Ph.D. Qualifying Examination - Manufacturing

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

Problem #1

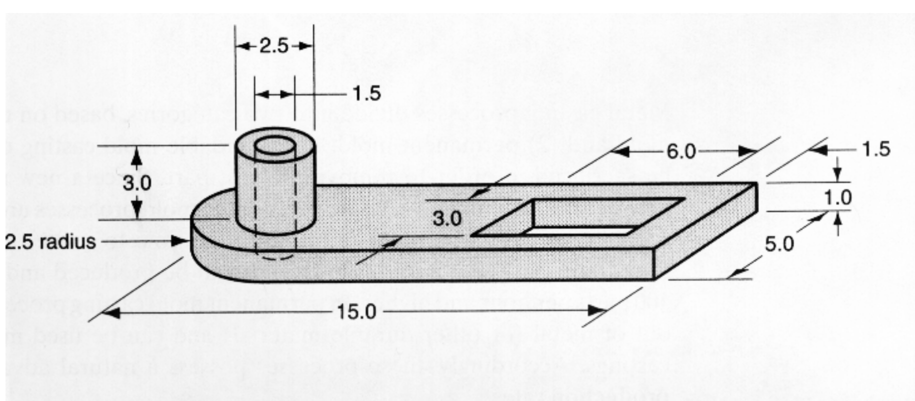
A cylindrical riser with diameter-to-length ratio = 1.0 is to be designed for a sand casting mold. The casting geometry is shown in the figure below, in which the units are inches.

i. If the mold constant in Chvorinov's rule is $C=19.5$ min/in^2, determine the dimensions of the riser so that the riser will take 0.5 min to freeze longer than the casting itself. What are the riser dimensions for a metallic mold if the mold constant for this case is $C=7$ min/in? State all assumptions.

ii. For each of the molds, sketch a plot of the thickness of solidified metal (or the solidification distance from the mold wall) S as a function of the variable t/C where t is time.

iii. Assume a pure metal is being cast. Provide qualitative sketches of the transient temperature distributions during the solidification process in each of the molds as a function of distance from the exterior surface of the mold, through the thickness of the mold wall, and to centerline of the mold cavity. Label your sketch with appropriate temperatures, T_∞ for the ambient temperature, T_m for the melting temperature, $x=0$ for the mold wall exterior, $x=w$ for mold wall interior surface. For the purposes of this sketch, you can approximate the mold cavity as a rectangle, 15 inches long, 5.0 inches deep, and 1.0 inches high. You may also assume that the thickness of the mold wall is the same on all sides of the cavity.

   Write the 1-D transient heat conduction equation for the temperature distribution in the mold wall. Provide appropriate boundary conditions for each of the sand and metallic mold situations.



Problem #2

A) It has been found that the specific energy of machining, u, is inversely related to the undeformed chip thickness, t_0, as follows:

$$u \sim \frac{1}{t_0}$$

Explain why this is true. You may assume that the width of cut is w, the chip thickness is t_c, the rake angle is α, the shear angle is ϕ, the clearance angle is ζ, and the speed of cutting is V.

B) The data presented in the table (see next page) have been generated for a grinding operation. The peripheral wheel speed was 26.37 m/s. The wheel was 13 mm wide. The part being ground was 25 mm by 25 mm.

i. Determine the relationship between the specific cutting energy and the depth of cut. A mathematical model(s) is required.

ii. Discuss whether your model(s) matches the relation presented in part (A).

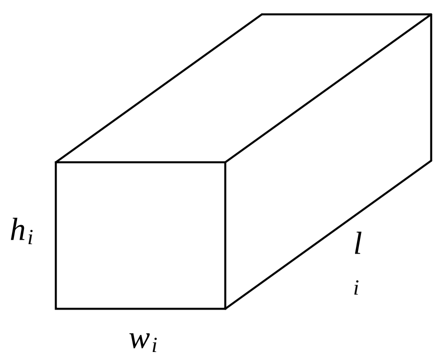
Depth of Cut in mm	Feed Rate 0.50 mm/pass	Feed Rate 0.25 mm/pass	Feed Rate 0.15 mm/pass
	Specific cutting energy in J/m^3		
0.004	2.45	4.35	9.08
0.005	2.07	3.61	7.11
0.006	1.81	3.12	5.50
0.007	1.71	2.8	4.30
0.008	1.63	2.58	3.63
0.009	1.51	2.42	3.14
0.010	1.41	2.50	2.36
0.011	1.38	2.57	2.04
0.012	1.27	2.63	1.84
0.013	1.17	2.51	1.73
0.014	1.08	2.41	1.63
0.015	1.01	2.33	1.54
0.016	0.95	2.23	1.58
0.017	0.89	2.16	1.60
0.018	0.84	2.08	1.61
0.019	0.83	2.08	1.62
0.020	0.81	2.12	1.63
0.021	0.81	2.19	1.64
0.022	0.82	2.23	1.65
0.023	0.82	2.29	2.36
0.024	0.82	2.33	2.39
0.025	0.82	2.37	2.50

Problem #3

A block of non-strain hardening metal of flow strength σ_{flow} and height h_i, width w_i, and length l_i (where $l_i >> h_i$ and w_i) is open die forged between two platens to a final height h_f. The coefficient of friction between the platen and block μ is 0.5.

i. Derive an equation for the forging pressure acting on the block during the operation. List all assumptions and show all steps clearly.

ii. Calculate the work done in the forging operation given the following data: $h_i = 24$ mm, $w_i = 24$ mm, $l_i = 150$ mm, $h_f = 0.25h_i$, $\sigma_{flow} = 600$ MPa.



Problem #4

As an owner of a polymer processing company you are tasked with making 500,000 internal components for a revolutionary new cellular phone, the Apple – Dimension. Before making the parts you must decide whether the best approach is polymer extrusion or injection molding.

Apple has supplied the materials and its pertinent data. The material has a density of 1700 kg/m^3 and viscosity of 600 $N\text{-}s/m^2$. The barrel of your machine has an internal diameter of 30 mm and the screw has the following dimensions: helix angle = 15^o, flight height = 5 mm, flight width = 25 mm and a length of 4 m.

i. Describe the polymer extrusion and injection molding processes e.g., process characteristics, advantages, and limitations, in 100 words or less.

ii. Based on this discussion decide which method should be used to manufacture cellular phone components. Justify your answer, in 50 words or less.

iii. If the die is a cylinder with a diameter and length of 20 mm and 15 mm, respectively, how fast must the barrel rotate (in RPM) to manufacture the units at a velocity of 25 mm/s?

iv. Using the boundary walls below, graphically illustrate the velocity profile of the material. Be sure to fully label.