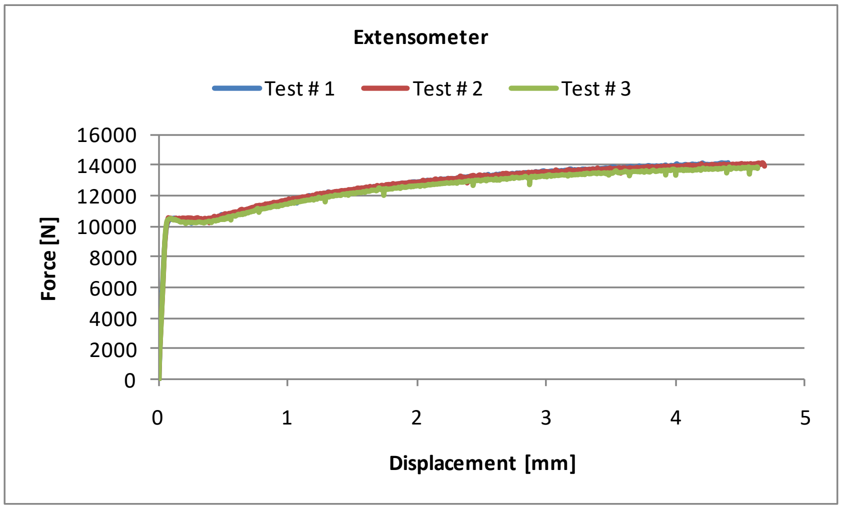
Problem Set 4 – data correction: Laboratory tests

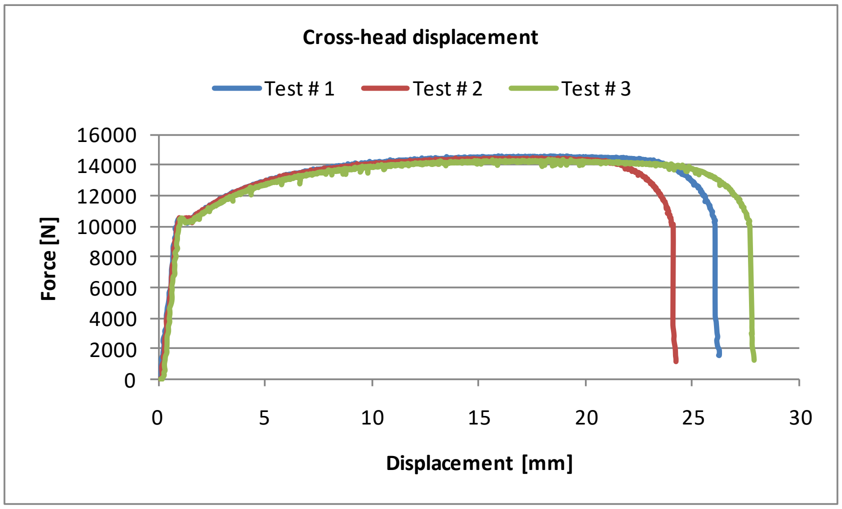
All laboratory tests were run at a displacement of 2.1 mm/min, giving a strain rate of about $\dot{\varepsilon}_e = 2.1/(70\cdot 60) = 5\cdot 10^{-4}\ \mathrm{s}^{-1}$ before necking. In the following, the principles in the calibration procedure will only be demonstrated for the DOMEX 240YP-B steel.

Procedure:

1) First of all, check the scatter in the measured force-displacement curves:



(a)



(b)

Fig. 1.Measured force-displacement curves of DOMEX 240YP-B from (a) extensometer values and (b) cross-head displacements.

There is hardly any scatter in the force-displacement curves between the three parallel tests, except in Fig. 1 (b) after necking, where the results are invalid. Thus, a typical curve can be used in the calibration of the constitutive relations, and we will use the curve from test # 1 in the following. If large scatter is observed you have to use an average curve or consider doing more tests.

