GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1998

Manufacturing
EXAM AREA

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

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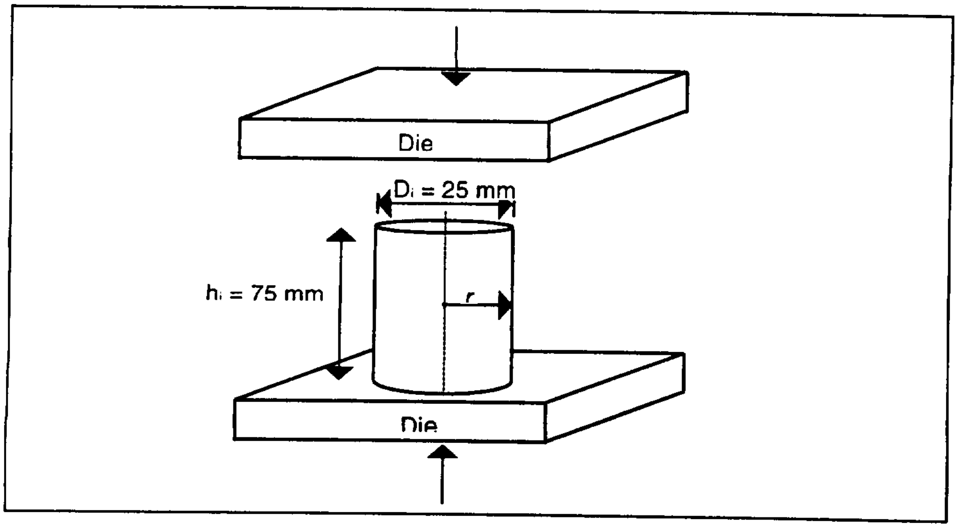
Spring 1998 Doctoral Qualifying Examination: Manufacturing

Note: Select five, and NOT MORE THAN FIVE, questions from the following to answer. Also note that questions 5 and 6 are coupled, although you do not need to select both of them.

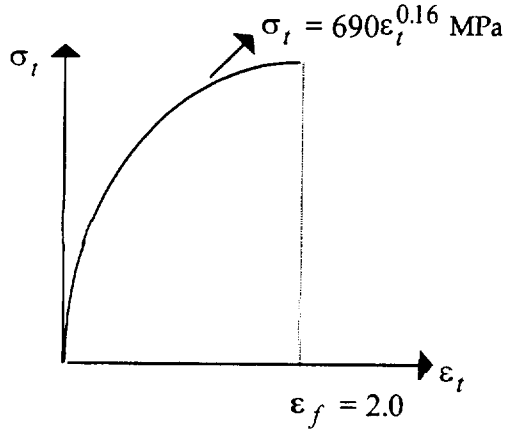
1. An AISI 2024-T4 Aluminum *cylinder* 75 mm high and 25 mm in diameter is to be upset forged at room temperature to *half height* in a press. The flow curve of the material is as shown in the sketch in part (b). A slab analysis of the stresses acting on an element yields the following average normal pressure distribution at the cylinder-die interface: $\overline{\sigma}_y = Y_f\,(1+\frac{2\mu r}{3h})$ where Y_f is the flow stress of the work material and μ is the coefficient of sliding friction at the die-workpiece interface. Redundant deformation is assumed to be negligible. Three presses are available for the operation: a mechanical press with a 500 KN capacity costing \$100K, a mechanical press with a 1 MN capacity costing \$250K, and hydraulic press with a 1.5 MN capacity costing \$600K.

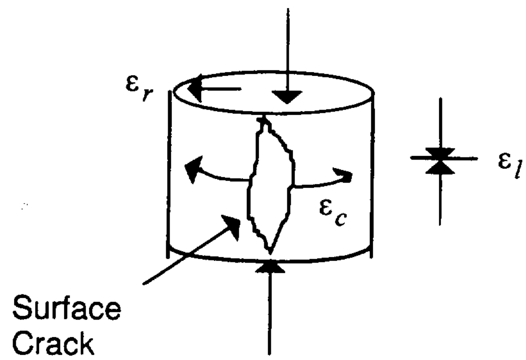


(a) Slab analysis considers the static equilibrium of a small radial "slab" subjected to stresses in order to determine the normal pressure distribution at the die-workpiece interface. Sketch the stresses acting on a "slab" in the upset forging process shown above.

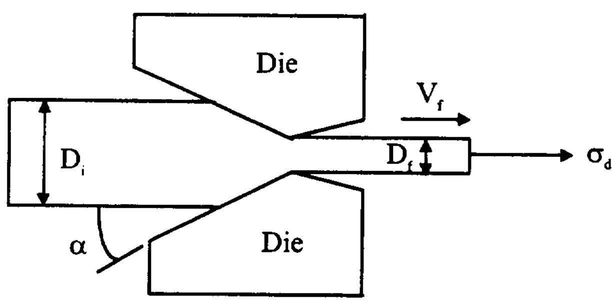
(b) As the manufacturing engineer, your job is to select a press that is adequate and economical for the forging operation. Justify your selection via appropriate calculations. Assume the coefficient of sliding friction $\mu = 0.1$.

forged. The three principal strains in the forged specimen are shown in the sketch. Note that the radial and circumferential strains are tensile (and equal to each other) and the longitudinal strain (in the forging direction) is compressive. Can the cylinder be reduced to half its original height without surface cracking? Justify your answer with appropriate calculations. (Note that the circumferential length at any instant of the forging operation is given by πD, where D is the instantaneous diameter.)





