Department of Mechanical Engineering – Clemson University

PhD Qualifying Examination

Manufacturing

August 2009

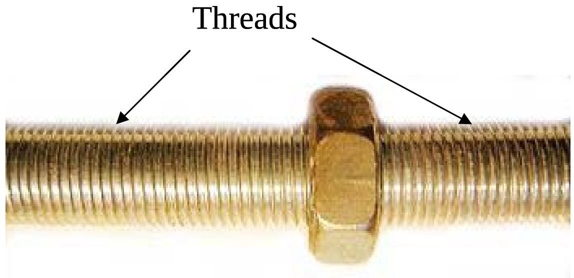
<u>IMPORTANT:</u>

- **You are to answer ALL EXAM QUESTIONS.**
- **Each problem will be WEIGHTED EQUALLY for grading purposes.**
- **The examination is CLOSED BOOK.**
- **No formula sheets allowed**
- **TWO HOURS are allotted for the exam**

Student Identifying Number______________________

(Please indicate your identification number on all pages.)

1. Turning

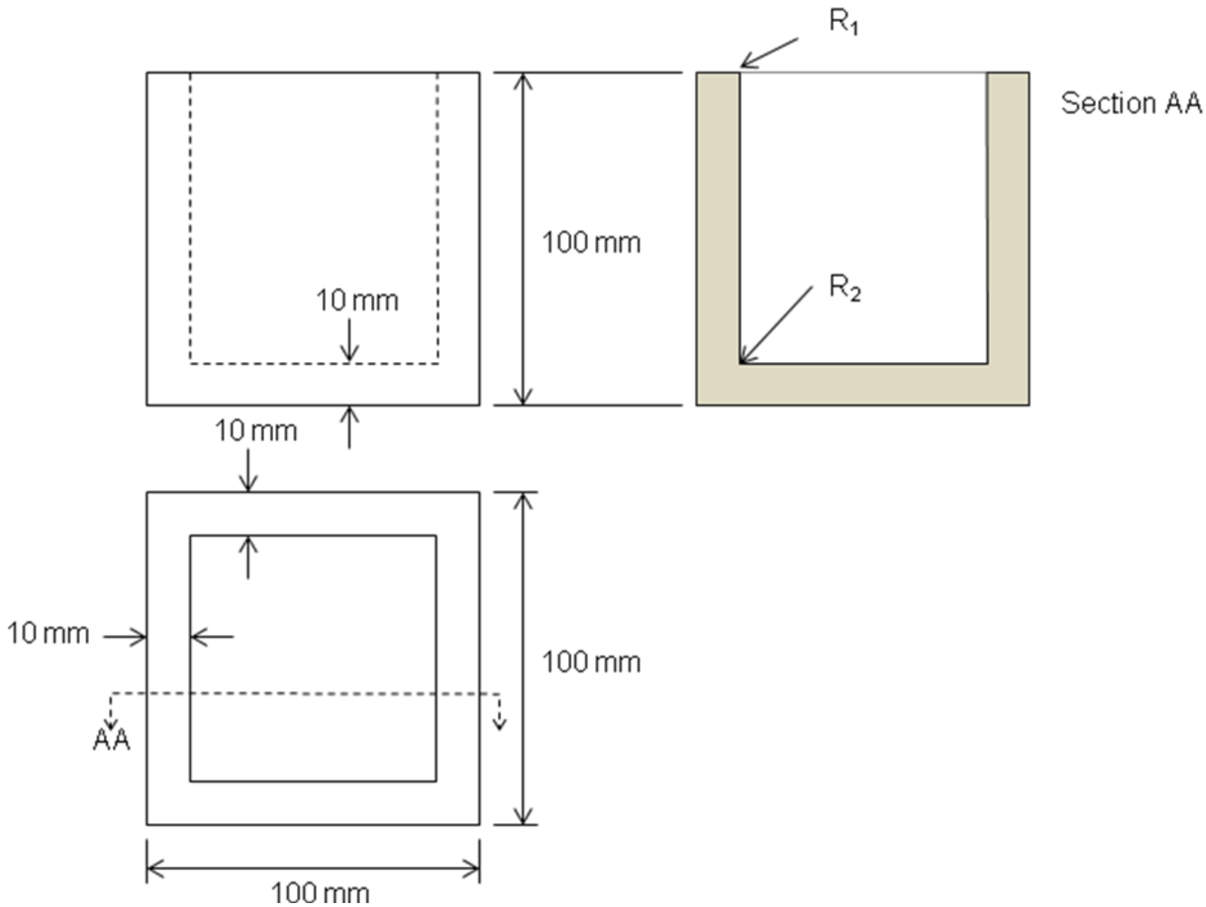


Threads can be made using either machining or forming. Explain the advantages and limitations of producing threads by machining or forming, respectively.

