재료공학 원리 Homework

7장 Dislocations and Strengthening Mechanisms 예제문제

1.

EXAMPLE PROBLEM 9.1

Resolved Shear Stress and Stress-to-Initiate-Yielding Computations

Consider a single crystal of BCC iron oriented such that a tensile stress is applied along a [010] direction.

(a) Compute the resolved shear stress along a (110) plane and in a $[\bar{1}11]$ direction when a tensile stress of 52 MPa is applied.

(b) If slip occurs on a (110) plane and in a $[\bar{1}11]$ direction, and the critical resolved shear stress is 30 MPa, calculate the magnitude of the applied tensile stress necessary to initiate yielding.

(a)

$$\tau_R = \sigma \cos\lambda \cos\phi$$

$$= 52\text{MPa} \cdot \frac{(0,1,0)\cdot(1,1,0)}{\sqrt{(0^2+1^2+0^2)\cdot(1^2+1^2+0^2)}} \cdot \frac{(0,1,0)\cdot(-1,1,1)}{\sqrt{(0^2+1^2+0^2)\cdot((-1)^2+1^2+1^2)}}$$

$$= 52\text{MPa} \cdot \frac{1}{\sqrt{2}} \cdot \frac{1}{\sqrt{3}} = 21.3\text{ MPa}$$

(b)

$$\sigma_y = \frac{\tau_{CRSS}}{(\cos\phi \cos\lambda)_{max}} = \frac{30\text{ MPa}}{(1/\sqrt{2})\cdot(1/\sqrt{3})} = 73.4\text{ MPa}$$

2.

EXAMPLE PROBLEM 9.2

Tensile Strength and Ductility Determinations for Cold-Worked Copper

Compute the tensile strength and ductility (%EL) of a cylindrical copper rod if it is cold worked such that the diameter is reduced from 15.2 mm to 12.2 mm.

$$\%CW = \frac{A_0 - A_d}{A_0} \times 100$$

$$= \frac{\pi(15.2\text{mm}/2)^2 - \pi(12.2\text{mm}/2)^2}{\pi(15.2\text{mm}/2)^2} \times 100$$

$$= 35.6\%$$

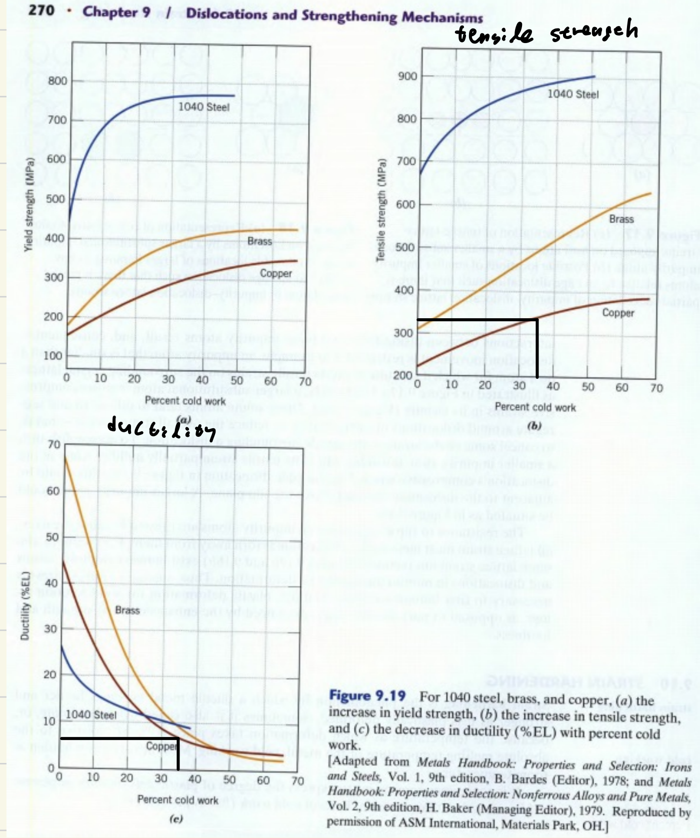


Figure 9.19 For 1040 steel, brass, and copper, (a) the increase in yield strength, (b) the increase in tensile strength, and (c) the decrease in ductility (%EL) with percent cold work.
[Adapted from *Metals Handbook: Properties and Selection: Irons and Steels*, Vol. 1, 9th edition, B. Bardes (Editor), 1978; and *Metals Handbook: Properties and Selection: Nonferrous Alloys and Pure Metals*, Vol. 2, 9th edition, H. Baker (Managing Editor), 1979. Reproduced by permission of ASM International, Materials Park, OH.]

