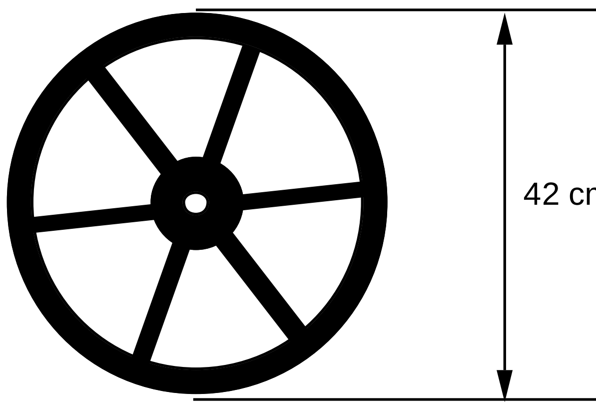
PhD Qualifying Exam - Manufacturing
Spring 2017

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

1. You are the casting design engineer for Yellow Jacket Automotive. Your assignment is to produce a fancy new wheel for the Buzz Mark XI line of luxury automobiles. The material to be used is a new alloy called Jacketium. Its materials properties are provided below. The wheel designer has provided you with the following drawing of the wheel as conceived by her group. The rim, spoke, and hub are rectangular in cross-section with dimensions of 2 cm by 2 cm.



a) For a 15 kW furnace operating at 65% efficiency, determine the time required to bring 350 kg of Jacketium from room temperature to the pouring temperature.
b) Estimate the pouring speed into a sand mold, if the sprue is in the center of the wheel's hub. Comment on your answer.

Material Properties:

- Jacketium melting point: 660°C
- Jacketium pouring temperature: Melting point + 50°C
- Jacketium heat of fusion: 250 kJ/kg
- Jacketium thermal conductivity: 0.222 kW/m °C
- Jacketium specific heat: 0.900 kJ / kg °C
- Jacketium density: 2700 kg / m^3
- Jacketium viscosity: 6 x 10^{-3} N s/m^2
- Sand thermal conductivity: 0.6 x 10^{-3} kW/ m °C
- Sand specific heat: 1.16 kJ / kg °C
- Sand density: 1500 kg / m^3
- Room temperature: 20°C

Useful Equations:

$$H = \rho V\left[c_s\left(T_{melt} - T_{initial}\right) + H_f + c_l\left(T_{pour} - T_{melt}\right)\right]$$

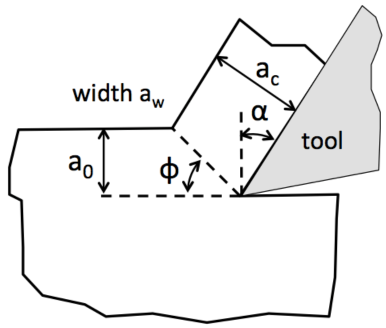
$$\mathrm{Re} = \frac{\rho V d}{\mu}$$

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

$$t = \frac{\rho_{casting}\left(\Delta H_f + c_l \Delta T\right)}{h\left(T_{melt} - T_{initial}\right)}\frac{V}{A}$$

$$t = \left[\frac{\pi}{4}\left(\frac{\rho_{casting}\left(\Delta H_f + c_l \Delta T\right)}{T_{melt} - T_{initial}}\right)^2 \frac{1}{k_{mold}\rho_{mold}c_{mold}}\right]\left(\frac{V}{A}\right)^2$$

2. In the orthogonal machining operation of Inconel 718 depicted below, a tool with rake angle $\alpha = 5$ degrees is used with an undeformed chip thickness $a_0 = 1$ mm, this resulting in a deformed chip thickness of $a_c = 3$ mm. Answer the questions below:



   a) What is the shear strain imposed in the chip, in this operation?

   b) What is the energy dissipated due to the shearing of the material in the machining process? Assume that the Inconel has a shear strength of 77.2 GPa.

   c) If the rake angle of the cutting tool is changed to $\alpha = 15$ degrees, what would be the new chip thickness? Assume that the following relationship holds: $2 * \phi + \beta - \alpha = 0.5 * \pi$ and that β is not influenced by changes in α.

3. You are cold drawing a metal wire from initial diameter = 0.75mm to final diameter = 0.5mm, with the following two options to consider:
   a) Drawing the wire through one die.
   b) Drawing the wire through multiple dies (i.e. draw from 0.75mm to D_1, then draw from D_1 to 0.5mm). Note, for this option, there is no buffer and no annealing of the wire between the dies.

   Which option would you select and why? Be quantitative in your answer (e.g. draw force, power, etc).

Material Properties:
The material has strength coefficient K=315 MPa and strain hardening coefficient n=0.54. The die has angle α=5° and friction coefficient μ=0.07.

Useful Equations:

$$\frac{\sigma_{x\_draw}}{2\tau_{flow}} = \left(\frac{1+B}{B}\right)\left(1-\left(\frac{D_{final}}{D_{initial}}\right)^{2B}\right) + \frac{\sigma_{x\_back}}{2\tau_{flow}}\left(\frac{D_{final}}{D_{initial}}\right)^{2B}$$

$$B \equiv \frac{\mu}{\tan\alpha}$$

$$2\tau_{flow} = \frac{K\varepsilon^n}{n+1}$$