PhD Qualifying Exam - Manufacturing
Fall 2017

Attempt <u>any three</u> of the four problems below. Clearly show all of your work. List all relevant assumptions.

1. You are tasked with designing a <u>compact</u> cylindrical riser for a sand mold used to cast a cube shaped aluminum part whose each side is 20 cm long. Assume that the riser sits directly on top of the mold cavity and is not open to the atmosphere. In order to obtain a compact design, you choose the diameter, *d*, and height, *h*, of the riser such that, for a given volume of the riser, the surface area of the riser across which heat transfer takes place is a *minimum*. In addition, you know that the smallest volume necessary for the riser needs to be at least <u>three times</u> the volumetric shrinkage of aluminum, which is known to be 7%. Find: (i) the dimensions of the cylindrical riser that satisfies the stated requirements, (ii) Is the riser design obtained in (i) adequate to prevent the formation of shrinkage voids in the cast part? If not, what should be the volume of the riser in order to prevent such defects?

2. You are designing a large cold rolling mill. The intended application is flat rolling of a sheet of aluminum foil of 1.8 m width, from 0.5 mm to 0.24 mm thickness in a single pass. The roll diameter is fixed at 0.18 m and the lubrication system available yields a friction coefficient of 0.09. The flow stress of the steel is given by $\sigma = 496\varepsilon^{0.28}$ MPa.

   (a) Is the specified thickness reduction feasible? Justify your answer through appropriate calculations.
   (b) If the mill motor power is 12.5 MW, what is the maximum peripheral velocity of the rolls for the stated thickness reduction?
   (c) Discuss three ways to lower the rolling mill power requirement for this problem and explain clearly why the proposed methods will do so.

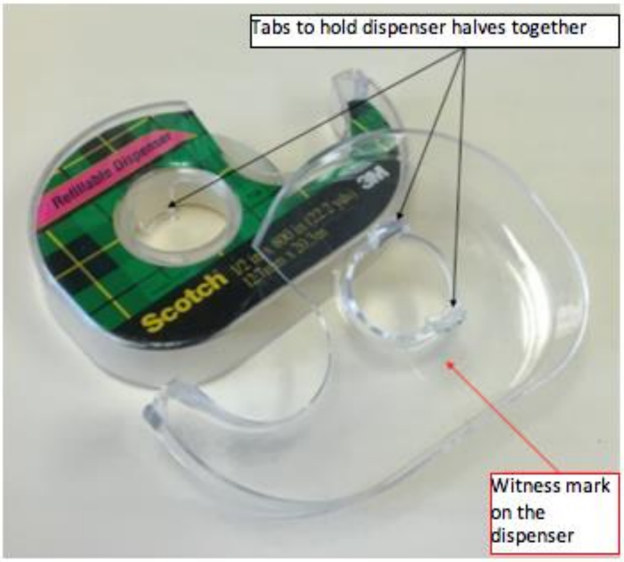
3. Hard turning is the process by which hard materials can be turned in a lathe. For example, 52100 bearing steel that is hardened to 55-60 RC (Rockwell hardness) can be turned given the proper process parameters. In fact, hard turning is used to replace cylindrical grinding in many, but not all, instances. Please discuss the differences between hard turning and cylindrical grinding and what factors you would consider in choosing between employing these two operations to produce an axially symmetric component.

4. You are injection molding a refillable tape dispenser, similar to that shown in the figure below. The dispenser weighs 0.5 oz and has a wall thickness of 1.6 mm. The plastic part is fabricated using 1,000 bar (4,500 psi) of injection pressure. Assuming the plastic has a density of 1,500 kg/m^3 (0.05 lb/in^3), thermal conductivity of 0.3 W/m-K and a thermal diffusivity of 10^{-3} cm^2/s, answer the following:

   (a) Estimate the cooling time.
   (b) Indicate any special features in the part that would result in moving parts for the mold. (Hint: See labeled marks on the dispenser)

(c) Clearly sketch the flow path during the mold filling sequence. Will there be any defects? If so, indicate them on the sketch as well.

(d) Specify the injection molding machine requirements, shot size and clamping force, to mold 4 of these parts at a time using a 4-cavity mold.



Relevant Equations for Problem 2

$$\Delta \equiv \frac{h_{ave}}{L} << 1 \quad p_{ave} = 1.15 \cdot \overline{Y}_{flow}\left(1 + \frac{\mu L}{2h_{ave}}\right)$$

$$\Delta \equiv \frac{h_{ave}}{L} >> 1$$

$$p_{ave} = 1.15 \cdot \overline{Y}_{flow}$$

$$L \approx \sqrt{R \Delta h}$$

$$\Delta h_{\max} = \mu^2 R$$

$$\varepsilon_f = \left| \ln\left(\frac{h_f}{h_b}\right) \right| \quad 2\tau_{flow} = 1.15 \cdot \overline{Y}_{flow} = 1.15 \cdot \frac{K\varepsilon^n}{n+1}$$

$$\dot{\varepsilon} = \frac{\overline{\varepsilon}}{t} = \frac{V_R}{L} \ln\left(\frac{h_b}{h_f}\right) \quad 2\tau_{flow} = 1.15 \cdot \overline{Y}_{flow} = 1.15 \cdot C \cdot \dot{\overline{\varepsilon}}^m$$