CARLETON UNIVERSITY

FINAL

EXAMINATION

April 2013 (Solutions)

Question 1

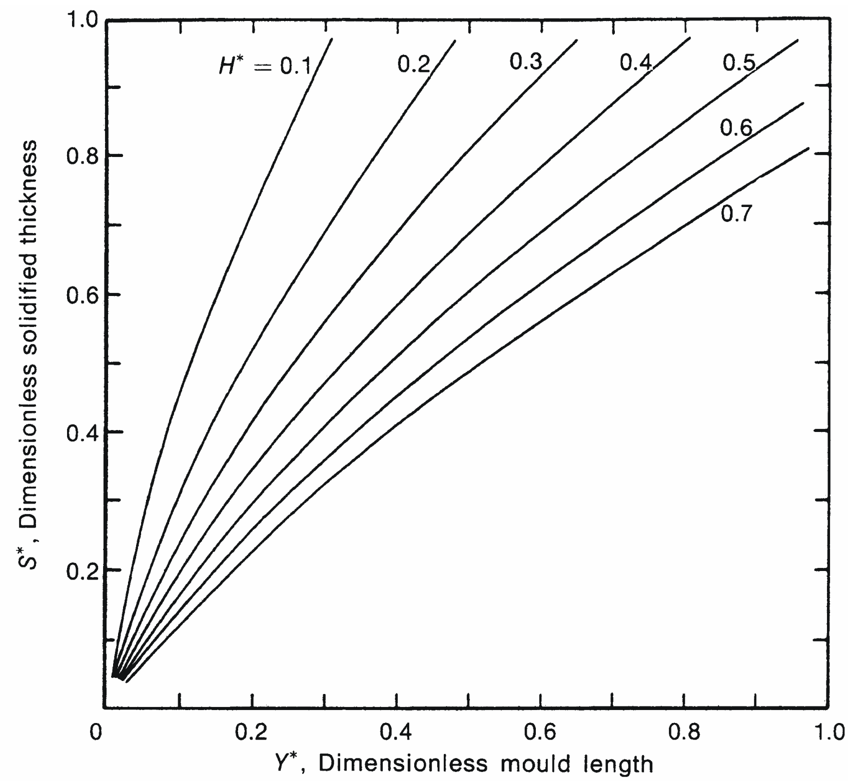

Fig. 1. Solidification diagram for continuous casting.

$\delta := 2.5 \cdot 10^{-2}$

$L := 1.0$ $\quad Tp := 1560$ $\quad Tm := 1520$ $\quad T0 := 25$

$Cs := 0.77 \cdot 10^{3}$ $\quad \rho := 7.9 \cdot 10^{3}$ $\quad Hf := 280 \cdot 10^{3}$ $\quad ks := 73$

$hf := 1200$

Dimensionless solidified thickness:

$$Sdl := \frac{hf \cdot \delta}{ks}$$

$Sdl = 0.411$

Dimensionless latent heat:

$$Hdl := \frac{Hf + Cs \cdot (Tp - Tm)}{Cs \cdot (Tm - T0)}$$

$Hdl = 0.27$

$Ydl := 0.22$

Required speed of withdrawal:

$$u := \frac{hf^{2} \cdot L}{Ydl \cdot ks \cdot \rho \cdot Cs}$$

$u = 0.015$

Find thickness at a shorter length (L-dL) from entrance:

$dL := 0.2$

Dimensionless length:

$$Ydl2 := \frac{hf^2 \cdot (L - dL)}{u \cdot ks \cdot \rho \cdot Cs}$$

$Ydl2 = 0.176$

Dimensionless solid skin from the graph:

$Sdl2 := 0.38$

Skin thickness:

$$\delta2 := \frac{Sdl2 \cdot ks}{hf}$$

$\delta2 = 0.023$

Time required to move forward by dL:

$$dt := \frac{dL}{u}$$

$dt = 13.568$

Growth Rate:

$$v := \frac{\delta - \delta2}{dt} \qquad v = 1.388 \times 10^{-4}$$

Question 2.

