ENGG103 – Materials in Design

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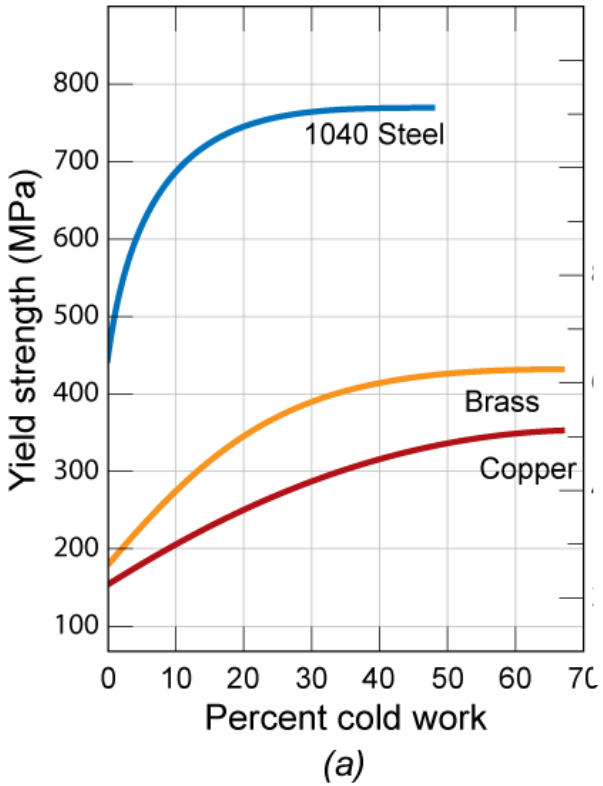
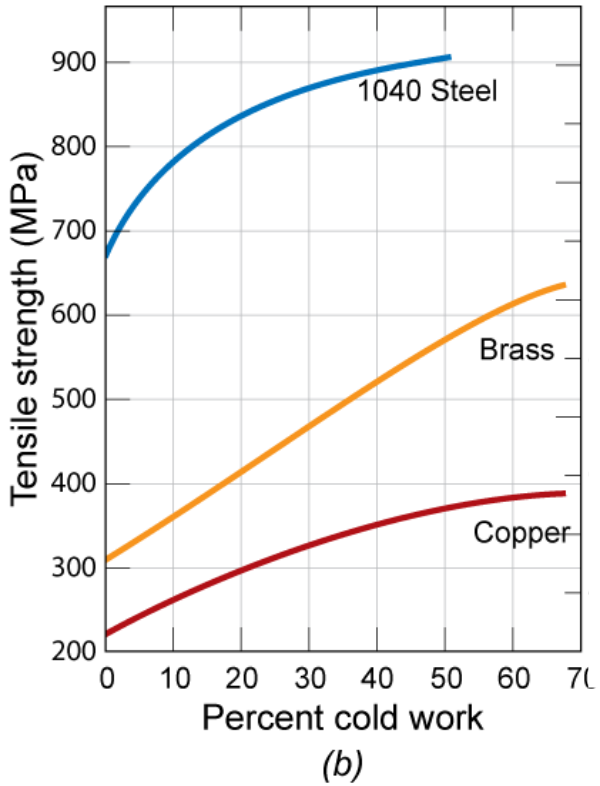
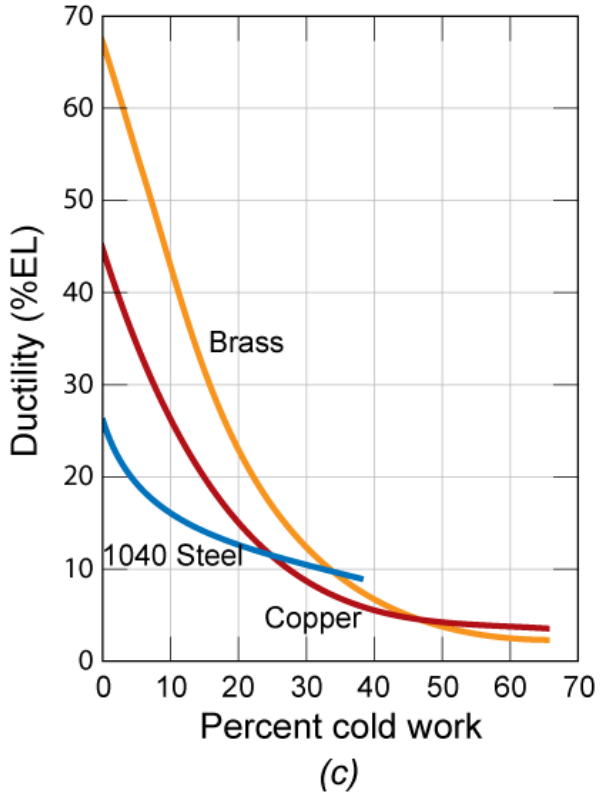
Strengthening Mechanisms

