The School of Materials Science and Engineering

Final Exam

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Course : Thermo - Mechanical Behavior of Materials **Code of course**: MSE3446

Exam [x] mid [ ] final 2 **Academic year** 2020-2021 **Date:** 29-30/6/2021 **Number….**

Grade	Lecturer	Ratify
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Exercise : Using the stresses and the strains in exercise2 for the tension test on AISI 1020 steel, determine the constants H and n if true stress-strain curves of a metal fit a relationship of the form $\sigma = H\varepsilon^n$.

Questions(oral): Comment on the comparison between the two curves in exercise2.

Explain the standard test method - Experiment and data treatment

and answer question (will be added) on topic given in your own words.

Solution

1. Exercise 2

1.1 Calculation:

Engineering (σ_e and ε_e)	**True (σ_T and ε_T)**
Eng.strain: ε_e: *known* Eng.stress: $\sigma_e = \frac{F}{A_o}$ With: *F is Load (kN)* A_o: *Initial cross section area* (m^2)	True.stain: In case: $\varepsilon_T < \varepsilon_u$ ⇨ $\varepsilon_T = \ln(1+\varepsilon_e)$ In case: $\varepsilon_T \geq \varepsilon_u$ (necking starts) ⇨ $\varepsilon_T = \ln(\frac{A_o}{A})$ True.stress: $\sigma_T = \frac{F}{A}$ With: ε_u is true strain at ultimate point. A is instantaneous cross-sectional area.

Test data			Calculated values			
Eng.strain ε_e	**Load P, (kN)**	**Diameter d (mm)**	**Eng.stress σ_e, (MPa)**	**True strain ε_T**	**Raw true stress σ_T, (MPa)**	**Corrected true stress σ_B, (MPa)**
0	0	9.11	0	0	0	0
0.0015	19.13	-	293	0.00149	293	-
0.0033	17.21	-	264	0.00329	264	-
0.0050	17.53	-	269	0.00498	269	-
0.0070	17.44	-	268	0.0069	268	-
0.010	17.21	-	264	0.00995	264	-
0.049	20.77	8.89	319	0.04783	335	335
0.218	25.71	8.26	394	0.19721	480	461
0.234	25.75	-	395	0.21026	481	460
0.306	25.04	7.62	384	0.35719	549	501
0.330	23.49	6.99	360	0.52978	612	539
0.348	21.35	6.35	328	0.72184	674	577
0.360	18.90	5.72	290	0.93081	735	614
0.366	17.39	5.28	267	1.09089	794	653

