Ph.D. Qualifier Examination – Manufacturing
Spring 2008

Closed book examination
Attempt all three questions

Question #1

A low carbon steel cylindrical work piece of 30 mm diameter is turned by a 20-degree rake angle cutter. The process applies an axial feed of 0.1 mm per revolution and a radial depth of cut of 3 mm. It is observed that the chip thickness turns out to be 0.5 mm while the surface cutting velocity is 6,000 mm/sec. The low carbon steel is known to have a specific cutting energy of 4.2 W-s/mm^3.

A. How much are the tangential force, the thrust cutting force, and the resultant cutting force?
B. How much is the power needed to feed the tool?
C. How much is the power needed to turn the spindle?
D. How much is the ratio between the power to overcome friction (at the tool rake and chip interface) and the power to shear the work piece material?

Question #2

You are permanent-mold casting a metal gear. The gear is shown below. The mold is maintained at 40°C. The metal has the following properties. The heat transfer between the metal and the mold is 5 kW/m^2-C. The part must be below 100°C before removal from the mold. The gear is 75 mm in outer diameter, 15 mm in inner diameter, and 25 mm thick. It is center gated; the metal flows into the center of the part. The gate has a diameter of 5 mm.

- Estimate the cycle time for the part

	Gear material	Mold material
Specific heat (C) (kJ/kg-°C)	0.90	0.441
Density (ρ) (kg/m^3)	2700	7125
Thermal conductivity (k) (kW/m-°C)	202 x 10^{-3}	42.7 x 10^{-3}
Thermal diffusivity (α) (m^2/s)	8.31 x 10^{-5}	1.36 x 10^{-5}
Viscosity (μ) (Pa-s)	1.3 x 10^{-3}	
Melting point (°C)	660	
Latent heat of solidification (fusion) (H_f) (kJ/kg)	396	

Solidification time (t) for an insulating mold

$$t = \left[\frac{\pi}{4}\left(\frac{\rho_{casting}\Delta H_{casting}}{T_{melting\_point} - T_{mold,initial}}\right)^2 \frac{1}{k_{mold}\rho_{mold}C_{mold}}\right]\left(\frac{V_{casting}}{A_{casting}}\right)^2$$

Solidification time (t) for a conducting mold

$$t = \left(\frac{\rho_{casting}\Delta H_{casting}}{h\left(T_{melting\_point} - T_{mold}\right)}\right)\left(\frac{V_{casting}}{A_{casting}}\right)$$

ΔH = latent heat for the process = $H_f + \Sigma C_i \Delta T$
H_f = latent heat of solidification (fusion)
V = volume
A = area
h = heat transfer coefficient
C = specific heat
ρ = density

Cooling time (t) for a solid object with negligible temperature gradient

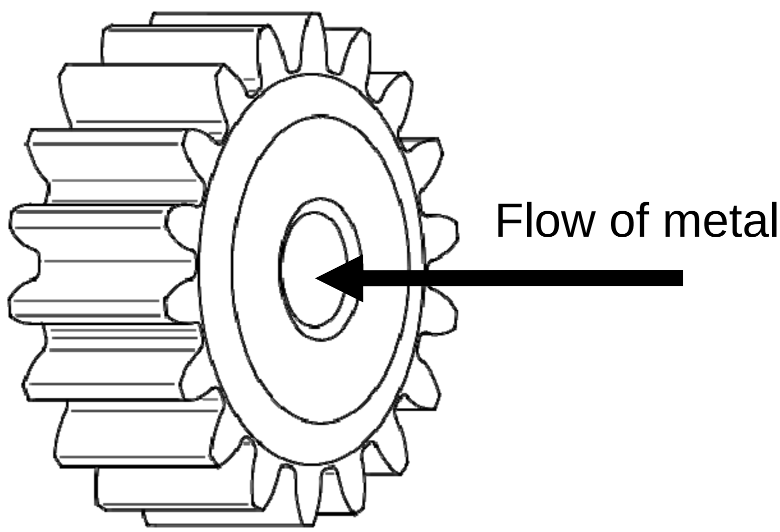
$$t = \frac{V_{casting}}{A_{casting}} \frac{\rho_{casting} C_{casting}}{h} \ln\left(\frac{T_{mold} - T_{casting,initial}}{T_{mold} - T_{casting,final}} \right)$$

Biot number

$$Bi = \frac{hl}{k}$$

Reynolds number

$$\mathrm{Re} = \frac{\rho v D}{\mu}$$



Question #3

A hollow cylindrical disk of initial height h_i, inner radius R_i and outer radius R_o is to be forged at room temperature between two rigid platens to a final height h_f as shown in the figure below. Note the rigid mandrel in the center of the disk. The mandrel does not undergo any deformation. The top platen has a cavity of sufficient depth to allow the forging operation to take place in the presence of the mandrel. The disk material has approximately constant shear yield strength k. The lubrication conditions at the platen-disk interfaces are such that sliding friction applies. The mandrel-disk interface and the mandrel-platen interfaces are lubricated such that negligible friction exists at these interfaces.

A. Using first principles derive an expression for the average forging pressure required for this operation. Show a sketch of the operation, clearly list all assumptions you make in your derivation, and show all steps leading to your final answer.
B. Calculate the work done in reducing the height of the disk by 30%. Assume the following values for the various parameters: h_i = 30 mm, R_i = 15 mm, R_o = 30 mm, k = 3.5 N/mm^2, coefficient of sliding friction at disk-platen interface, $\mu = 0.2$.