UCL Mechanical Engineering 2021/2022

MECH0026 Coursework Two

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1 Calculation and definition of the material properties from experimental data

1.1 Young's modulus

The Young's Modulus of a material is a measure of stiffness of an elastic material. It has the following formula:

$$E = \frac{\sigma}{\varepsilon} = \frac{\frac{F}{A}}{\frac{\Delta L}{L_0}} \tag{1.1}$$

where σ is the stress and ε is the strain of the material.

The Young's Modulus of the material can be calculated by finding the gradient of the elastic region on the engineering stress-strain curve. Using MATLAB, the following value for the slope of the curve was found:

$$E = 67.12\,\text{GPa} \tag{1.2}$$

1.2 Yield point

The Yield Point is the stress at which a predetermined amount of permanent deformation occurs. To find the yield point of our material, we can use the offset method [1]. This is a recommended method of finding the yield point as stated in ASTM E8 [2]. The offset method involves plotting a line with gradient E with an offset from the origin, typically in the range of 0.1% - 0.2% strain. Using MATLAB, we can find the yield stress and strain:

$$\sigma_y = 119.98\,\text{MPa at } 0.2\% \text{ offset} \tag{1.3}$$

$$\varepsilon_y = 3.78 \times 10^{-3} \text{ at } 0.2\% \text{ offset} \tag{1.4}$$

1.3 True stress-strain

We can find the true stress and strain of our material by using the following equations:

$$\sigma_t = \sigma_n e^{\varepsilon_n} \tag{1.5}$$

$$\varepsilon_t = \ln(1 + \varepsilon_n) \tag{1.6}$$

The true stress-strain is a good fit until necking occurs, after which we have an instability in the material. After necking, three things happen:

- volume does not remain constant.
- material is no longer homogeneous.
- material is no longer continuous.

Hence, 1.5 and 1.6 represent the stress-strain of the damaged sample.

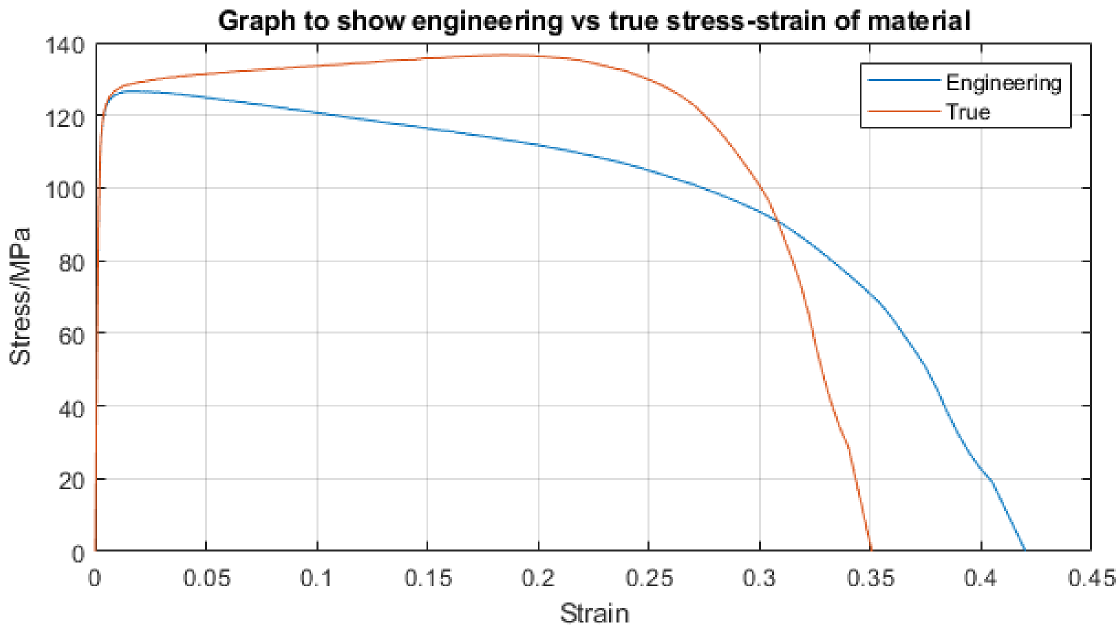

Figure 1: Graph to show engineering vs true stress-strain response of material.

1.4 Necking point/UTS

To find the necking point, we need to find the ultimate tensile strength of our material, which can be found by indexing the largest stress value in our data.

