Q) The plastic behaviour of a metal can be expressed as

$$\bar{\sigma} = 500\,\bar{\epsilon}^{0.5} \text{ MPa.}$$

Estimate the yield strength if a bar of this material is uniformly cold worked to a reduction of $r = 0.3$

Ans:

$$\epsilon = \ln\left[\frac{1}{1-r}\right] = \ln\left[\frac{1}{1-0.3}\right] = 0.357$$

$$r = \frac{A_0 - A}{A_0} \qquad \bar{\sigma} = 500(0.357)^{0.5} = 299 \text{ MPa.}$$

Q) (a) The strain hardening behavior of an annealed low-carbon steel is approximated by $\bar{\sigma} = 700\,\bar{\epsilon}^{0.2}$

estimate yield strength after bar is cold worked 50%.

(b) Suppose another bar of same steel was cold worked an unknown amount and then cold worked 15% more and found to have yield strength 525 MPa. What was the unknown amount of cold work?

Ans: (a) Strain was $\ln\left(\frac{1}{1-0.5}\right) = 0.693$, $\quad \sigma = 700(0.693)^{0.2}$

$$= 650 \text{ MPa.}$$

(b)

$$\bar{\epsilon} = \left(\frac{\bar{\sigma}}{K}\right)^{1/n} = \left(\frac{525}{700}\right)^{5} = 0.237.$$

15% cold work $\approx \ln\left[\frac{1}{1-0.15}\right] = 0.1625$

Hence unknown strain $= 0.237 - 0.1625 = 0.0745$

Calculate $r = ?$

$$\epsilon = \ln\frac{1}{1-r} \Rightarrow \frac{1}{1-r} = e^{\epsilon} \Rightarrow 1-r = \frac{1}{e^{\epsilon}}$$

$$\Rightarrow r = 1 - \frac{1}{e^{\epsilon}} = \frac{e^{\epsilon}-1}{e^{\epsilon}}$$

Q) An aluminium test specimen 100 mm long, 20 mm wide and 2 mm thick is elongated to 130 mm. If anisotropy ratio r = 2, determine true strain in length, width and thickness directions.

Ans:

$$\frac{\epsilon_w}{\epsilon_t} = 2$$

$$\epsilon_L + \epsilon_w + \epsilon_t = 0$$

$$\Rightarrow 3\epsilon_t = -\epsilon_L = -\ln\left(\frac{130}{100}\right)$$

$$= -0.262$$

$$\epsilon_t = -0.0873.$$

$$\epsilon_w = 2 \times \epsilon_t = -0.1746$$

Q) The K, n and m values for a stainless steel sheet are 1140 MPa, 0.35 and 0.01 respectively. A test piece has initial width, thickness and gauge length of 12.5, 0.45 and 50 mm respectively. Determine the increase in load when extension is 10% and the extension rate of gauge length is increased from 0.5 to 50 mm/min.

Ans:

$$\sigma = K \epsilon^n \dot{\epsilon}^m$$

$$\epsilon = \ln\left(\frac{l}{l_0}\right) = \ln\left(\frac{55}{50}\right) = 0.0953$$

as l = 10% ext. 50 $= 50 + \frac{50 \times 10}{100} = 55$

$$\dot{\epsilon}_1 = \frac{v_1}{l} = \left(\frac{0.5 \times 10^{-3}}{60}\right) \Big/ \left(55 \times 10^{-3}\right) = 0.1515 \times 10^{-3}\ \text{Sec}^{-1}$$

m/sec

$$\dot{\epsilon}_2 = \frac{v_2}{l} = \left(\frac{50 \times 10^{-3}}{60}\right) \Big/ \left(55 \times 10^{-3}\right) = 15.15 \times 10^{-3}\ \text{Sec}^{-1}$$

$$\sigma_1 = K \epsilon^n \dot{\epsilon}_1^m = 459\ \text{MPa} \qquad \sigma_2 = 480\ \text{MPa}$$

$$\Delta P = (\sigma_2 - \sigma_1) \cdot A = (\sigma_2 - \sigma_1) \cdot \frac{A_0 l_0}{l} = 0.27\ \text{kN}$$

Q1 A cylindrical test specimen of diameter 10mm and gauge length 50mm is extended to 65mm. Determine the true strain. Neglect elastic deformation. If the ultimate strength occurs at a force of 25000N and at an extension of 70mm, determine the strain hardening exponent n and ultimate strength of the material

Ans:

true strain at 65mm = $\epsilon = \ln \frac{65}{50} = 0.2623$

& true strain at 70mm = $\epsilon_u = \ln \frac{70}{50} = 0.3364$

$\epsilon_u = n = 0.3364.$

$\epsilon_u = \ln\left(\frac{l}{l_0}\right) = \ln\left(\frac{A_0}{A}\right)$

$\Rightarrow \frac{A_0}{A} = e^{\epsilon_u}$

$\Rightarrow A = \frac{A_0}{e^{\epsilon_u}} = \frac{\frac{\pi}{4} \times 10^2}{e^{0.3999}} = 56.104 mm^2.$

True ultimate strength $= \frac{25000}{56.104} = 445.6\ N/m^2$

Engg " $= \frac{25000}{\frac{\pi}{4} \times 10^2} = 318.31\ N/m^2$

Q) A mild steel rectangular specimen of length 100mm is extended to 120mm. Neglecting elastic deformation and taking the material as isotropic, determine the true strain in length, width and thickness direction.