2) Based on the measured force-displacement curves in Fig. 1, the engineering stress-strain relations can be established from the relations

$$\varepsilon_e = \frac{L - L_0}{L_0} = \frac{\Delta L}{L_0}, \quad \sigma_e = \frac{F}{A_0}$$

Remember to use the correct gauge length ($L_0 = 40$ mm for the extensometer and $L_0 \approx 70$ mm for the specimen) and the measured values of A_0 (i.e. the cross-section area). The results are shown in Fig. 2.

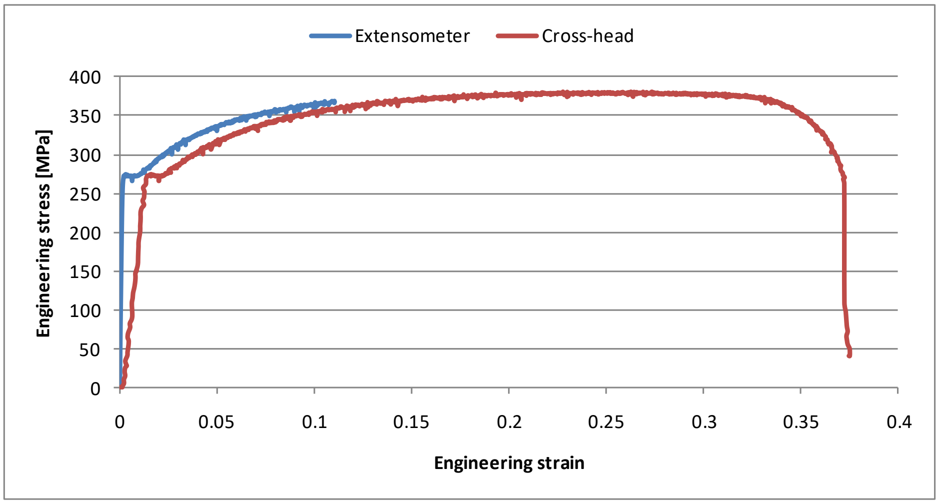


Fig. 2. Uncorrected engineering stress-strain curves.

3) The extensometer, which gives the most accurate measure of the displacement, is normally removed after about 10-12% elongation, to avoid damage to the extensometer. For this particular material this is before necking occurs. Thus, to be able to extract engineering values, such as the ultimate tensile strength and the strain at maximum load, we will use the force-displacement curves based on the cross-head displacement. However, as visible in Fig. 2, the initial stiffness of the stress-strain curve based on the cross-head displacement is too low. There are several reasons for this. Firstly, the cross-head displacement is not accurate enough (too low resolution) to accurately measure the small strains in the elastic region. Secondly, the specimen gauge length of 70 mm is inaccurate because there will be some straining of the remaining parts of the specimen. Thirdly, the machine stiffness and the wobble in the gripping system will affect the measurements.

Thus, the engineering strain based on the cross-head displacement needs to be corrected. The following correction of the strain may be carried out (see also Fig. 3)

$$\varepsilon_{ce} = \varepsilon_{me} - \Delta\varepsilon_e - \frac{\sigma_{ce}}{E_{meas}} + \frac{\sigma_{ce}}{E_{corr}} = \varepsilon_{me} - \Delta\varepsilon_e - \left(\frac{E_{corr} - E_{meas}}{E_{corr} E_{meas}}\right)\sigma_{ce}$$

Here, ε_{ce} is the corrected engineering strain (based on the correct elastic modulus), ε_{me} is the measured engineering strain, $\Delta\varepsilon_e$ is a possible deviation in strain at origin, E_{corr} is the correct elastic modulus, E_{meas} is the measured elastic modulus, and σ_{ce} is the measured stress. If this correction is carried out, simultaneously as the specimen gauge length is corrected to ~80 mm (instead of 70 mm), the results shown in Fig. 4 are obtained. In this figure, the nominal (or correct) elastic modulus is also plotted. The elastic modulus based on the extensometer is very accurate in this particular test. It is also seen that by doing these corrections, the engineering stress-strain curves based on the extensometer and the cross-head coincide.

