Mae 20 Homework 4 solution

4-27 A copper-zinc alloy has the following properties:

grain diameter (mm)	strength (MPa)	$d^{-½}$
0.015	170 MPa	8.165
0.025	158 MPa	6.325
0.035	151 MPa	5.345
0.050	145 MPa	4.472

Determine (a) the constants in the Hall-Petch equation and (b) the grain size required to obtain a strength of 200 MPa.

Solution: *The values of $d^{-½}$ are included in the table; the graph shows the relationship. We can determine K and σ_o either from the graph or by using two of the data points.*

(a) $170 = \sigma_o + K(8.165)$

$145 = \sigma_o + K(4.472)$

$25 = 3.693K$

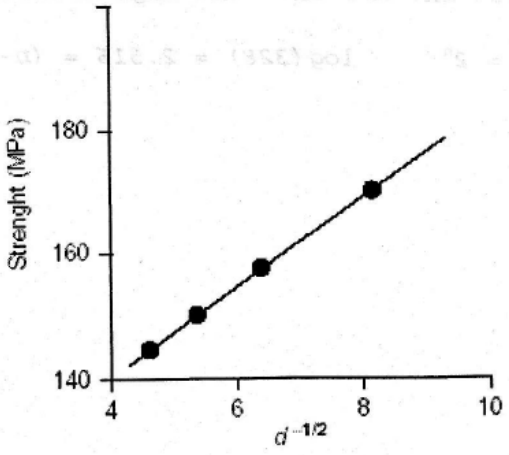
$K = 6.77$ MPa/$\sqrt{mm}$ $\quad \sigma_o = 114.7$ MPa

(b) To obtain a strength of 200 MPa:

$200 = 114.7 + 6.77/\sqrt{d}$

$85.3 = 6.77/\sqrt{d}$

$d = 0.0063$ mm



4-31 Determine the ASTM grain size number for the materials in
a. Figure 4-15 b. Figure 4-18

Solution: *(a) There are about 26 grains in the photomicrograph, which has the dimensions 2.375 in. x 2 in. The magnification is 100, thus:*

$$\frac{26}{(2.375)(2)} = 2^{n-1} \quad \log(5.47) = 0.738 = (n-1)\log(2) \qquad n = 3.5$$

(b) There are about 59 grains in the photomicrograph, which has the dimensions 2.25 in. x 2 in. The magnification is 500, thus:

$$\frac{59(500/100)^2}{(2.25)(2)} = 2^{n-1} \quad \log(328) = 2.516 = (n-1)\log(2) \qquad n = 9.4$$

4.33

The grain size of this 0.12% carbon steel is around 8.26 *10^{-5} mm. As long as this material obeys the linear relationship of a Hall-Petch equation, we can use it to predict possible yield strength.

5-4 Atoms are found to move from one lattice position to another at the rate of 5 x 10^5 jumps per second at 400°C when the activation energy for their movement is 30,000 cal/mol. Calculate the jump rate at 750°C.

Solution:

$$\text{Rate} = \frac{5\times10^5}{x} = \frac{c_o \exp[-30{,}000/(1.987)(673)]}{c_o \exp[-30{,}000/(1.987)(1023)]}$$

$$= \exp(-22.434 + 14.759)$$

$$\frac{5\times10^5}{x} = \exp(-7.675) = 4.64\times10^{-4}$$

$$x = \frac{5\times10^5}{4.64\times10^{-4}} = 1.08\times10^9 \text{ jumps/s}$$

5.28

Solution: $D = 0.23\ exp[-32{,}900/(1.987)(1253)] = 42 \times 10^{-8}\ cm^2/s$

$$\frac{1 - c_x}{1 - 0.1} = erf[x/(2\sqrt{(42 \times 10^{-8})(3600)}] = erf[x/0.0778]$$

$x = 0.01$: $erf[0.01/0.0778] = erf(0.1285) = \frac{(1 - c_x)}{0.9} = 0.144$ $c_x = 0.87\%\ C$

$x = 0.05$: $erf[0.05/0.0778] = erf(0.643) = \frac{(1 - c_x)}{0.9} = 0.636$ $c_x = 0.43\%\ C$

$X = 0.10$: $erf[0.10/0.0778] = erf(1.285) = \frac{(1 - c_x)}{0.9} = 0.914$ $c_x = 0.18\%$