$d0 := 0.04 \qquad h0 := 0.03$

$F1 := 1250 \cdot 9.8 \qquad F2 := 1500 \cdot 9.8 \qquad F3 := 1350 \cdot 9.8$

$t1 := 100 \qquad t2 := 50 \qquad t3 := 120$

$h1 := 0.019 \qquad h2 := 0.021$

$$V := h0 \cdot \left(\pi \cdot \frac{d0^2}{4}\right) \qquad V = 3.77 \times 10^{-5}$$

$$C1 := \sqrt{\frac{2 \cdot F1^2 \cdot t1}{V^2 \cdot \left(\frac{1}{h1^2} - \frac{1}{h0^2}\right)}} \qquad C1 = 112.824 \times 10^6$$

$$C2 := \sqrt{\frac{2 \cdot F2^2 \cdot t2}{V^2 \cdot \left(\frac{1}{h2^2} - \frac{1}{h0^2}\right)}} \qquad C2 = 114.662 \times 10^6$$

$$C := \frac{(C1 + C2)}{2} \qquad C = 113.743 \times 10^6$$

$$h3 := \frac{1}{\sqrt{\frac{1}{h0^2} + \frac{2 \cdot F3^2 \cdot t3}{C^2 \cdot V^2}}} \qquad h3 = 0.017$$

Question 3.

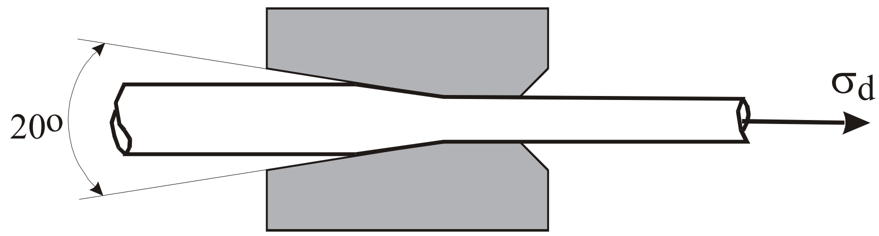

Fig. 2 Principle scheme of the drawing process and die geometry.

$d0 := 3.0 \cdot 10^{-3}$ $dfin := 0.75 \cdot 10^{-3}$ $\alpha := \frac{20 \cdot \pi}{180}$ $\mu := 0.2$

$l0 := 4 \cdot 10^{-2}$ $Fmax := 2.5 \cdot 10^{3}$ $\Delta l := 12 \cdot 10^{-3}$ $\alpha = 0.349$

$eneck := \frac{\Delta l}{l0}$ $eneck = 0.3$

$\varepsilon neck := \ln(eneck + 1)$ $\varepsilon neck = 0.262$

$n := \varepsilon neck$ $n = 0.262$

$$UTS := \frac{Fmax}{\pi \cdot \frac{d0^2}{4}} \qquad UTS = 354 \times 10^6$$

$$\sigma neck := \frac{UTS}{\exp(-\varepsilon neck)} \qquad \sigma neck = 460 \times 10^6$$

$$K := \frac{\sigma neck}{n^n} \qquad K = 653 \times 10^6$$

$$\varepsilon max := n + 1 \qquad \varepsilon max = 1.26$$

$$\varepsilon total := \ln\left(\frac{d0^2}{dfin^2}\right) \qquad \varepsilon total = 2.77$$

$$N := ceil\left(\frac{\varepsilon total}{\varepsilon max}\right) \qquad N = 3$$

$$\varepsilon actual := \frac{\varepsilon total}{N} \qquad \varepsilon actual = 0.92$$

$$ractual := 1 - \exp(-\varepsilon actual) \qquad ractual = 0.6$$

$$\Delta := \frac{\alpha}{ractual} \cdot \left[1 + (1 - ractual)^{\frac{1}{2}}\right]^2$$

$$\sigma dreal := \frac{K \cdot \varepsilon actual^n}{n + 1} \cdot \frac{3.2}{\Delta + 0.9} \cdot (\alpha + \mu) \qquad \sigma dreal = 365 \times 10^6$$

$$\sigma ydrawn := K \cdot \varepsilon actual^n \qquad \sigma ydrawn = 639.775 \times 10^6$$

Drawing stress is significantly below the yield strength of drawn material, therefore drawing is possible.

Question 4.

