PhD Qualifying Exam
Manufacturing
Spring 2015

Answer all problems. Clearly show all of your work. List all relevant assumptions.

1. Metal Casting

(a) Determine the necessary power of a furnace, in kW, that is required to raise a 400 kg billet of aluminum from 20º C to 75º C above its melting temperature of 660º C in 30 minutes. Assume a furnace efficiency of 80%. Note aluminum has the following characteristics: density, 2700 kg/m^3; heat of fusion, 396 kJ/kg; specific heat of liquid phase, 1.05 kJ/kg-K; specific heat of solid phase, 0.9 kJ/kg-K. What factors do you need to consider in terms of the accuracy of your answer. Please discuss these factors in no more than 10 sentences.

(b) The aluminum that is melted in the first part of this problem is poured into a sprue that has a height of 300 mm. It is to be used to fill a mold cavity of 2000 cm^3. Determine the diameter of the sprue (assuming a constant cross sectional area for the sprue) that allows the mold cavity to be filled in 4 seconds. Clearly state your assumptions. Discuss, in 10 sentences or less, how your answer would change if the sprue had a square cross section rather than a circular one.

2. Machining

An orthogonal cutting operation is carried out under the following conditions: undeformed chip thickness t_0 = 0.254 mm, width of cut w = 2.54 mm, cutting speed V = 120 m/min, rake angle α = 0 deg. Cutting force measurements show that the cutting force F_c = 900 N and thrust force F_t = 670 N. Measurements of the deformed chip thickness yield t_c = 0.7 mm. The workpiece density ρ = 7197 Kg/m^3 and specific heat c = 502 J/kg-°C.

(a) Sketch the Merchant's force circle diagram and clearly label the following quantities on it: cutting force (F_c), thrust force (F_t), shear force (F_s), normal force on shear plane (F_n), friction force (F), normal force on tool-chip interface (N), friction angle (β), shear angle (ϕ).

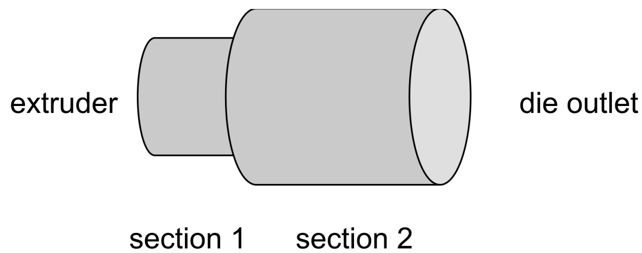
(b) Calculate the power dissipated in the shear plane and express it as a fraction of the total cutting power.

(c) Determine the average temperature rise in the chip if the power dissipated in the *workpiece* is known to be 100 W. Neglect heat lost to the environment and assume that the tool is insulated.

3. Polymer Processing

You are extruding a polymer into a die that has two sections, one after the other in series (see figure below). The section closest to the extruder has a radius R_1, and length, L_1. The second section has radius R_2 and length L_2. You may ignore the transitions between the die's sections, but not the differences of the die's sections.

The extruder barrel has internal diameter D. The screw rotates and has helix angle q, axial length *l*, flight width w, and flight depth H. The polymer has viscosity μ.



(a) Derive an algebraic expression for the flow rate (Q) of the extruded product out of the die as a function of the screw's rotational speed (ω). Be sure to reduce the equation to the basic geometry of the problem.

(b) Using the following numerical values, determine a numerical value for the velocity of the extruded product.

(μ) = 30 N-s/m^2	(R_1) = 20 mm
(D) = 35 mm	(L_1) = 15 mm
(θ) = 17 degrees	(R_2) = 40 mm
(l) = 2.5 m	(L_2) = 20 mm
(w) = 45 mm	The screw rotates (ω) at 50 rpm
(H) = 8 mm	

Screw flow equation (drag and pressure flow) $$Q = w\left[\frac{v_z H}{2} - \frac{H^3}{12\mu}\frac{dp}{dz}\right]$$ Round channel flow equation (pressure flow) $$Q = \frac{\pi R^4}{8\mu}\frac{\Delta p}{L}$$	Q = flow rate (m^3/s) w = width of flight or channel (m) H = height of flight or channel (m) R = radius of channel (m) μ = viscosity (N-s/m^2) *l* or L or dz = length of channel (m) Dp or dp = pressure drop (Pa) v_z = velocity along flight (helix) z = direction along flight (helix) length along a helix = axial length/sinθ velocity along helix = velocity of barrel x cosθ