 Aleeuy J.B.

CARLETON UNIVERSITY

FINAL EXAMINATION December 2000

Duration: 3 HOURS

No. of Students: 54

Department Name & Course Number: **Mechanical & Aerospace Engineering 88.370** A

Instructor(s): **A. Artemev**

AUTHORIZED MEMORANDA

Calculators only

Student **MUST** count the number of pages in this examination question paper **before** beginning to write and report any discrepancy immediately to a proctor. This question paper has 5 pages.

This examination paper **MAY** be taken from the examination room.

All questions have the same value.

1. (a) List four basic raw materials used in making pig iron and explain their functions. (b) List major types of steel making processes. Describe briefly the advantages and disadvantages of every process. (c) What are the major products of the Bayer and Hall-Héroult processes?

2. A very large 150 mm-thick iron plate is cast by pouring iron into a sand mould at the temperature 50 °C above the plate's melting temperature, so that heat is withdrawn from both faces of the solidifying plate. Estimate (by calculation) the solidification rate df_S / dt, where f_S is a fraction of solid and t is time, at the moment when the fraction of the solid phase in the casting is 0.2. Material parameters of iron are: melting point 1540 °C; density 7.9 g/cm^3; specific heat 0.77 $J/g°C$; latent heat of

solidification 280 J/g; thermal conductivity 73 $W/m^\circ C$. Material parameters of sand are: density 1.5 g/cm^3; specific heat 1.15 $J/g^\circ C$; thermal conductivity 0.6 $W/m^\circ C$.

3. The motors of a rolling mill are capable of producing 1400 *kW* when the work rolls are rotating at 100 *rpm*. The mill is to be used for cold rolling of AA-2017 from 30 *mm* to 20 *mm* thickness. The mill has an efficient lubrication system that reduces friction to such low values that a zero friction coefficient can be assumed. If the work roll diameter is 30 cm, what is the maximum width that can be rolled at full power? Is the deformation produced under the described conditions homogeneous or inhomogeneous? Material properties of AA-2017 are: yield strength 100 *MPa*; ultimate tensile strength 180 *MPa*; percent elongation 30%; strength constant (strain hardening coefficient) 380 *MPa*; strain hardening exponent 0.15.

4. A piece of sheet metal with the length of 500 *mm* and thickness of 0.4 *mm* is to be bent through 90° using either a v-die with a width of 50 *mm* or a wiping die with the die radii of 15 *mm* (Fig. 1). Calculate the bending force for the two die arrangements.

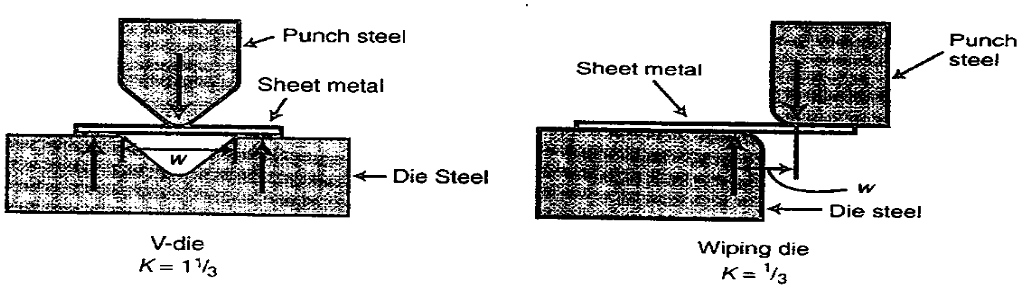

Fig. 1

5. An orthogonal machining operation is performed on a mild steel part 10 *mm* wide. The tool cutting depth is 0.2 *mm*, thickness of the chip is 0.25 *mm* and the tool rake angle is 15°. The cutting force is measured as 3000 *N*. Determine the shear angle and the friction coefficient between the chip and tool face, and estimate the yield strength of the workpiece material.

6. Explain why reverse polarity results in the deepest penetration for MIG welding, but straight polarity causes the deepest penetration during TIG or shielded (manual) metal arc welding.

