GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam – Spring Semester 2020

MANUFACTURING

EXAM AREA

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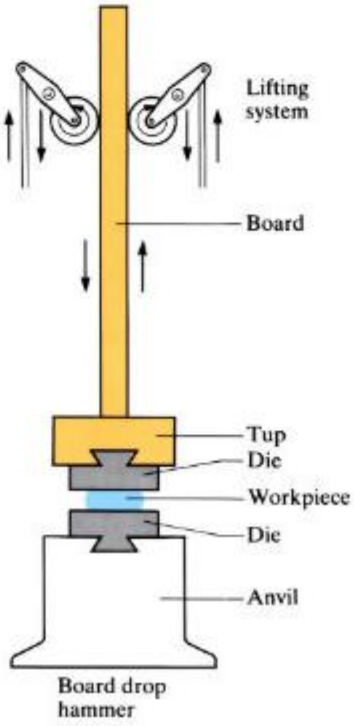
Assigned Number (DO NOT SIGN YOUR NAME)

✷ Please sign your **name** on the back of this page —

Question #1 – Metal Forging

Consider the gravity drop hammer forging of a piece of metal, as shown below. The hammer (board, tup and upper die) has a mass of 4200 kg. The hammer is dropped from a height of 1.8 m. The operation is **open die** forging of a cylindrical billet. The cylindrical billet is initially 1 m in height and 500 mm in diameter. The gravity constant is 9.8 m/s^2. The operation can be considered cold.



(a) Assume that the material is perfectly plastic with a yield stress of 250 MPa. Assume that the friction condition is all sticking. Determine the maximum change in height of the billet in millimeters.

(b) Now, assume that the material is strain hardening with the following material model:

$$\sigma = K\varepsilon^n$$

K = 760 MPa, n = 0.19. Assume that the friction condition is all sticking. Determine the change in height of the billet. You are not to provide a single numerical answer; rather, this is a modeling and algebra question. Your answer should an algebraic equation in terms of geometric and material parameters. Do substitute numbers for the values that you are given, for example initial height, initial diameter, K, n.

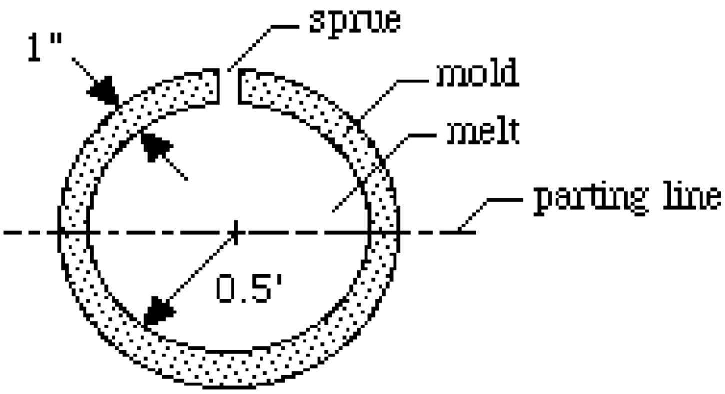
(c) List the primary defect that you would expect to see with this process. What is this defect due to?

Question #2 – Metal Casting

In die casting of complicated parts, a mold consisting of a cope (top half of mold) and a drag (bottom half of mold) is often used in conjunction with the needed clamping force along the parting line.

(a) Discuss what could be the disadvantages of using a clamping force that is too low, and of using a clamping force that is too high.

(b) Consider the case of a 1 ft diameter spherical part that is to be die cast in a graphite mold as shown in the cross-sectional view below. The cope and the drag both have a 1 inch thickness and a specific weight (density) of 172.8 lbf/ft^3. Because of the sizes of the casting and the mold in this case, a clamping force of 29.6 lbf is needed to keep the mold halves from separation. Being a tooling consultant, you are asked to re-design the mold thickness so that there is no need for clamping force in casting this part. What should be that thickness? Is that a minimum or a maximum required thickness?



Question #3 – Injection Molding of a Polymer

You have been tasked with manufacturing one million buttons, similar to that shown below, which will be sewn onto new GT yellow jackets. Using this image and assuming symmetry, answer the questions listed below. State all critical assumptions when answering the questions.