2. Forming (Wire drawing)

Sometimes a rod drawing operation can be carried out either in one pass or in two passes in tandem. If the die angles are the same and the total reduction is the same during the process, will the drawing forces be different between the one- and two-pass configurations? Please support your conclusion with mathematical derivations.

3.) Milling.
You are going to mill a pocket as shown in the Figure below.



You will start with a block of 6061-T6 aluminum that is already milled to the dimensions of 100 mm X 100 mm X 100 mm and use a diamond coated high speed steel ball mill cutter with a 10 mm diameter. The bottom of the pocket should have a peak to valley surface finish (R_t) of no more than 1 μm. You should minimize the machining time for this operation. Please provide the following information for the pocket milling operation:

- **a)** The feed speed, rotational velocity (RPM), surface speed and depth of cut for the ball mill cutter. **(30 points)**

b) The smallest and largest value of the radii R_1 and R_2 that you can produce on this part. **(20 points)**

c) The machining time for your part. **(10 points)**

d) If we now change the part material to 1017 steel hardened to 50 RC, how would you change the process. Just describe what would be different in your answers to parts A-C, there is no need to redo the calculations. **(20 Points)**

e) For both the aluminum and steel parts, please provide any recommendations for a substitute tool material, if you think that a better material should be used. Make sure to fully explain your answer. **(20 points)**

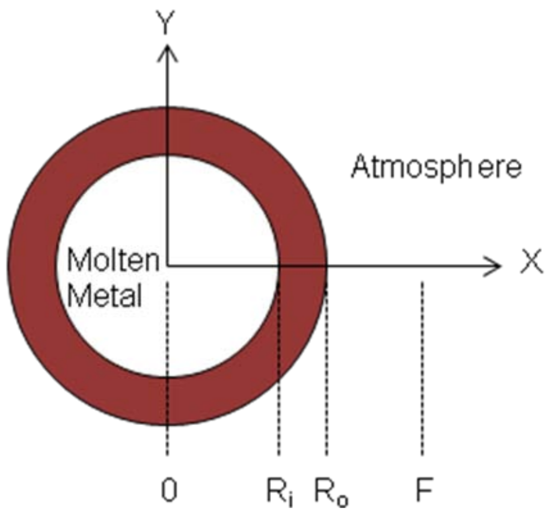
4. Casting

a.) (20 points)

Here we will compare and discuss three different cast parts that all have the **same mass of metal**. The three parts are a sphere, a cylinder that has equal height and diameter, and a cube. Which part will solidify the fastest and slowest. Assume that you are pouring standard cast iron.

b.) (20 points)

For this problem, please consider only the spherical part. Please use the coordinate system shown in the figure below, which is a cross section of the spherical mold. Molten metal completely fills the mold from X=0 to $X=\pm R_i$. The mold walls are shown in the figure between R_i and R_o, and outside of R_o is the atmosphere at standard temperature (20ºC) and pressure (1013.25 mbar). Assuming that the metal has been poured into the mold, and is beginning to solidify but is not completely solidified yet, please sketch temperature T as a function of X for $0 \leq X \leq F$. Please use T_m for the melting temperature of the metal and show this on your sketch.



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c.) (20 points)
For the center location (X=0, Y=0) on the part in problem 2, please show a time history of the temperature. Please start with time, t=0, where the initial temperature of the metal is T_i and is above the melting point of the cast material, T_m.

d.) (20 points)
For all the parts described in part (a), please sketch any shrinkage that might occur, and describe what you might do to reduce the shrinkage.

e.) (20 points)
No doubt you mentioned porosity in part (d). Let's look a bit more into porosity. Please discuss potential causes of porosity, and how you can reduce it. Is porosity desirable or not, please explain why this is so.

5. Welding

a.) A welded blank is proposed for an automotive component. For this component, 2 pieces of steel plate 5 mm thick are to be arc-welded in an automated production process. The total length of the weld for each assembly is 275 mm. The weld bead is to be the full thickness of the part and is 4 mm wide. The specific energy of the material is 14 J/mm^3, and the efficiency of the process is 85%. How much electrical energy is required per part?

E = ________________________J

b.) If the process uses a constant voltage power supply with V = 20 Volts, and a current of 110 amperes, how much time is required for each weld?

t = _____________________________sec

c.) The required production rate for this part is 2000/week. The weld station where the part is produced has a load/unload time of 20 seconds per part, and the station is in operation for 7 hours/day and 5 days/week. How many welding stations are necessary?

Number of stations = _____________________

d.) An alternative welder power supply is 15% less expensive, but is only capable of putting out 75 amperes at 20V. If this power supply is selected, how many welding stations will be required?

Number of stations = _______________________

e.) If the lower cost power supply is used, will the cost per part for this operation be higher or lower? Assume the useful life of the power supply is 2 years.