<u>Ph.D. Qualifying Examination - Manufacturing</u>

The exam is closed books and notes. **<u>Attempt any three out of four problems</u>**. Show all work clearly and list all assumptions.

Problem #1

A molten metal is being poured into the downsprue of a sand mold at constant flow rate during the time it takes to completely fill the mold. At the end of the pouring, the sprue is filled and there is negligible metal in the pouring cup. The downsprue is 6.0 in long. Its cross-sectional area at the top is 0.8 in^2 and it cross-sectional area at the base is 0.6 in^2. The cross-sectional area of the runner leading from the sprue is also 0.6 in^2 and it is 8.0 in long before leading into the mold cavity, whose volume is 65 in^3. The volume of the cylindrical riser, which is located along the runner, near the mold cavity, is 25 in^3. The time taken to fill the mold (including the cavity, riser, runner, and sprue) is 3.0 seconds. It turns out that this is more than the theoretical mold filling time required, indicating there is a loss of velocity due to friction in the sprue and runner.

Provide a labeled sketch, state all your assumptions, and find:

(a) The theoretical velocity and flow rate at the base of the sprue.
(b) The actual velocity and flow rate at the base of the sprue.
(c) The loss of head (in inches) in the gating system due to friction.
(d) The length of the cylindrical riser is to be 1.25 times its diameter. The casting is a rectangular plate 13 in x 5 in x 1 in. Determine the riser dimensions so that it will take the riser 30% longer to solidify than the casting.

Problem #2

A manufacturing engineer is given a workpiece made from an alloy whose mechanical strength is not known. The engineer decides to use a simple machining test to estimate the mean shear yield strength of the material. He performs a series of shaping tests with a high speed steel (HSS) tool of +5° rake angle and no cutting fluid under the following conditions: undeformed chip thickness t_o = 0.25 mm, cutting speed V = 2 m/s, and width of cut w = 4 mm. He uses a micrometer and a force dynamometer to measure the deformed chip thickness (t_c) and machining forces, respectively, and obtains the following average values: t_c = 0.4 mm, cutting force F_c = 800 N, and thrust F_t = 400 N.

(a) Estimate the average shear strain induced by the tool and the mean shear yield strength of the alloy using the data gathered in the above experiment.

(b) Given the hardness of the HSS tool depends on the mean chip temperature as follows: $H(\Theta) = 850\left[1 - \left(\frac{\Theta}{600}\right)^{2.1}\right]$ HV, determine the change in tool hardness for the cutting conditions used by the engineer in the above experiment. Assume that ~ 90% of the energy dissipated in the shear zone goes into the chip. Clearly list any other assumptions you make in your analysis. *Note*: HV stands for Vickers Hardness.

Density of alloy, ρ = 7200 kg/m^3
Specific heat, c = 502 J/kg-°C
Room temperature θ_o = 30°C

Problem #3

Consider the forward (direct) hot extrusion of a piece of metal from an initial diameter, D_1, to a final diameter, D_2 at a ram speed of V_0. The die has angle, α. The metal has thermal conductivity, k, specific heat, c, and density, ρ. The material model is given by the following expression:

$$\sigma_{flow} = C\left(\dot{\varepsilon}\right)^m$$

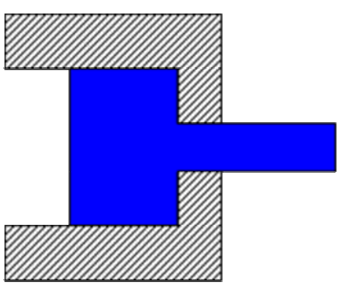
The strain rate in extrusion is given by the following expression:

$$\dot{\varepsilon} = \frac{12 v_{ram} D_1^2 \cdot \tan\alpha}{D_1^3 - D_2^3} \cdot \ln\left(\frac{D_1}{D_2}\right)$$

a) Develop an expression to estimate the adiabatic temperature rise in the metal.

b) Using the following data for copper, determine the value for that rise for a 60% reduction in area.