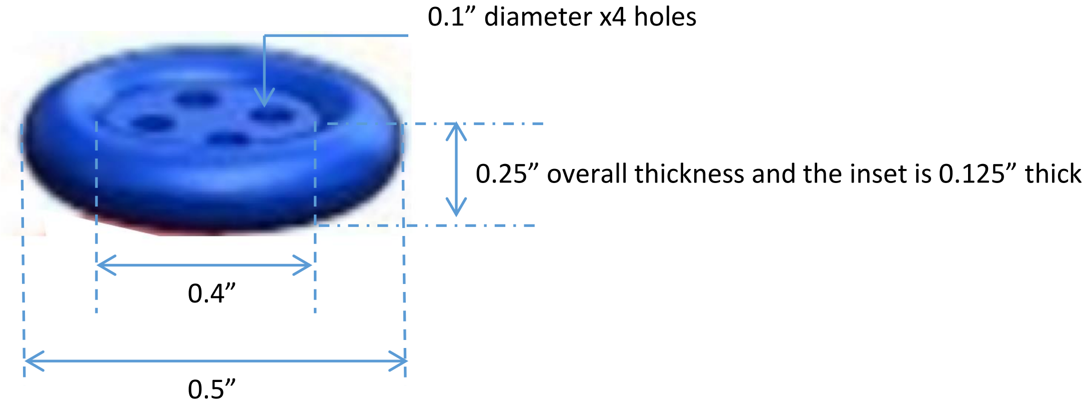


Illustration of a button.

a) Make a detailed sketch of an injection mold that fabricates twelve buttons at a time; all pertinent components should be clearly illustrated.
b) In a separate image, sketch the flow path in one button's cavity during the mold filling process. Will there be any defects? If so, indicate them on the sketch and describe how you would minimize or eliminate them.
c) Each button weighs 1.4 grams. Twelve buttons are fabricated using the single mold designed in part (a) at 100 MPa injection pressure. Assume that the plastic has a density of 1,500 kg/m^3, thermal conductivity of 0.3 W/m-K, and thermal diffusivity of 10^{-3} cm^2/s.
    a. Calculate the shot size.
    b. Calculate the clamping force.
    c. Calculate the cooling time.
d) For this button, are you satisfied with the given product design, product material, and fabrication process? Why or why not? How would you change any or all of them? Be specific.

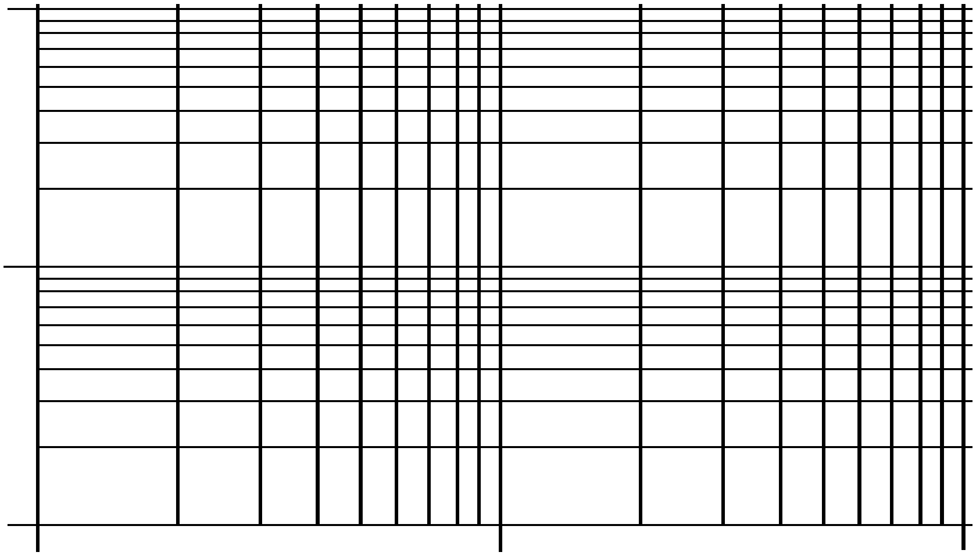
Question #4 – Metal Cutting

The following flank wear data were collected in a series of machining tests using C6 carbide tools on 1045 steel (HB=192). The feed rate was 0.015 inch/revolution and the width of cut was 0.030 inch.

Cutting speed, ft/min	**Cutting time, min**	**Flank wear, in.**
400	0.5	0.0014
	2.0	0.0023
	4.0	0.0030
	8.0	0.0055
	16.0	0.0082
	24.0	0.0112
	54.0	0.0150
600	0.5	0.0018
	2.0	0.0035
	4.0	0.0060
	8.0	0.0100
	13.0	0.0145
	14.0	0.0160
800	0.5	0.0050
	2.0	0.0100
	4.0	0.0140
	5.0	0.0160
1000	0.5	0.0100
	1.0	0.0130
	1.8	0.0150
	2.0	0.0160

(a) Plot flank wear as a function of cutting time on the graph below. Then, using a 0.015 inch wear land as the criterion of tool failure, determine the lives for the four cutting speeds shown in the table. Use the plot that you create to determine the lives graphically.

(b) Plot the results for the four tool lives determined in part (a) on the log-log plot below and determine the values of n and C in the Taylor tool life equation (assume a straight-line relationship). You can do this graphically and/or numerically.



(c) Using the result of part (b) for the Taylor tool life equation constants, calculate the tool life for a cutting speed of 300 ft/min.