Table 1. Data for tension test on AISI 1020 hot-rolled steel

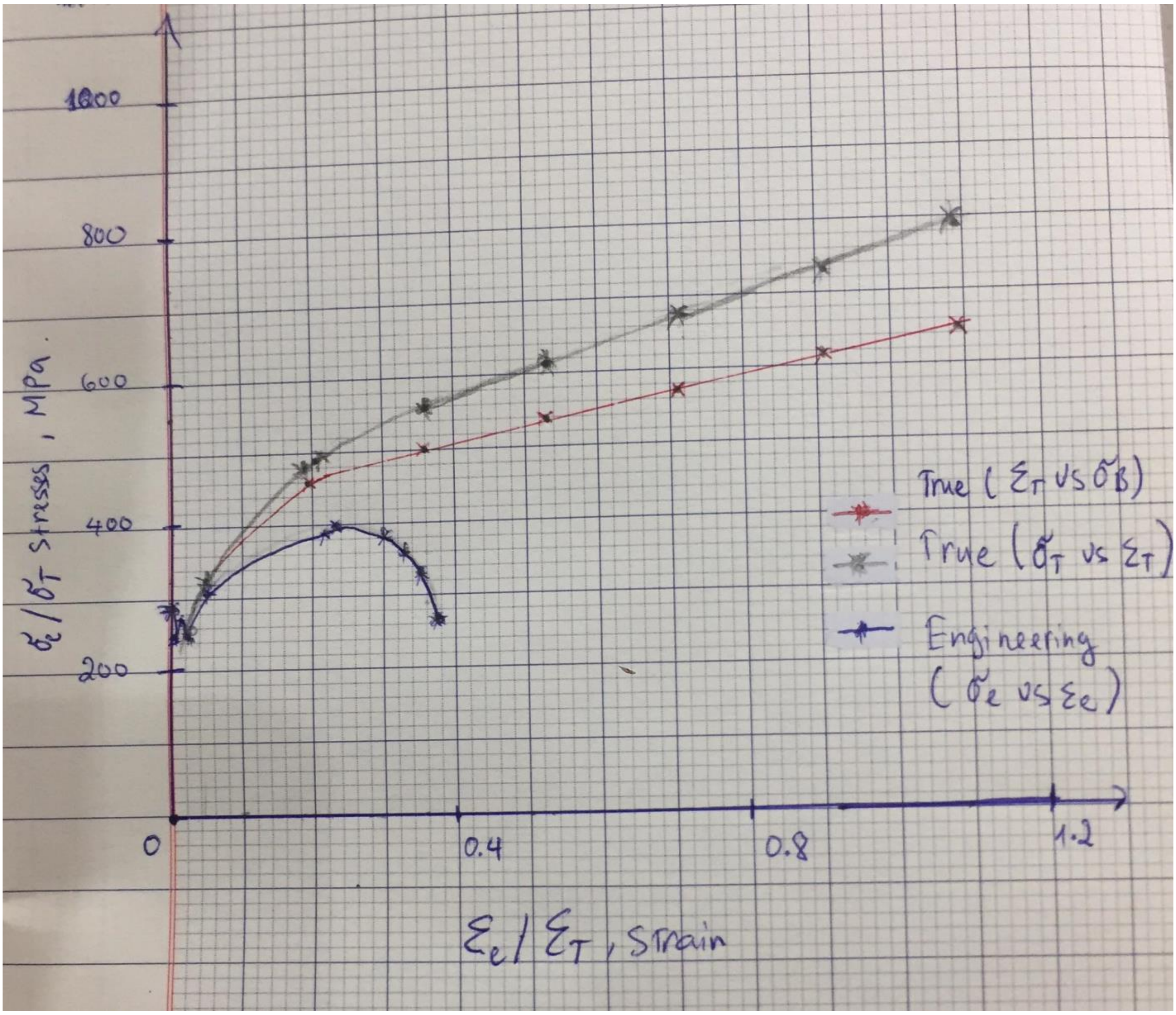

Figure 1. AISI 1020 hot-rolled steel stress-strain flow curves.

1.2 Comment:

- The true and engineering stress-strain flow curves differ drastically due to the large strains applied (diameter starts change from 9.11mm to 8.89mm and continues to fraction). When the diameter decreases, the true stress is larger than engineering stress with changing strain values.
- Using the equation:

  $$\sigma_B = \sigma_T (0.83 - 0.186 \log \varepsilon_T)$$

  to calculate corrected stress or Bridgman correction. The red curve is "corrected" true stress-strain curve takes into account the complex stress state within the neck region. As a consequence, the correct stress within the neck is slightly lower than the true stress.

2. Determine constants H and n

We have:

$$\sigma_T = H.\varepsilon_T^n$$

Take ln both side:

$$\ln(\sigma_T) = n ln(\varepsilon_T) + \ln(H)$$

$$\text{Or} \quad Y_i = aX_i + b$$

From least squares method, we have least squares normal equations:

$$\begin{cases} nb + a\sum \ln(\varepsilon_T)_i = \sum ln(\sigma_T)_i \\ b\sum ln(\varepsilon_T)_i + a\sum \left(ln(\varepsilon_T)_i^2\right) = \sum [ln(\varepsilon_T)_i \times ln(\sigma_T)_i] \end{cases}$$

Table 2. Data of set equations for calculating a and b

	$\ln(\varepsilon_T)$	$\ln(\sigma_T)$	$\ln(\varepsilon_T) \times \ln(\sigma_T)$	$(\ln(\sigma_T))^2$
1	-6.508979159	5.680172609	-36.97212513	42.36680969
2	-5.716867714	5.575949103	-31.8769634	32.68257646
3	-5.302325388	5.59471138	-29.66498019	28.11465452
4	-4.976233867	5.590986981	-27.82205876	24.7629035
5	-4.610182728	5.575949103	-25.70614425	21.25378478
6	-3.040102221	5.814130532	-17.67555114	9.242221516
7	-1.623486128	6.173786104	-10.0230561	2.635707208
8	-1.559410419	6.17586727	-9.630711766	2.431760854
9	-1.029487426	6.308098442	-6.494108027	1.05984436
10	-0.635293453	6.416732283	-4.076508008	0.403597771
11	-0.325951771	6.513230111	-2.122998892	0.106244557
12	-0.071700104	6.599870499	-0.473211402	0.005140905
13	0.086993877	6.677083461	0.580865376	0.007567935
$\sum$	-35.3130265	78.69656788	-201.9575517	165.0728141

And with data in Table 2, we got the results:

$$\begin{cases} a = n = 0.17 \\ b = \ln(H) = 6.52 \end{cases}$$

$$\rightarrow H = e^b = e^{6.52} = 678.58$$

Then,

$$\sigma_T = 678.58.\varepsilon_T^{0.17}$$

This equation results in a line that is a "best fit" to the data and to minimize the sum of the squares of the vertical deviations from estimating the parameter a and b (regression model).