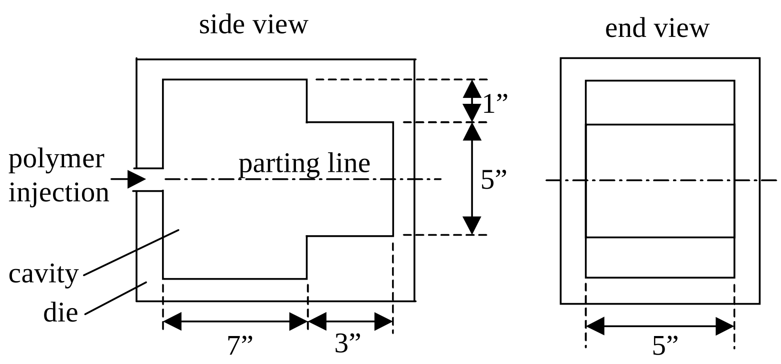
The die has a square bottom
The initial diameter, D_1, = 100 mm
The ram is moving v_{ram} = 125 mm/second
The material has C = 180 MPa and m = 0.08
The material has k = 393 W/m-C , c = 385 J/kg-C, and ρ = 8970 kg/m^3



Forward (direct) extrusion

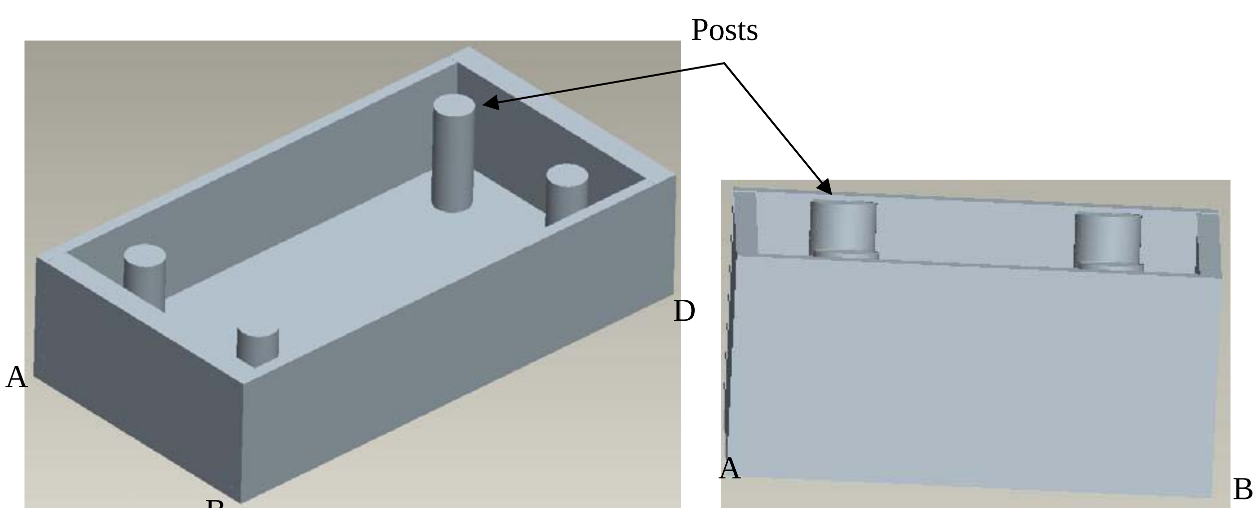
Problem #4

You are injection molding a plastic part shown in the figure. You want to fill the 200°C mold in 3 seconds. The injection mold machine has a 120,000 lb capacity (clamping force).



(a) What is the upper and lower bound of molding pressure that can be applied? Explain why.

(b) The picture below shows one half of an injection molded housing. With the basic design rules for injection molding in mind, is this a good design? Explain why/why not and suggest any improvements you might want to make. You can use a sketch to explain your thoughts.



Top View

Side View