Ans:

$$\epsilon_l = \ln\frac{120}{100} = 0.1823$$

$$\epsilon_l + \epsilon_w + \epsilon_t = 0 \Rightarrow \epsilon_w = \epsilon_t = -\tfrac{1}{2}\epsilon_l$$

$$= -0.09115$$

Q) Determine true strain in length, width and thickness of sheet if specimen is elongated to 130% of its original length and because of anisotropy the ratio $\epsilon_w/\epsilon_t = 1.5$. Also determine the % decrease in area of c/s.

Ans:

$$\epsilon_l = \ln\frac{130}{100} = 0.2623$$

$$\frac{\epsilon_w}{\epsilon_t} = 1.5 \qquad \epsilon_l + \epsilon_w + \epsilon_t = 0$$

$$\Rightarrow \epsilon_l + 1.5\epsilon_t + \epsilon_t = 0$$

$$\Rightarrow 2.5\epsilon_t = -\epsilon_l \Rightarrow \epsilon_t = -\epsilon_l/2.5$$

$$= -0.1049$$

and $\epsilon_w = 1.5\epsilon_t = -0.1573$.

during plastic deformation $\frac{da}{a} = -\frac{dl}{l} = -30\%$

Q1) Brass chaplets are used to support sand core inside a sand mold cavity. The projected core print area is 13 cm^2 for each end of the cylindrical sand core when support at both ends. ~~The ma~~ The design of the chaplets and the manner in which they are placed in the mold cavity surface allows each chaplet to sustain a force of 45N. If the volume of the core = 7.5×10^3 cm^3 and the metal poured is brass, determine the minimum number of chaplets that should be placed (a) beneath the core, and (b) above the core (Density of sand core and brass are 1.6 and 8.67 gm/cm^3 respectively and the green sand strength is 6.9×10^3 N/m^2.

Ans: (a) The weight of the core $= W_c = V_c \times \rho_c$

$$= \frac{7.5 \times \cancel{10^3}^{\,2} \times 1.6}{\cancel{1000}^{\,10}} \times 9.8 \text{ N}$$

$$= 117.6 \text{ N}.$$

The support from core print $= F_{cp} = 2 \times 6.9 \times \cancel{10^3} \times \frac{13}{\cancel{10000}\ 10}$

$$= 17.94 \text{ N}.$$

No of Chaplets requireds $= \dfrac{W_c - F_{cp}}{F_{chap}} = \dfrac{117.6 - 17.94}{45}$

$$= 2.21 \approx \underline{3 \text{ nos}}$$

(b) after pouring the liquid metal the bouyancy force.

$$= V_c \times (\rho_L) \times g$$

Net force $= V_c \times (\rho_L - \rho_c) \times g = \dfrac{7.5 \times 10^3 \times (8.67 - 1.6)}{1000} \times 9.8$

519.65N

Support f- Core pnt = 17.94

No of Chplets at top = $\dfrac{519.65 - 17.94}{45}$

$= 11.15 \approx 12$ Nos

Ans:

$\Delta T = 236^\circ C$

$T_E = 1085 + 273 = 1358^\circ K$.

$L = 1628 \ J/cm^3$.

$\gamma = 177 \times 10^{-7} \ J/cm^2$

$$r^* = \frac{2\gamma T_E}{L \Delta T} = \frac{2 \times (177 \times 10^{-7}) \times (1358)}{(1628) \times (236)}$$

$= 12.51 \times 10^{-8}$ cm.

Lattice parameter of FCC copper $a = 0.3615$ nm

$= 3.615 \times 10^{-8}$ cm.

Volume of unit cell $= a^3 = (3.615 \times 10^{-8})^3 = 47.24 \times 10^{-24}$ cm^3

The number of unit cells in the critical nucleus is

$$= \frac{\text{Vol of critical nucleus}}{\text{Vol of unit cell}}$$

$$= \frac{\left(\frac{4}{3}\pi r^3\right) = \frac{4}{3} \times \pi \times (12.51 \times 10^{-8})^3}{47.24 \times 10^{-24}}$$

$= 174$ unit cells

There are four atoms in each unit cell.

No of atoms in the critical nucleus $= 4 \times 174 = 696$ atoms.

