PhD qualifying examination on Manufacturing
Fall 2013

Note: Out of the following four problems, select only <u>three</u> to work on, and clearly identify which three

(1) A casting is being produced out of pure aluminum in a sand mold. The metal level in the pouring basin is 254 mm above the level of metal in the mold, and the runner is circular with a 10 mm diameter. What is the velocity and rate of the flow of the metal into the mold? Is the flow turbulent or laminar? Is any corrective action required? State all assumptions.

For the sprue described above, determine the runner diameter needed to ensure a Reynolds number of 2000. How long will a $2.5x10^6$ mm^3 casting take to fill with such a runner? Provide your analysis (quantitative and qualitative) on the impact of this filling time on the castability of the component. Is the casting process expected to proceed flawlessly or are some difficulties or concerns expected? Explain.

Assume now that the mold is bottom-gated. The casting has a square cross-section of 150mm per side and a height of 100mm. Derive the equation for the mold filling time and use it to determine the filling time for this mold using the original runner diameter. Assume the sprue is frictionless.

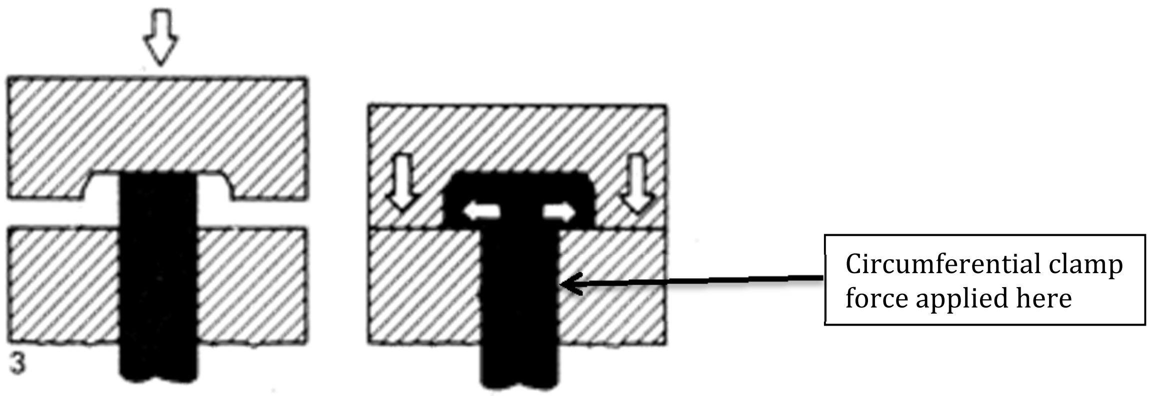
The constant C in Chvorinov's rule for this situation is given as 3 s/mm^2. Estimate the time for the casting to fully solidify. It has been stated that the mold can be broken safely and the casting retrieved when its solidified shell is at least 25 mm thick. Assuming that the casting cools evenly, how much time must transpire after pouring the molten metal before the mold can be broken? Provide justification for your analysis.

Pure aluminum has a density of 2700 kg/m^3 and a viscosity of around 0.0015 N-s/m^2 around 700˚C.

(2) Consider the forming of a head of a rivet by upsetting (forging). The initial diameter of the cylindrical rod is 10 mm. The final diameter of the cylindrical head is 15 mm and its height is 10 mm. The metal can be modeled as strain-hardening, with K = 760 MPa and n = 0.19.

The rod is held by a clamp, with a coefficient of friction of 0.15.

Determine the circumferential clamp force needed.

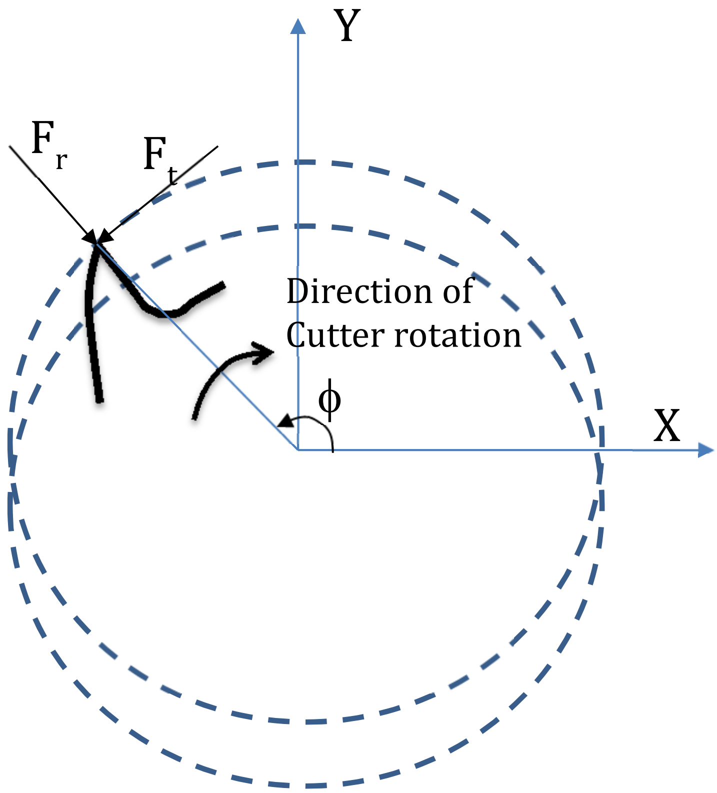


(3) The figure below shows the instantaneous forces acting on the tooth of an end milling tool during cutting of a <u>slot</u> in a metal with a mean shear yield strength of τ (MPa). The cutter has a diameter *D* (mm), two straight (zero helix angle) flutes (for simplicity, only one cutting tooth is shown), and a rake angle of α (degrees). The tool rotates at *N* rpm and is fed in the Y direction at f_r mm/rev. The axial depth of cut (along the Z axis) is given by d_a (mm). The mean coefficient of friction between the chip and the tool rake face is μ.

i) Using your knowledge of orthogonal metal cutting theory, derive equations for the <u>maximum</u> tangential (F_t) and radial (F_r) cutting forces experienced by the end mill tooth. Assume that the tool rotates perfectly about the spindle axis (i.e. no cutter runout). State clearly any assumptions you make in your derivation.

ii) Estimate the power requirement for the process given the following values for the quantities given in the problem:

τ = 400 MPa,
$\mu = 0.6$,
$\alpha = 0$ deg.,
D = 19.05 mm,
f_r = 0.2 mm/rev,
d_a = 2.54 mm,
N = 300 rpm



Top view

(4) You are tasked with mass-producing 500,000, cylindrical parts for internal use in a cell phone. Before making the parts you must decide, which processing method to use and what the appropriate operating conditions should be. Based on data provided by the customer, it is known that the material has a density of 1700 kg/m^3 and viscosity of 600 N-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.

a. In 150 words or less describe which processing method should be used to make the parts. Justify your answer. Discuss the advantages and disadvantages of the chosen process and what types of defects may arise if optimal operating conditions are not maintained.
b. A cylindrical die with a diameter and length of 20 mm and 15 mm, respectively, is used. How fast must the barrel rotate (in RPM) to manufacture the units at a velocity of 25 mm/s?
c. Graphically depict the velocity profile of the fluid flowing between the dies, be sure to fully label.