GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam – Fall Semester 2004

Manufacturing

Exam Area

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Assigned Number **(DO NOT SIGN YOUR NAME)**

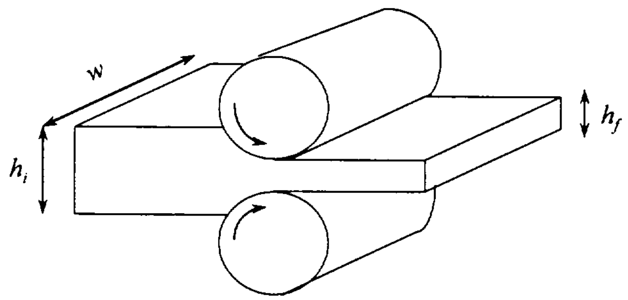
- Please sign your <u>name</u> on the back of this page—

PhD Qualifying Exam
Manufacturing
Fall 2004

Note: Answer all problems. Show your work steps clearly. List all relevant assumptions.

1. A two-high non-reversing rolling mill rated at 100 kW maximum power and 60 rpm maximum speed is used to roll aluminum sheet of 4 mm initial thickness. The flow stress of the aluminum is given by the following power-law function: $\sigma = K\varepsilon^n$ where K = 200 MPa and n = 0.18. The rolling mill can apply a maximum roll-separating force of 1 MN. The roll-gap is lubricated to yield a coefficient of friction $\mu = 0.1$. It is also known that the maximum reduction in thickness achievable in flat rolling is given by: $\Delta h_{\max} = \mu^2 R$ where $\Delta h = h_i - h_f$ and R is the roll diameter.

(a) Determine the smallest thickness of the sheet that can be produced by the rolling mill.
(b) Assuming maximum reduction in thickness, find the maximum width of sheet that can be rolled if the mill is run at maximum power and speed.
(c) Suggest <u>three</u> ways to further increase the maximum reduction in thickness for the specified rolling mill <u>and</u> explain why they will work.



2. Consider the compression molding of a thermoplastic polymer (see figure below). The initial, undeformed billet is rectangular (w x h x unit depth). The polymer can be modeled as a non-Newtonian fluid, with its viscosity (μ) as a function of shear rate ($\dot{\gamma}$) represented by:

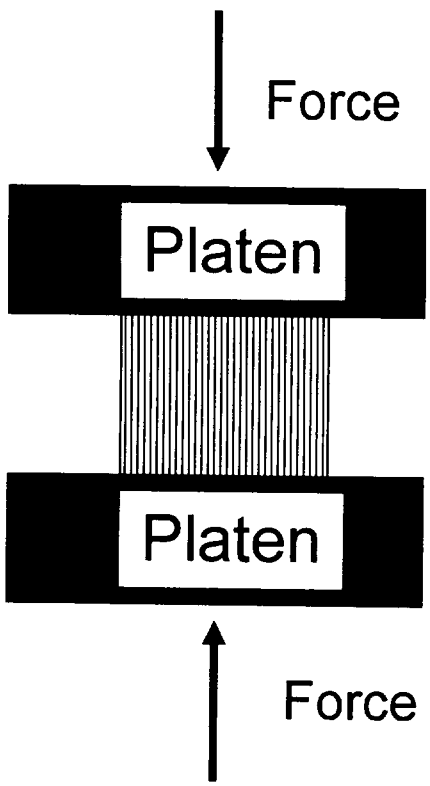
$$\mu(\dot{\gamma}) = k \cdot \dot{\gamma}^{n-1}$$

where k and n are constants.

(a) Derive an expression for the pressure as a function of position across the face of the forging.
(b) Derive an expression for the compression molding force.
(c) Determine the compression molding force using your result for (b) and the following values:

The initial dimensions of the part are 50 mm wide, 50 mm high, and 150 mm deep (into the paper).
The final part height is 25 mm.
The constants for the viscosity model are $k = 2 \times 10^4$ N-s^n/m^2 and $n = 0.2$.
The platens close at 0.1 m/s.

