**Woodruff School of Mechanical Engineering**
**Georgia Institute of Technology**

**PhD Qualifier** **Manufacturing** **Fall 2012**

Choose 3 from the following 4 problems to work on

(1) A metal is being cast into a rectangular solid that is 3 cm on a side and 8 cm tall. The mold is bottom-gated. The vent on this part should be 1.5 cm high, and does NOT fill with metal. You wish the part to fill in 6 seconds with no aspiration. The metal has a density of 2700 kg/m$^3$ and a viscosity of 2.8x10$^{-3}$ N-s/m$^2$. The pouring basin is 1 cm tall. Determine the dimensions of top and bottom of the sprue, and of the runner and gate. The bottom of the sprue, the runner and the gate should have the same diameter.

(2) Consider the open die forging of a rectangular part. The instantaneous dimensions of the part are height (h), width (w) and depth into the page (d). The coefficient of friction is $\mu$. $x_k$ has its usual meaning, as does $\sigma_{flow}$.

(2-1) What relationships (e.g., equalities, inequalities, etc.) exist between the initial dimensions $h_{initial}$, $w_{initial}$, and $d_{intial}$ and the final dimensions $h_{final}$, $w_{final}$, and $d_{final}$? What assumptions do you need to make to develop these relationships? Explain these assumptions.

(2-2) The average forging pressure in the sliding region can be shown to be:

$$p_{average} = 1.15 * \sigma_{flow} * \frac{h}{2\mu x_k} * \left[\exp\left(\frac{2\mu x_k}{h} - 1\right)\right]$$

Show where the term (1.15 * $\sigma_{flow}$) comes from.

(2-3) If one assumes that the entire forging is sliding, the all-sliding approximation for the average pressure can be shown to be:

$$p_{average} = 1.15 * \sigma_{flow} * \left[1 + \frac{\mu w}{2h}\right]$$

Show how you would develop this relationship.

(3) The traditional orthogonal metal cutting theory proposed by Ernst and Merchant assumes that chip formation occurs on a shear plane inclined at an angle to the cutting direction such that the energy consumed in cutting is minimized. The shear angle obtained from their analysis is given by:

$$\emptyset = \frac{\pi}{4} - (\beta - \alpha),$$

where $\beta$ is the friction angle and $\alpha$ is the rake angle of the tool. A key assumption in this analysis is the constancy of shear yield strength $\tau_s$ of the material along the shear plane. In contrast, Bridgman proposed that the shear yield strength is a linear function of the normal stress ($\sigma$) acting on the shear plane as follows:

$$\tau_s = \tau_0 + k_1\sigma$$

where $\tau_0$ and $k_1$ are material constants.

(3-1) Sketch the Merchant's Force Circle and clearly label <u>all force decompositions</u> of the resultant force. Also indicate the shear angle, friction angle and rake angle.

(3-2) Derive an expression for the shear plane angle assuming Bridgman's theory for the shear yield strength holds true and the minimum energy principle is applicable. Clearly state any other assumptions you make.

(4) (4-1) 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.

(4-2) 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.

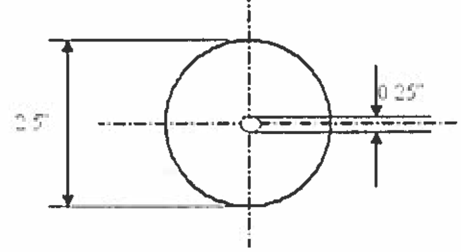


Figure 1. Polymer part.

(4-2-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?

(4-2-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.

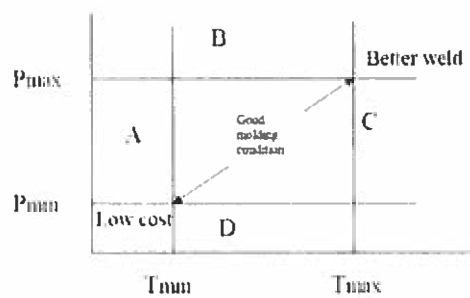


Figure 2. Processing window for injection molding.

(4-2-c) 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 to 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.)