Exam Example

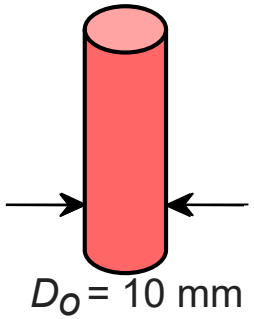






Diameter Reduction Procedure - Problem

A cylindrical rod of brass originally 10 mm in diameter is to be cold worked by drawing.



The circular cross section will be maintained during deformation.

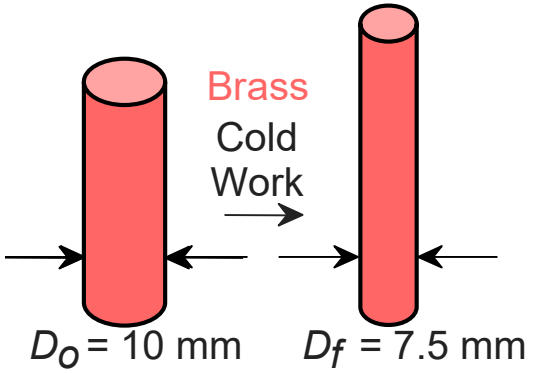
A cold-worked tensile strength in excess of 380 MPa and a ductility of at least 15 %*EL* are desired.

Furthermore, the final diameter must be 7.5mm.

Explain how this may be accomplished.