Hint: the process is analogous to open-die forging.



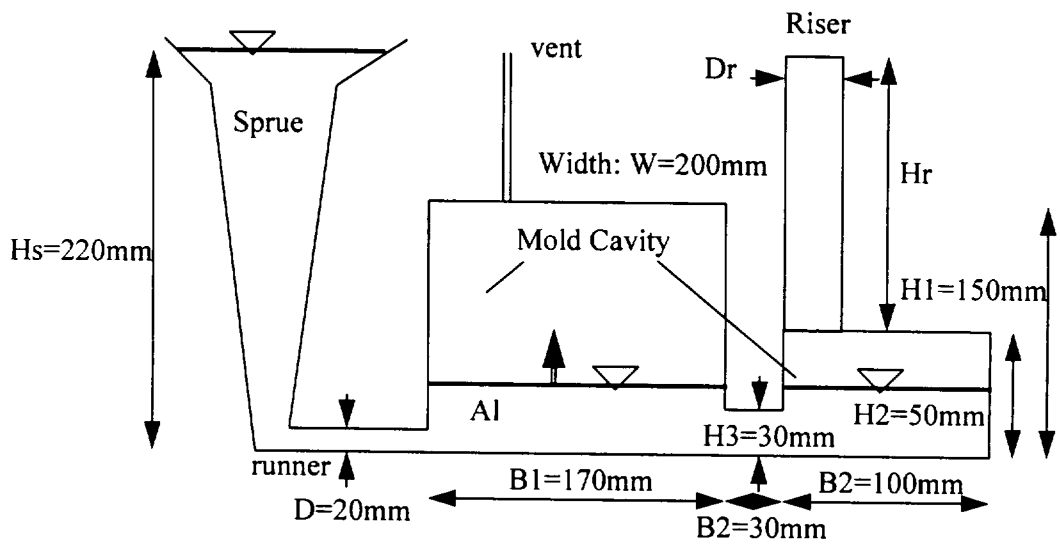
3. A 5 inch long, 3/4 inch diameter cast iron (specific cutting energy = 2.05 hp-min/in^3) rod is being reduced in diameter to 5/8 inch by turning on a lathe. The spindle rotates at 1200 rpm, and the tool travels at an axial speed of 4 inch/min. Calculate (a) the cutting speed in inch/minute, (b) material removal rate in inch^3/minute, (c) time of cut in minute, (d) power required in hp, and (e) cutting force, tangential to workpiece, in lb.

   If the tangential cutting force is 50 lb in the above case, how will the tangential force change in the following cases:

   (i) undeformed chip thickness is doubled, all else unchanged
   (ii) depth of cut is doubled, all else unchanged
   (iii) spindle speed is doubled, all else unchanged
   (iv) rake angle is doubled, all else unchanged

   Estimate how much the change in cutting force will be for each case and explain why.

4. Your task is to design a casting and mold system for manufacturability and to estimate critical process cycle times to be used in a life cycle manufacturing cost analysis model. The part is to be manufactured of Al (thermal conductivity 218 W/mK, specific heat 1146 J/kgK, density 2792 kg/m^3, melt temperature 660°C, heat of fusion 204.8 kJ/kg) and is to be sand cast in a green sand mold (thermal conductivity 2.17 W/mK, specific heat 1105 J/kgK, density 2220 kg/m^3). You are asked to estimate the solidification time and design a riser for the part shown.



(a) Estimate the ratio of the longest solidification time for the part to the shortest solidification time.

(b) How long should the part remain in the mold to completely solidify prior to demolding. Justify your answer with relevant calculations and discuss the major assumptions in your analysis.

(c) Finally, you are to design a riser for the molding. Your design criterion for the riser is that its solidification time must equal that of the local part to which it is connected. The riser is cylindrical having a height Hr (governed by the cope dimensions) and diameter Dr. Note that the cylindrical nature of the part is best.