Aleury 5.8

$$J=-k_m\frac{\partial T}{\partial x} \qquad \frac{\partial^2 T}{\partial x^2}=\frac{1}{\alpha_{th}}\cdot\frac{\partial T}{\partial t} \qquad \alpha_{th}=\frac{k_m}{C_m\cdot\rho_m} \qquad \frac{dQ}{dt}=\rho_c\Delta H_f\frac{dV}{dt}$$

$$\lambda=\frac{x}{\sqrt{t}} \qquad T(x)=A\cdot\int\exp\left(\frac{-\lambda^2}{4\cdot\alpha_{th}}\right)d\lambda+B \qquad \mathrm{erf}(x)=\frac{2}{\sqrt{\pi}}\cdot\int_0^x\exp\left(-\xi^2\right)d\xi$$

$$\mathrm{erf}(x)=\frac{2}{\sqrt{\pi}}\left(x-\frac{x^3}{3\cdot 1!}+\frac{x^5}{5\cdot 2!}-\frac{x^7}{7\cdot 3!}+\ldots\right) \qquad \frac{\partial T}{\partial x}=\frac{T_M-T_0}{\sqrt{\pi\cdot\alpha_{th}\cdot t}}\cdot\exp\left(-\frac{x^2}{4\cdot\alpha_{th}\cdot t}\right)$$

$$S=\frac{2}{\sqrt{\pi}}\frac{T_M-T_0}{\rho_c\cdot\Delta H_f}\sqrt{k_m\cdot\rho_m\cdot C_m\cdot t} \qquad G=k\cdot\sqrt{p_g} \qquad h+\frac{v^2}{2\cdot g}+\frac{p}{\rho\cdot g}=const$$

$$S=\frac{F}{A_0} \qquad e=\frac{\Delta l}{l_0} \qquad \sigma=\frac{F}{A} \qquad \varepsilon=\ln\left(\frac{l_f}{l_0}\right) \qquad S=E\cdot e \qquad RA=\frac{A_0-A_f}{A_0}$$

$$\sigma=K\cdot\varepsilon^n \qquad u(\varepsilon_f)=\int_0^{\varepsilon_f}\sigma(\varepsilon)d\varepsilon=\sigma_{tm}\cdot\varepsilon_f \qquad W_i=V\cdot u \qquad \dot{\varepsilon}=\frac{v}{l}=-\frac{1}{A}\frac{dA}{dt}$$

$$\sigma=C\cdot\dot{\varepsilon}^m \qquad p_{av}=\frac{W_i}{t_{av}} \qquad W=C\cdot V\cdot\dot{\varepsilon}^m\int_{h_0}^{h_1}\frac{dh}{h}=C\cdot V\cdot\dot{\varepsilon}^m\cdot\varepsilon_f \qquad \sigma_a=Q_a\cdot\sigma$$

$$p_{av}=\frac{1}{t_{av}}\cdot CV\cdot\dot{\varepsilon}^m\cdot\varepsilon_f \quad \sigma_p=Q_p\cdot\sigma \quad p_e=Q_e\cdot\sigma_{tm} \quad Q_e=0.8+1.2(\ln R_e) \quad R_e=\frac{A_0}{A_f}$$

$$F_f=\tau_t\cdot\pi\cdot D\cdot l \qquad \dot{\varepsilon}_m=\frac{6\cdot v\cdot D_0^2\cdot\ln R_e}{D_0^3-D^3} \qquad L=\sqrt{R(h_0-h_1)} \qquad p_r=\sigma_{tm}\cdot Q_p$$

$$F_r=L\cdot w\cdot Q_p\cdot\sigma_{tm} \qquad \dot{\varepsilon}=\frac{v}{L}\cdot\ln\left(\frac{h_0}{h_1}\right) \qquad \frac{h_0}{R}>\left(\frac{h_0}{h_1}-1\right)\cdot 1.81 \qquad T=F_r\cdot L$$

$$Power=\omega\cdot T \qquad F_s=0.7\cdot(UTS)\cdot A \qquad \varepsilon_f=\frac{R+t}{R+t/2} \qquad R_m=t\cdot\frac{(1-RA)^2}{2\cdot RA-RA^2}$$