Ans:

$\Delta T = 480^\circ C$

$r^* = \frac{2 \gamma T_E}{L \Delta T}$

$T_E = 1453 + 273 = 1726\ ^\circ K$

$L = 2756\ J/cm^3$

$\gamma = 255 \times 10^{-7}\ J/cm^2$

$$r^* = \frac{2 \gamma T_E}{L \times \Delta T} = \frac{2(255 \times 10^{-7})(1726)}{(2756)(480)}$$

$$= 6.654 \times 10^{-8}\ cm.$$

Volume of Nucleus $= \frac{4}{3}\pi r^{*3} = \frac{4}{3} \times \pi \times (6.654 \times 10^{-8})^3$

Lattice parameter of FCC nickel $= a = 0.356\ nm = 0.356 \times 10^{-9}\ m$

$= 0.356 \times 10^{-7}\ cm$

$= 3.56 \times 10^{-8}\ cm$

$$V_{unit\ cell} = a^3 = (3.56 \times 10^{-8})^3 = 45.11 \times 10^{-24}\ cm^3$$

$$\text{No of unit cell} = \frac{\frac{4}{3} \times \pi \times (6.654)^3 \times \cancel{10^{-24}}}{45.11 \times \cancel{10^{-24}}}$$

$$= \frac{4 \times \pi \times (6.654)^3}{3 \times 45.11} = 27.356$$

Contact angle related to Lattice mismatch. $\delta = \frac{\Delta a}{a}$

a is lattice parameter of crystal, $VC = \frac{\Delta a}{a} = 0.014$

for Al $\rightarrow$ $TiC = \frac{\Delta a}{a} = 0.060$ $TiB_2 = \frac{\Delta a}{a} = 0.048$

$\epsilon_1 + \epsilon_2 + \epsilon_3 = 0$

$\ln(1+e_1) + \ln(1+e_2) + \ln(1+e_3) = 0$

$\ln(1+e_1)(1+e_2)(1+e_3) = 0$

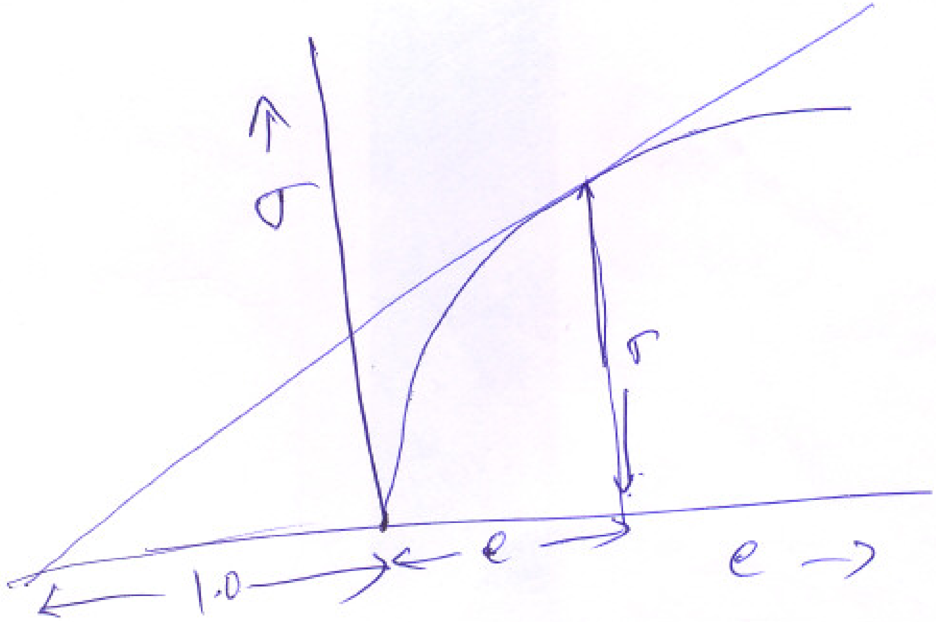
$\Rightarrow (1+e_1)(1+e_2)+(1+e_3) = 1$

$$\frac{d\sigma}{\cancel{\sigma}\, d\epsilon} = \sigma$$

$\epsilon = \ln(1+e)$

$d\epsilon = \frac{de}{1+e}$

$\therefore \frac{d\sigma}{de} = \frac{\sigma}{1+e}$



The following data pairs (load kN, extension mm) were obtained from plastic part of the load extension file of a tensile test of extra deep drawing quality steel of 0.8 mm thickness. The initial test piece width was 12.5 mm and gauge length was 50 mm.

1.57, 0.080 : 1.90, 0.760 : 2.24, 1.85 : 2.57, 3.66 :
2.78, 5.84 : 2.90, 8.92 : 2.93, 11.06 : 2.94, 13.49 :
2.92, 16.59 : 2.86, 19.48 : 2.61, 21.82 : 2.18, 22.69

obtain, eng stress strain, true stress - true strain, UTS, ϵ_u, total elongation %, K value, n-value.

Q16 Determine the work done if a bar of 10mm diameter and 200mm length is elongated by 22mm. The yield strength of the material of specimen is given as $\sigma = 250 \cdot \epsilon^{0.3}$ N/mm²
(Neglect elastic deformation)

(Ans 158.38 Nm)