Diameter Reduction Procedure - Solution

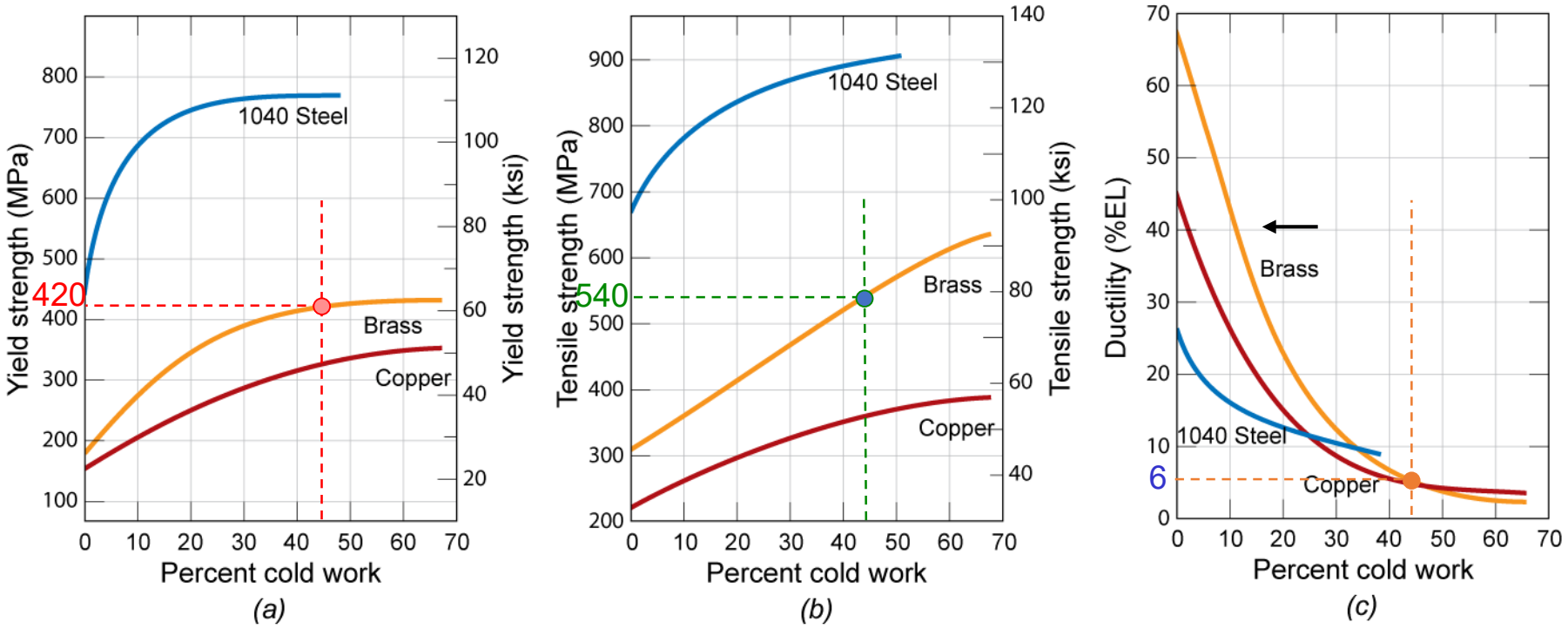
What are the consequences of directly drawing to the final diameter?



$$\%CW = \left(\frac{A_o - A_f}{A_o} \right) x\,100 = \left(1 - \frac{A_f}{A_o} \right) x\,100$$

$$= \left(1 - \frac{\pi D_f^2 / 4}{\pi D_o^2 / 4} \right) x\,100 = \left(1 - \left(\frac{7.5}{10} \right)^2 \right) x\,100 = 43.8\%$$

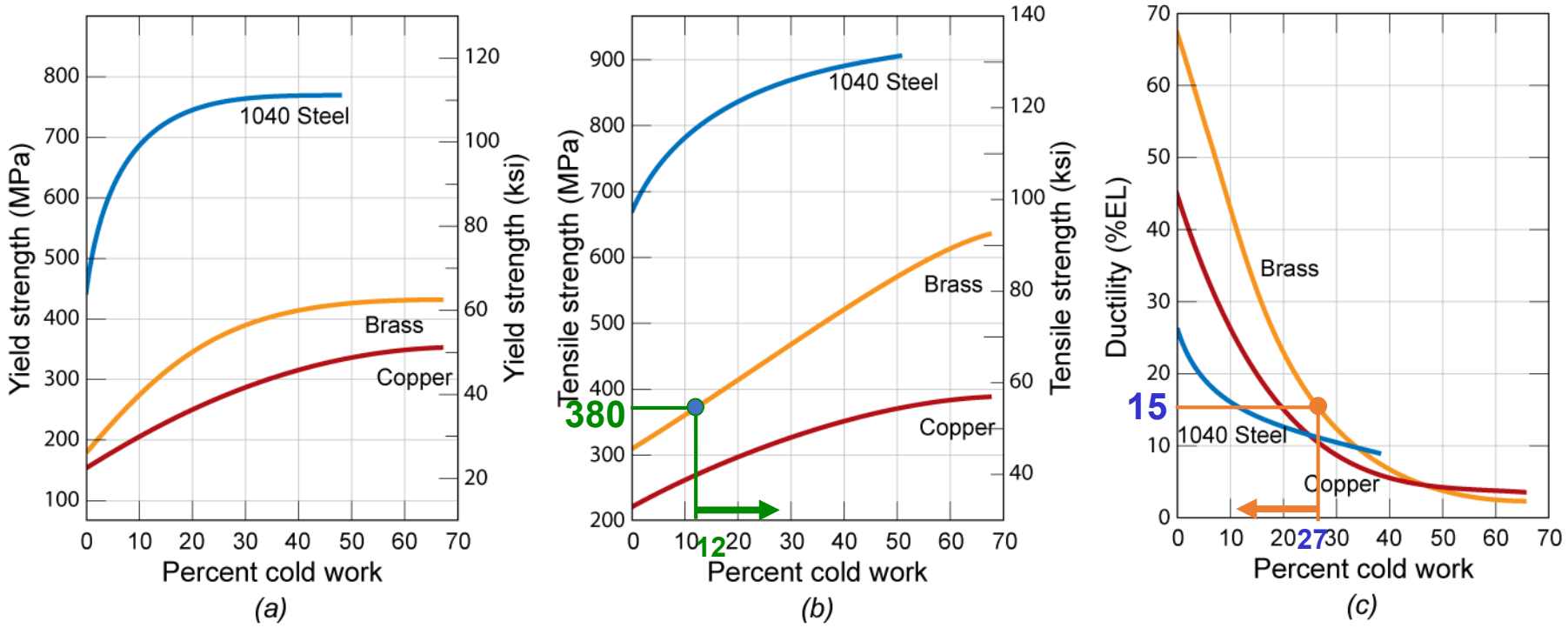
Diameter Reduction Procedure – Solution (Cont.)