Alan J

$$\frac{R_b}{R_f} = 4\cdot\left[\frac{R_b\cdot\sigma_{0.2}}{t\cdot E}\right]^3 - 3\cdot\left[\frac{R_b\cdot\sigma_{0.2}}{t\cdot E}\right]+1 \qquad F = K\cdot\frac{l\cdot t^2\cdot UTS}{w} \qquad LDR = \frac{d_{0_{MAX}}}{d_p}$$

$$\%\,\mathrm{Re}\,d = 100\cdot\left(1-\frac{d_p}{d0}\right) \qquad F_d = \pi\cdot d_p\cdot t_{avg}\cdot UTS\cdot\left[\frac{d_0}{d_p}-0.7\right] \qquad D = D_0\cdot\exp\left(\frac{-Q}{R\cdot T}\right)$$

$$r = \frac{\varepsilon_w}{\varepsilon_t} \qquad r_m = \frac{r_0 + r_{90} + 2\cdot r_{45}}{4} \qquad D_0 = \frac{\rho_a}{\rho_s}\cdot 100 \qquad D_y = \left[\frac{(1-D_0)\cdot P}{1.3\cdot\sigma_f} + D_0^3\right]^{1/3}$$

$$v_{av_{turn}} = \frac{\pi\cdot N\cdot(d_w + d_m)}{2} \qquad MRR_{turn} = \pi\cdot f\cdot d_c\cdot N\cdot d_m \qquad v_{\max_{turn}} = \pi\cdot N\cdot d_m$$

$$u_c = f\cdot\sin\kappa_r \qquad MRR_{planning/shaping} = v\cdot f\cdot d_c \qquad MRR_{drill} = \frac{\pi\cdot D^2\cdot N\cdot f}{4}$$

$$u_{c_{drill}} = \frac{f}{2}\cdot\sin\kappa_r \qquad MRR_{milling} = v_f\cdot d_c\cdot w \qquad f = \frac{v_f}{N\cdot n_t} \qquad u_{c_{avg\,milling}} = \frac{v_f}{N\cdot n_t}\cdot\sqrt{\frac{d_c}{D}}$$

$$P = \frac{p_s\cdot MRR}{\eta} \qquad \psi = \alpha + 90 - \phi \qquad \gamma = 90 - \psi \qquad \gamma = \phi - \alpha \qquad L = \frac{d_c'}{\cos(\phi-\alpha)}$$

$$\sin(\phi) = \frac{d_c}{L} \qquad \tan(\phi) = \frac{d_c}{d_c'}\cdot\frac{\cos\alpha}{1-\frac{d_c}{d_c'}\cdot\sin\alpha} \qquad F_s = \tau_s w\cdot L \qquad F = F_c\cdot\sin\alpha + F_t\cdot\cos\alpha$$

$$N = F_c\cdot\cos\alpha - F_t\cdot\sin\alpha \qquad F_s = F_c\cdot\cos\phi - F_t\cdot\sin\phi \qquad F_n = F_c\cdot\sin\phi + F_t\cdot\cos\phi$$

$$F_c = R\cdot\cos(\beta-\alpha) \qquad F_s = R\cdot\cos(\phi+\beta-\alpha) \qquad F_c = \frac{\tau_s\cdot d_c\cdot w\cdot\cos(\beta-\alpha)}{\cos(\phi+\beta-\alpha)\cdot\sin\phi}$$

$$\tan(\phi+\beta-\alpha) = \tan(90-\phi) \qquad 2\cdot\phi = 90-(\beta-\alpha) \qquad T_M \propto v^a f^b d_c^c \qquad v\cdot t^n = C$$

$$v\cdot t^n\cdot f^m\cdot d_c^p = C' \qquad F \approx 0.04\cdot E\cdot A_w \qquad \frac{d^2y}{dx^2} = \frac{M}{E\cdot\hat{I}} \qquad \delta = 0.005\cdot\frac{\bar{y}\cdot l^2\cdot A_w}{\hat{I}}$$

$$\frac{\partial^2 T}{\partial\xi^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = -2\cdot k\cdot v\cdot\frac{\partial T}{\partial\xi} \qquad \tau_{8/5} = \frac{Q}{2\cdot\pi\cdot k}\cdot\left[\frac{1}{(500^\circ C - T_0)} - \frac{1}{(800^\circ C - T_0)}\right]$$

$$\tau_{8/5} = \frac{(Q/h)^2}{4\cdot\pi\cdot k\cdot\rho\cdot C}\cdot\left[\frac{1}{(500^\circ C - T_0)^2} - \frac{1}{(800^\circ C - T_0)^2}\right] \qquad \lambda = h\cdot\sqrt{\frac{\rho\cdot C\cdot(550^\circ C - T_0)}{Q}}$$