**HW #6 Chapters 6 and 7**

**1) A cylindrical nickel wire 2 mm in diameter and 3 m long is subjected to a load of 300 N. What is the final length if a load of 300 N is applied? What load would be required to bring the sample to its yield stress? What would be the length of the sample loaded to the yield stress?**

F = 300 N, A = d2/4 = 3.14 10-6 m2, stress = F/A = 9.55 x 107 N/m2 = 95 MPa

strain  = l/l, Hooke’s law  = E From Table 6.1, E for Nickel is 207 GPa = 207 x 109 Pa. So  =/E = 0.00046, or 0.046%. Given l = 3 m, so l = l = (0.00046)(3 m) = 0.00138 m or 1.38 mm. Yield strength of Nickel = 138 MPa (Table 6.2), so F =  A = 433 N. l = l = (138 106/207 109)(3 m) = 0.002 m = 2 mm. So final length of sample = 3.002 m = 3002 mm

**2) The stress-strain plot enclosed (with the stress on the y-axis in Pa, and strain on x-axis) was determined using the small tensile testing machine demonstrated in class on an aluminum sample. The second graph shows the same data, replotted with a different x-axis scale to focus on the small strain region. From the data, estimate the following parameters: a) the Young’s modulus, b) the yield strength using plastic strain offset of 0.2%, c) the yield strength using the total strain of 0.5%, c) the elongation at break, d) the tensile strength, and e) the toughness, as determined by the total energy of failure.**

a) Young’s modulus: from initial slope: 2.2 108 Pa/0.005 = 4.4 1010 Pa = 44 GPa. Note, this value is somewhat smaller than text estimate of 69 GPa (Table 6.1). Perhaps different alloy?

b) Yield strength (using 0.2% plastic strain offset method): 3.8 108 Pa = 380 MPa… this is much higher than text estimate of 36 MPa (Table 6.2)… but a quick search of internet reveals that yield strengths of specific aluminum alloys can vary widely, and this number is reasonable:

http://www.amesweb.info/Materials/Aluminum-Yield-Tensile-Strength.aspx

c) Yield strength (using 0.5% total strain method) = 2.2 108 Pa = 220 MPa.

c’) Elongation at break: strain = 0.1 = 10%

d) Tensile strength (maximum engineering stress) = 4.7 108 Pa = 470 MPa

e) Toughness: approximate area under curve by taking areas of polygons.. a triangle up to knee in curve at strain of ~0.008 (A1), then a trapezoid (A2) from 0.008 to failure strain of 0.1

A1 = ½ b h = 0.5(0.008)(4 108) = 1.6 106 Pa = 1.6 MPa

A2 = (0.1-0.008)(4 108 + 4.8 108)/2 = 4.0 107 Pa = 40.5 MPa

Note.. trapezoid area is equal to a rectangle + triangle

So estimate of total energy to failure = ~42.1 MPa

More complicated methods for estimating the area under the curve are possible, but this approach is sufficiently accurate to give a reasonable value.

**3) A 70 Cu – 30 Zn Brass alloy is examined in a microscope and found to have an average grain diameter of 10 m. What is the expected yield strength of this sample, in MPa? The sample was then annealed at a particular temperature for 3 hours, and was found to have increased the average grain diameter to 100 m. What would be the expected yield strength of the annealed sample? If the sample were annealed for another 6 hours at this same temperature, what would be the final grain diameter? What would be the yield strength of the sample after this second annealing step?**

Figure 7.15 in text gives estimated yield strength of 70-30 brass as a function of grain size. For d=10 **m** (10-2 mm), graph shows yield strength = 160 MPa. After annealing for 3 hours, new grain size is 100 **m** (10-1 mm), so now yield strength = 70 MPa (from this same graph). From relationship given in class (equation 7.9 in text, with n=2), d2 – d02 = K t, where d0 is initial grain size, d is grain size after some time t, and K is a constant. So K=(1002-102)/3 = 3300 **m**2/hr. So new grain size after another 6 hours given by d2 = K (3 + 6 hr) + d02 , so d= 164 **m**. From the graph 7.15 again, new yield strength is about 50 MPa.

**4) A rod-shaped sample of pure copper with an initial cross section of 10 mm x 10 mm is drawn through a rigid die with a cross section of 9 mm x 9 mm. What is the percent cold work induced by this process? What is the expected yield strength and percent elongation of the initial pure copper sample? What is the expected yield strength and percent elongation of the copper after deformation? What would be the amount of nickel that would need to be added to copper to give an alloy with the same yield strength as the deformed sample? What would be the percent elongation of this copper-nickel alloy?**

%CW = (Ao-Ad)/Ao x 100 = ((10 x 10)-(9 x 9))/(10 x 10) x 100 = 19%

From graph 7.19a, at 0% cold work copper should have a yield strength 160 MPa, and from Figure 7.19c percent elongation 44%.

After CW deformation of 19%, yield strength of copper = 250 MPa, percent elongation 15%.

To get copper to a yield strength of 250 MPa, would require more than 50% nickel, per Figure 7.16b, so if this is strictly true then it is not possible to match this yield strength. However note from Figure. 7.19b that the tensile strength after 19% CW should go up from 220 MPa to 300 MPa. Graph 7.16a suggests that a tensile strength of 300 MPa can be obtained after 13 wt% nickel addition. This 13% copper-nickel alloy has a percent elongation of 45%, down from 55% for the pure copper sample.







3.8 108 Pa

2.2 108 Pa

0.002





A1

A2