GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1997

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—**

GEORGIA INSTITUTE OF TECHNOLOGY
The George W. Woodruff School of Mechanical Engineering

Doctoral Qualifying Examination-Manufacturing

Note: Answer FIVE (of your choice) from the following 6 problems. If all problems are answered the best five will be counted

1. A relatively small rectangular part is being ***sand cast*** using a mold configuration shown below. As a manufacturing engineer, you are asked to estimate the cycle time for casting the part.

(a) Derive an expression to estimate the mold filling time. To model the mold filling time consider the molten metal flow to be invisid flow, neglect the head loss at the pour basin and the sprue to runner transition. Also consider the fluid level in the sprue to maintain a constant value Hs during the pour. Note for the mold design given, the runner is short producing negligible flow losses. The head loss associated with the free expansion of the flow at the exit of the runner is significant and given by the factor $f = K\frac{v^2}{2g}$ where K $\approx$1.0.

(b) Using this expression as a guild, suggest two mold redesign strategies (i.e., changes) that will decrease the casting cycle time, given that the dimensions of the part are fixed by the design specifications.

(c) If the runner solidifies in a time of t_{runner}=60s, derive an expression to estimate the cooling time of the ***die*** cast part and calculate the value.

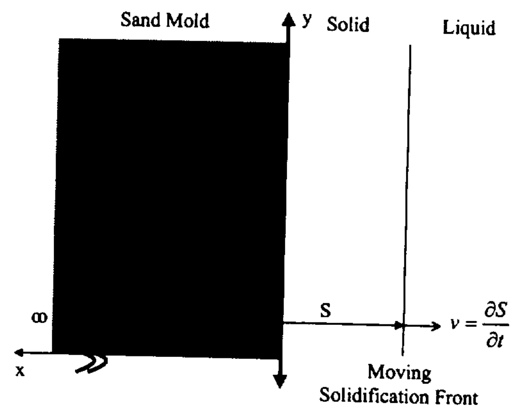
(d) Based on the ratio of solidification times of the runner and the part, what additional feature(s) (list two possibilities) would you include in the mold design to prevent ***casting defects***.

(f) Sketch on a relative scale the temperature profiles across the mold/part system shown for both insulating molds, like sand casting, and high heat transfer rate molds like in die casting (approximate the temperature profile based on plane front solidification) Focus only on the part and adjacent mold walls.

2. As a manufacturing engineer, you are charged with verifying the design of a steel production line using a continuous casting technique. Of particular concern is the design of the solidification die. Your task is to estimate the length of the die. To model the solidification process, consider the material to experience plain from solidification with solidification being governed by the conduction heat transfer through the mold.

(a) Modeling the mold as a semi-infinite medium, develop an expression to predict the solidification time. Assume that the metal is poured without superheat and neglect surface contact thermal resistance between the mold and cast solid. Know parameters are the density of the mold material, r_m, thermal conductivity of the mold materials, k_m, specific heat of the mold material, c_{pm}, latent heat of fusion of the mold materials, H_m, latent heat of fusion of the cast materials, H_c, half thickness of the sheet, h, density of cast material, r_c, specific heat of the cast material, c_{pc}, ambient temperature, T_0, melt temperature of the cast materials, T_m.

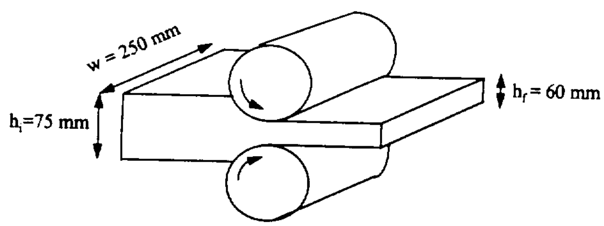
(b) If the velocity of the cast sheet exiting the die is v_s derive an expression to estimate the required die length.



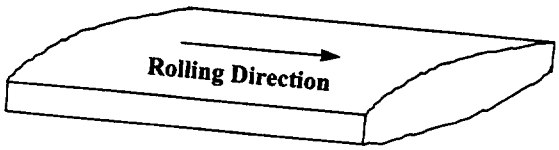
3. A 75 mm thick by 250 mm wide slab of AISI 4135 steel is being cold-rolled to a thickness of 60 mm in a single pass. A two-high non-reversing rolling mill (shown below) with 750 mm diameter tool steel rolls is available for this task. The rolling mill has a power capacity of 5 MW per roll. The rolls rotate at a constant angular speed of 100 rev/min. The workpiece material has the following true stress-true strain curve: $\sigma_t = 1100\varepsilon_t^{0.14}$ MPa. The coefficient of friction between the steel plate and steel rolls is known to be $\mu = 0.2$.

(a) Sketch and state the stress state imposed on a infinitesimal element in the steel plate by the rolling process shown below.

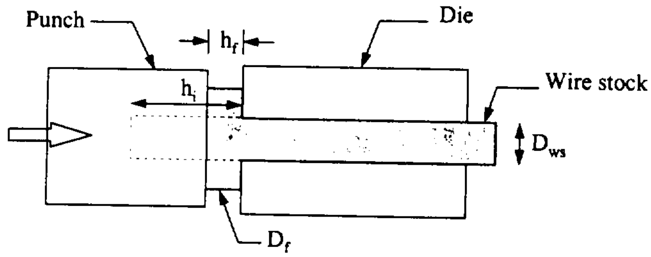
(b) Is the available rolling mill adequate for the desired operation? Show appropriate calculations in support of your answer.



(c) It is found that the thickness of the cold-rolled steel slab varies considerably across its width as shown in the sketch below. Explain the primary cause of this thickness variation and discuss at least two ways in which this variation in thickness can be reduced or entirely eliminated. Be sure to briefly explain why each of your suggestions, if properly implemented, will work.



4. Heading is an operation that is often used to produce heads on nails, bolts, and other fasteners. One such heading operation for a steel nail is shown in the figure below. The flow curve for the nail material is known to be $\sigma_t = 1015(\varepsilon_t)^{0.17}$ MPa. The diameter of the wire stock (D_{ws}) from which the nail is to be made is 4.75 mm. The final diameter (D_f) and thickness (h_f) of the head of the steel nail are required to be 9.525 mm and 1.5875 mm, respectively. (Note: In the figure below, the punch is shown at the end of its travel toward the die; the workpiece is held firmly in the die while the head is being formed).



Heading (Upset Forging)

(a) Assuming that friction at the punch-head and die-head interfaces is negligible, calculate the maximum force the punch must exert to form the head on the steel nail.
(b) How will friction influence the pressure distribution at the punch-head interface? Explain with the help of a sketch of the pressure distribution.
(c) What type of defect(s) would you expect in such a operation? List the defect(s) and briefly explain the cause(s).

5. In a single point turning process, the cutting tool had a rake angle of 12° and a relief angle of 3°. The feed was 0.025 ipr while the radial depth of cut was 0.1 inch. It was observed that the resulting chip had a sectional area of 0.1 inch (in the workpiece radial direction) by 0.045 inch. The cutting force in the tangential direction was 420 lb while that in the thrust direction was 250 lb. Suppose that an orthogonal cutting model describes well the behavior of the process, estimate the shear strength of the work material in cutting.

6. In the following surface grinding process the part was ground by a wheel of 2.5" cup diameter at the bottom. The feedrate of the grinding table was 2 ipm. (1) Estimate the total amount of grinding time required for 1 pass, (2) What is the reason for a spark out pass in grinding? How is it typically done?