2. A 4 mm (D_f) diameter electrical conductor made of copper is required to be produced from a 12 mm (D_i) diameter copper wire. The process engineer selects the wire drawing process to accomplish this task. This process is shown schematically in the figure below. The conical die chosen by the engineer has a 4 degree half-die angle (α). The true stress-true strain curve for the material is $\sigma_t = 80 + 320\varepsilon_t$ MPa. Past experience with this material and process reveals that the sum of frictional and redundant work is approximately 20% of the ideal work of plastic deformation.

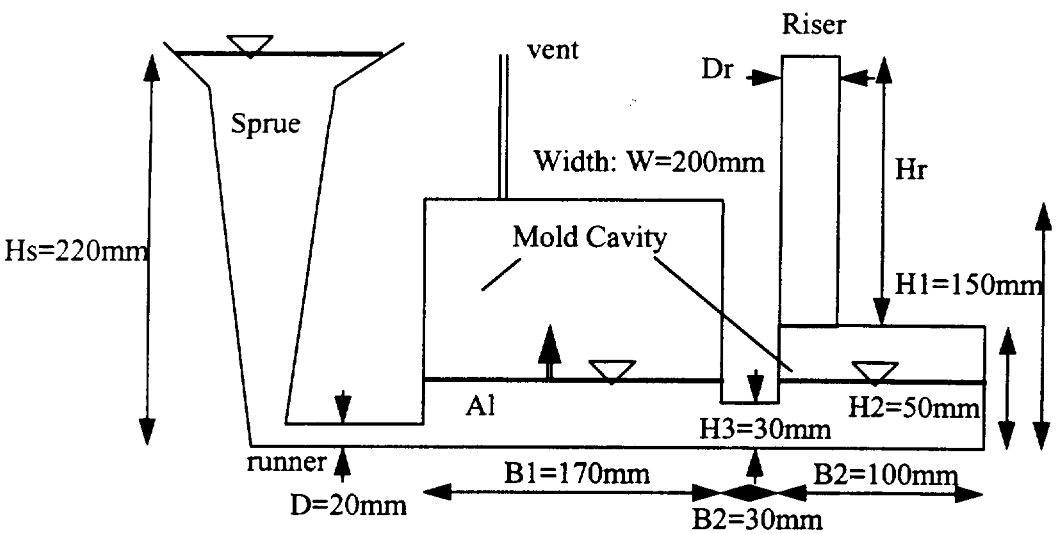


(a) Sketch the stresses acting on an infinitesimal element of the copper wire inside the die.
(b) Briefly discuss the key factor(s) that severely limit the maximum uniform reduction in diameter that can be achieved in a single pass of the drawing process.
(c) Can the desired reduction in the given problem be achieved in a single drawing pass? Justify your answer via appropriate calculations.

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 is traveling 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. Note that $1\text{ hp} \approx 4 \times 10^5$ in - lb/min.

4. Consider the turning of a cylindrical workpiece of which the apparent shear strength is known to be 315 GPa. The diameter of the cylinder is to be reduced by 2 mm using a cutter of 10° rake angle at a feed of 0.2 mm per spindle revolution. If the cutting ratio in this case is found to be 0.5, could you estimate the thrust cutting force in Newton?

5. 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 out of Aluminum (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, specific heat at 100 K 482 J/kgK, thermal conductivity at 100 K 302 W/mK, specific heat at 400 K 949 J/kgK, thermal conductivity at 400 K 240 W/mK, specific heat at 800 K 1146 J/kgK, thermal conductivity at 800 K 218 W/mK) and is to be sand cast in a green sand mold (thermal conductivity 2.17 W/mK, specific heat 1105 J/kgK, emissivity 0.9, density 2220 kg/m^3).



(a) Derive an expression for the mold filling time. Note that for the mold design given, the runner is short producing negligible flow losses. However, the free expansion at the runner exit has a loss factor of $f = 1.5(v^2/2g)$.

(a) Estimate the mold filling time in seconds using the data given in the problem.

(b) List and briefly discuss four common casting defects that could occur in the given mold and part design. Your discussion should address the physical cause of the defects and possible remedies to eliminate the defect in future part runs.

6. Continuing with the manufacturability analysis of problem 5, you are next 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 state the major assumptions of your analysis. Assume the ambient temperature to be 25° C.

(c) Finally, you are to design a riser for the molding. Your design criteria 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.