Poisson ratio for the material was $\nu = 0.3$? Comment on the expected differences in the elastic regime of the response.

2.8 Plasticity formulation limitations

Is the small strain theory of plasticity appropriate for this loading condition? Why/Why not?

[1] von Mises strain can be computed similarly as von Mises stress, just by using the strain tensor instead of the stress tensor $\boldsymbol{\tau}$ in Slide 4 of Lecture 5