**Ph.D. Qualifier Examination – Manufacturing**
**Spring 2014**

This is a closed book examination.
Attempt any three out of four questions.
All questions are of equal weight.

## Question #1 Metal Forming

1. Outline the advantages and disadvantage of drawing operation with respect to extrusion.

2. A 0.25"- diameter wire made of material with a true-stress-true-strain relationship of $\sigma = 10{,}000\varepsilon^{0.3}$, in which the true stress is $\sigma$ and true strain is $\varepsilon$. What is the smallest possible diameter (in inches) to which this wire can be drawn down to in one pass – assuming friction and redundant work are negligible?

## Question #2 Machining

A mild steel workpiece is being cut at a speed of 120 m/min on a shaping machine using a zero rake angle wedge-shaped High Speed Steel (HSS) tool. The depth of cut is 0.25 mm and the width of cut is 2.5 mm. The cutting force components are measured using a piezoelectric platform dynamometer placed underneath the workpiece and the following mean values of the forces are obtained: cutting force ($F_c$) = 890 N, thrust force ($F_t$) = 667 N. Based on measurements of the deformed chip thickness, the cutting ratio is found to be 0.3. Assuming that 10% of the energy dissipated in the primary deformation (shear) zone is conducted into the workpiece surface, calculate the following:

1. Mean temperature rise in the workpiece surface.

2. Mean temperature of the chip.

List clearly all assumptions you make and justify them.

The density of mild steel ($\rho$) is 7200 kg/m$^3$, its thermal conductivity ($K$) is 43.6 W/m.K, and the specific heat ($c$) is 502 J/kg.K. Assume the ambient temperature to be 25°C.

## Question #3 Polymer Processing

1. What are the three major classifications (types) of polymers? Sketch the stress versus strain behavior for each class of material. Be sure to label the axes and create a legend to identify what material corresponds to a particular line.
2. 500,000 parts made of polypropylene (PP), shown in Figure 1 need to be fabricated by your company. A member of the group has setup the injection mold machine to fabricate the parts, but did not have time to begin processing the parts. You are tasked with fabricating the first few batches of parts.

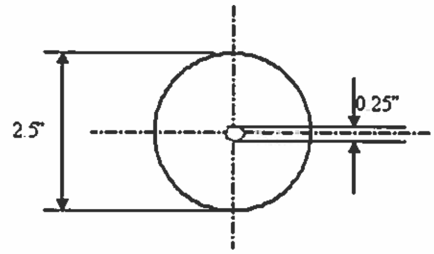


Figure 1. Polymer part.

a) After running the first 30 shots you realized that all of the parts have excessive flash. Why has this occurred and how would you correct this issue?
b) To adjust for the flash, you randomly turned the knobs on the machine and created various defects with respect to the melt temperature and injection pressure. Using the processing window, shown in Figure 2, describe the different defects that you observed in regions A, B, C and D and explain how you would correct or eliminate them.

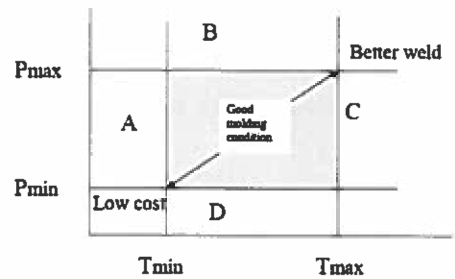


Figure 2. Processing window for injection molding.

You were able to establish good molding conditions. Upon doing so, the cycle time of the part was measured as 60 seconds distributed as follows: mold filling (10%), part cooling (70%), ejecting and mold closing, etc. (20%). This cycle time is too high for the cost of the part. In order to compensate for this, the part thickness has to be reduced by 30% and the injection speed increased by 100%. Based on these new conditions, estimate the new cycle time for the part. (Assume a uniform thickness change.)

**Question #4: Metal Casting**

A casting is being produced out of pure aluminum metal in a sand mold. The metal level in the pouring basin is 254 mm above the level of metal in the mold, and the runner is circular with a 10 mm diameter. Pure aluminum has a density of 2700 kg/m$^3$ and a viscosity of approximately 0.0015 N-s/m$^2$ around 700°C.

First, determine the following:

1. The velocity and rate of the flow of the metal into the mold
2. Whether the flow is turbulent or laminar
3. What, if any, corrective action is required

Next, for the sprue described above, determine the following:

4. The runner diameter needed to ensure a Reynolds number of 2000

5. The time it will take for such a runner to fill a $2.5 \times 10^6$ $mm^3$ casting

Now, provide your analysis (quantitative and qualitative) on the impact of this filling time on the castability of the component.

6. Is the casting process expected to proceed flawlessly or are some difficulties or concerns expected? Explain.

Next, assume that the mold is bottom-gated. The casting has a square cross-section of 150 mm per side and a height of 100 mm.

7. Derive the equation for the mold filling time and use it to determine the filling time for this mold using the original runner diameter. Assume the sprue is frictionless.

Finally, you are to estimate the time for the casting to solidify. The constant "C" in Chvorinov's rule for this situation is given as 3 $s/mm^2$. The mold can be broken safely and the casting retrieved when its solidified shell is at least 25 mm thick. You should assume that the casting cools evenly.

8. Determine the time that must transpire after pouring the molten metal before the mold can be broken. Provide justification for your analysis.