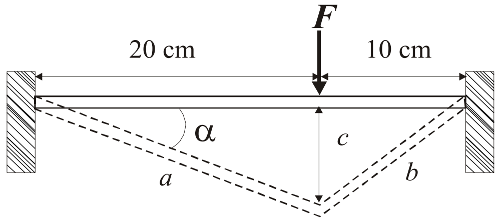

Fig. 3

$L0 := 30\cdot 10^{-2}$ $a0 := 20\cdot 10^{-2}$ $b0 := L0 - a0$ $b0 = 0.1$

$K := 250\cdot 10^{6}$ $A := 2.0\cdot 10^{-4}$

$n := 0.45$

$\alpha := \frac{30\cdot\pi}{180}$

$a := \frac{a0}{\cos(\alpha)}$ $a = 0.231$

$b := \sqrt{b0^2 + (a0\cdot\tan(\alpha))^2}$ $b = 0.153$

$\varepsilon := \ln\left(\frac{a + b}{a0 + b0}\right)$ $\varepsilon = 0.246$

The work per unit volume:

$u := \frac{K\cdot\varepsilon^{n+1}}{n + 1}$ $u = 2.257\times 10^{7}$ J/m^3

$V := L0\cdot A$ $V = 6\times 10^{-5}$

The total work of stretching:

$W := u\cdot V$ $W = 1.354\times 10^{3}$

$Lmax := L0 \cdot e^{n}$ $Lmax = 0.47$ m

$a_{max}{}^2 - a_0{}^2 = b_{max}{}^2 - b_0{}^2$ & $a_{max} = L_{max} - b_{max}$

$b_{max}{}^2 - a_{max}{}^2 = b_0{}^2 - a_0{}^2$

$b_{max}{}^2 - (L_{max} - b_{max})^2 = b_0{}^2 - a_0{}^2$

$bmax := \frac{Lmax^2 + \left(b0^2 - a0^2\right)}{2 \cdot Lmax}$ $bmax = 0.203$

$amax := Lmax - bmax$ $amax = 0.267$

$\alpha max := acos\left(\frac{a0}{amax}\right)$ $\alpha max = 0.725$

$\alpha maxdeg := \frac{\alpha max \cdot 180}{\pi}$

$\alpha maxdeg = 41.522$

Question 5.

$w := 20 \cdot 10^{-3}$ $dc := 0.2 \cdot 10^{-3}$ $dcp := 0.22 \cdot 10^{-3}$ $\alpha := \frac{12 \cdot 2 \cdot \pi}{360}$ $Fc := 1920$ N

$\phi := \operatorname{atan}\left(\frac{dc}{dcp} \cdot \frac{\cos(\alpha)}{1 - \frac{dc}{dcp} \cdot \sin(\alpha)}\right)$ $tngns := \frac{dc}{dcp} \cdot \frac{\cos(\alpha)}{1 - \frac{dc}{dcp} \cdot \sin(\alpha)}$

$\phi deg := \phi \cdot \frac{360}{2 \cdot \pi}$ $\phi deg = 47.635$ Shear Angle $tngns = 1.096$

$\beta := \frac{\pi}{2} + \alpha - 2 \cdot \phi$ $\beta deg := \beta \cdot \frac{360}{2 \cdot \pi}$ $\beta deg = 7$

Friction Coefficient

$\mu := \tan(\beta)$ $\mu = 0.118$

$R := \frac{Fc}{\cos(\beta - \alpha)}$ $R = 1.928 \times 10^{3}$

$Fs := R \cdot \cos(\phi + \beta - \alpha)$ $Fs = 1.425 \times 10^{3}$

$\tau s := \frac{Fs \cdot \sin(\phi)}{w \cdot dc}$ $\tau s = 263.15 \times 10^{6}$ Pa

$\sigma y := 2 \cdot \tau s$ $\sigma y = 526.3 \times 10^{6}$ Pa Yield Strength

Question 6. a). Describe briefly the major advantages of the metal injection moulding process as compared to other powder metallurgy processes.

Complex shapes can be produced with very good dimensional accuracy and high density (>99%)

b). What are the driving force(s) and mechanism of densification during the sintering process used in powder metallurgy?

Driving force – Surface Energy, Mechanism – Diffusion.

c) List three major groups of fusion welding processes. For each group list two types of welding processes belonging to it.

Arc welding: Manual, MIG, TIG etc.
Thermal: Gas, thermit, electron beam, etc.
Resistance: Spot, seam.