Tensile strength ≈ 330 MPa

Ductility ≈ 6 %EL

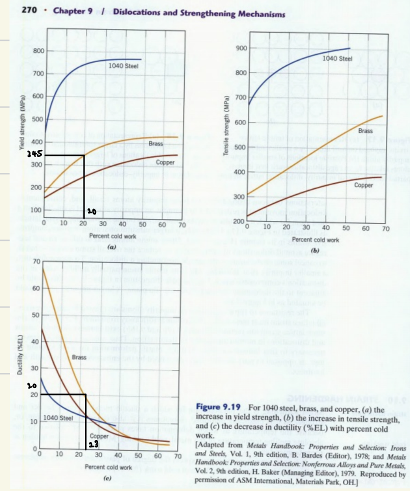
3.

DESIGN EXAMPLE 9.1

Description of Diameter Reduction Procedure

A cylindrical rod of noncold-worked brass having an initial diameter of 6.4 mm is to be cold worked by drawing such that the cross-sectional area is reduced. It is required to have a cold-worked yield strength of at least 345 MPa and a ductility in excess of 20%EL; in addition, a final diameter of 5.1 mm is necessary. Describe the manner in which this procedure may be carried out.

Brass



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6.4mm → 5.1mm의 % CW를 계산한다.

$$\%CW = \frac{\pi(0.4\,mm/2)^2 - \pi(5.1\,mm/2)^2}{\pi(6.4\,mm/2)^2} \times 100 = 36.5\%\,CW$$

그러나 이 %CW는 주어진 σ_y, %EL 기준을 만족시키지 못한다.

따라서 공정에 heat treatment에 의한 recrystallization으로 cold work의 과정을 nullify하는 과정을 추가해야 한다. 필요한 공정은 다음과 같다.

① cold work : 6.4mm → d

② heat treatment (①에 의한 σ_y, %EL 변화 무효화

③ cold work : d → 5.1mm, %EL < 20, σ_y > 345MPa

%EL < 20, σ_y > 345MPa 조건을 위해 필요한 %CW의 범위는 20 < %CW < 23이다 (Figure 9.17 a, c). 여기서 21.5%CW를 택한다. 즉, 다음이 성립한다.

$$21.5\%\,CW = \frac{\pi(d/2)^2 - \pi(5.1\,mm/2)^2}{\pi(d/2)^2} \times 100$$

$\therefore d = 5.8\,mm$

따라서 전체 공정은 다음과 같다.

① cold work : 6.4mm → 5.8mm

② heat treatment

③ cold work : 5.8mm → 5.1mm

4.

EXAMPLE PROBLEM 9.3

Computation of Grain Size after Heat Treatment

When a hypothetical metal having a grain diameter of 8.2×10^{-3} mm is heated to 500°C for 12.5 min, the grain diameter increases to 2.7×10^{-2} mm. Compute the grain diameter when a specimen of the original material is heated at 500°C for 100 min. Assume the grain diameter exponent n has a value of 2.

$$d^n - d_0^n = Kt$$

$n = 2$

$$K = \frac{d^n - d_0^n}{t} = \frac{(2.7\times10^{-2}\,mm)^2 - (8.2\times10^{-3}\,mm)^2}{12.5\,min} = 5.29\times10^{-5}\,mm^2/min$$

$$d = \left(d_0^n + Kt\right)^{\frac{1}{n}}$$

$$d = \left((8.2\times10^{-3}\,mm)^2 + 5.29\times10^{-5}\,mm^2/min \cdot 100\,min\right)^{\frac{1}{2}}$$

$$= 7.3\times10^{-2}\,mm$$