Ultimate tensile strength (engineering):

$$\sigma_{e,uts} = 126.52\,\mathrm{MPa} \text{ at } \varepsilon = 0.019 \tag{1.7}$$

Ultimate tensile strength (true):

$$\sigma_{t,uts} = 136.51\,\mathrm{MPa} \text{ at } \varepsilon = 0.186 \tag{1.8}$$

We take the value from our true stress-strain curve as this accurately represents the stress-strain of our material until necking occurs.

1.5 Effective stress-strain

The effective stress-strain allows us to model the true undamaged stress-strain of the material. This is useful as ABAQUS requires this to model the behaviour of our material. This can be calculated by assuming a perfectly plastic response after the onset of necking:

$$\widetilde{\sigma}_t = \begin{cases} \sigma_t & \text{for } \varepsilon_n \leq \varepsilon_{n,uts} \\ \sigma_{n,uts}\,(1+\varepsilon_n) & \text{for } \varepsilon_n > \varepsilon_{n,uts} \end{cases} \tag{1.9}$$

$$\widetilde{\varepsilon}_t = \varepsilon_t \tag{1.10}$$

A plot of the effective stress-strain curve is shown below.

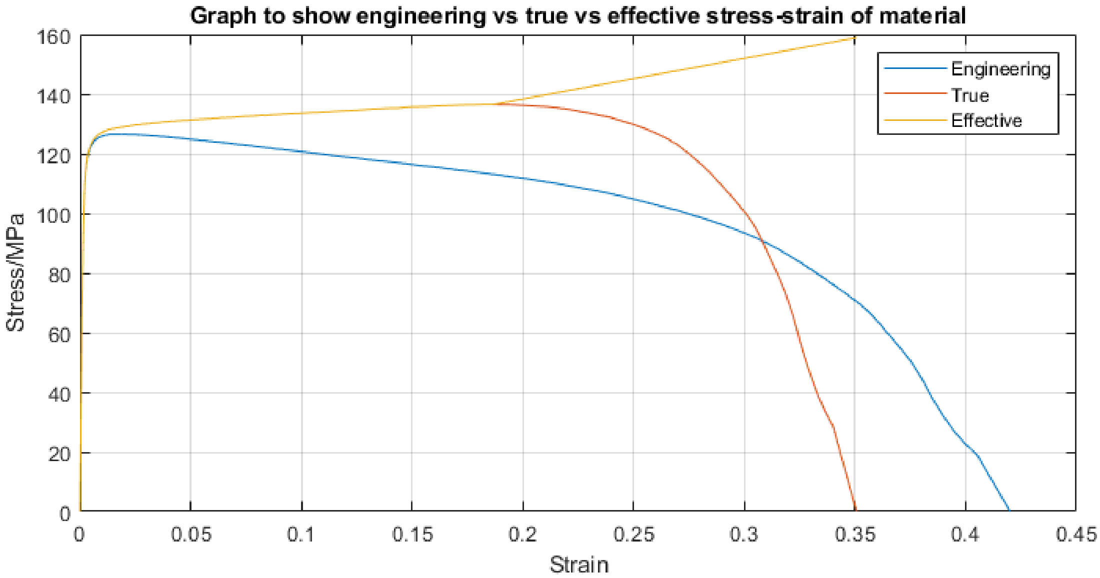

Figure 2: Graph to show engineering vs true vs effective stress-strain response of material.

1.6 Damage parameter

The damage of the material is a measure of the area of voids in a material. The effective true stress can be written in terms of the damage variable:

$$\widetilde{\sigma}_t = \frac{F}{A - A_D} = \frac{F}{A\left(1 - \frac{A_D}{A}\right)} = \frac{\sigma_t}{1 - D} \tag{1.11}$$

Rewriting Hooke's Law:

$$\widetilde{\sigma}_t = E\varepsilon_t \rightarrow \sigma_t = E\left(1 - D\right)\varepsilon_t \tag{1.12}$$

References

[1] Illinois Tool Works, (2022) 'Offset Yield Strength' https://www.instron.com/en-gb/our-company/library/glossary/o/offset-yield-strength Accessed: 01/03/22

[2] ASTM, (2022) 'Standard Test Methods for Tension Testing of Metallic Materials' https://www.astm.org/e0008_e0008m-21.html Accessed: 01/03/22