Adapted from Fig. 7.19, *Callister & Rethwisch 8e.*

- For %CW = 43.8%
  - σ_y = 420 MPa
  - *TS* = 540 MPa > 380 MPa
  - %*EL* = 6 < 15
- This doesn't satisfy criteria… what other options are possible?

Diameter Reduction Procedure – Solution (cont.)



Adapted from Fig. 7.19, *Callister & Rethwisch 8e.*

For *TS* > 380 MPa → > 12 %CW

For %*EL* > 15 → < 27 %CW

∴ our working range is limited to 12 < %CW < 27

Diameter Reduction Procedure – Solution (cont.)

Cold work, then anneal, then cold work again

- For objective we need a cold work of 12 < %CW < 27
  - We'll use 20 %CW
- Diameter after first cold work stage (but before 2nd cold work stage) is calculated as follows:

$$\%CW = \left(1 - \frac{D_{f2}^{\,2}}{D_{02}^{\,2}}\right) x\,100 \quad \Rightarrow \quad 1 - \frac{D_{f2}^{\,2}}{D_{02}^{\,2}} = \frac{\%CW}{100}$$

$$\frac{D_{f2}}{D_{02}} = \left(1 - \frac{\%CW}{100}\right)^{0.5} \quad \Rightarrow \quad D_{02} = \frac{D_{f2}}{\left(1 - \frac{\%CW}{100}\right)^{0.5}}$$

$$\text{Intermediate diameter} = D_{f1} = D_{02} = 7.5\,\text{mm} \Big/ \left(1 - \frac{20}{100}\right)^{0.5} = \boxed{8.39\,\text{mm}}$$

Diameter Reduction Procedure – Summary

Stage 1: Cold work – reduce diameter from 10 mm to 8.39 mm

$$\%CW_1 = \left(1 - \left(\frac{8.39\,\text{mm}}{10\,\text{mm}}\right)^2\right) x\,100 = 29.6$$

Stage 2: Heat treat (allow recrystallization)

Stage 3: Cold work – reduce diameter from 8.39 mm to 7.5 mm

$$\%CW_2 = \left(1 - \left(\frac{7.5}{8.49}\right)^2\right) x\,100 = 20$$

Fig 7.19 $\Rightarrow$

$\sigma_y = 340\,\text{MPa}$

$TS = 400\,\text{MPa}$

$\%EL = 24$

Therefore, all criteria satisfied