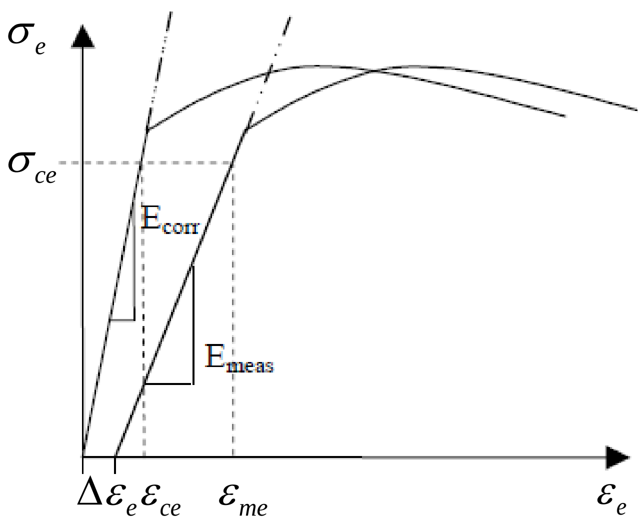


Fig. 3. Correction of the engineering stress-strain curve.

Based on these data it is possible to find the engineering stress-strain data as

Yield stress:	$\sigma_0 \approx 272$ MPa
Ultimate tensile strength:	$\sigma_u \approx 380$ MPa
Strain at maximum load:	$\varepsilon_u \approx 0.217$
Elongation at fracture:	$\varepsilon_f = \frac{L_f - L_0}{L_0} = (81.1 - 60)/60 = 35.2$ %

L_f is the specimen length at fracture and is measured after the test, whereas L_0 is the initial specimen length.

Note that the corresponding values given in the material inspection certificate are $\sigma_0 = 286$ MPa, $\sigma_{eu} = 389$ MPa and $\varepsilon_f = 39$ % (i.e. slightly higher than the measured values), while nominal values are found to be $\sigma_0 = 240$ MPa, $\sigma_{eu} = 360$ MPa and $\varepsilon_f = 28$ % (or slightly lower than the measured data).

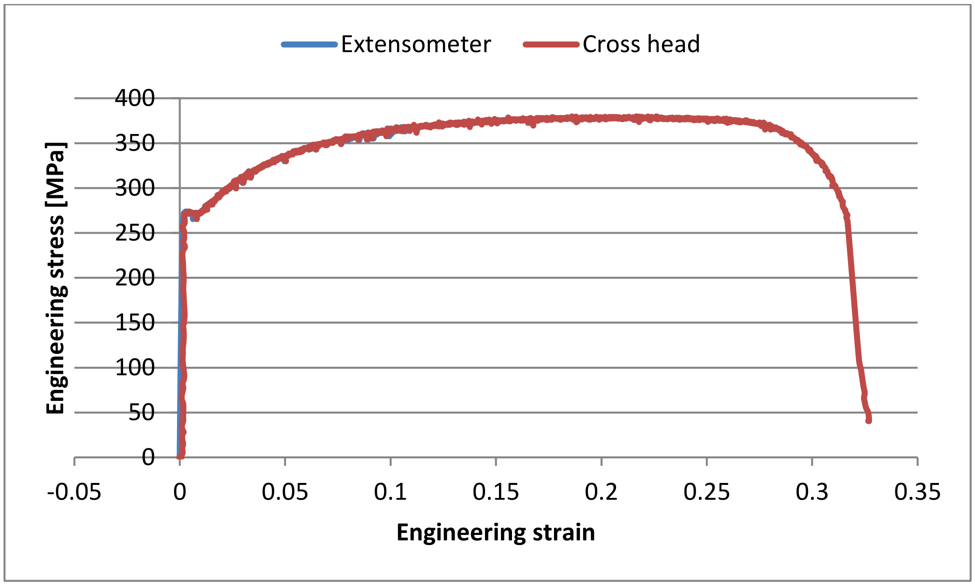


Fig. 4. Corrected engineering stress-strain curves.