030117 Polymer Processing Quiz 1

The processing of polymers differs from that of metals and ceramics in several important ways. Metals and ceramics are generally cast from a Newtonian melt with low viscosity. Most processing of metals occurs in the solid state through processes such as rolling and drawing.

1) Consider the formation of an aluminum can, a glass bottle and a plastic bottle for beer.
   -a) List what you think are the advantages of each as a container.
   -b) Briefly explain how each of these containers might be made. (Continuous, batch or semi-continuous operations?)
   -c) Consider the overall economic feasibility (cost assessment) of these containers and their processing.
   -d) Consider the aesthetic appeal and safety of the three materials.

2) a) Plot the log of viscosity versus shear rate for an aluminum melt, a silica melt and for a typical polymer.
   -b) Explain the different behaviors observed in this plot.
   -c) For the polymer what value of viscosity would be used to compare between different molecular weights?

3) Generally, the most important property of a polymer is the molecular weight and molecular weight distribution.
   -a) From a processing perspective explain why you would want to know in detail the molecular weight distribution of a polymer.
   -b) For a polymer with a broad molecular weight distribution, which part of the distribution is most important to polymer flow?

4) -a) Show that the rate of strain and the velocity gradient are different terms for the same tensor. (You can use simple shear flow between parallel plates to show this.)
   -b) For simple shear flow between parallel plates does the shear rate vary across the gap?
   -c) For shear flow in the Couette viscometer used in lab can the shear rate vary across the gap?

Answers: 030117 Polymer Processing Quiz 1

1) a) Glass and metal are good barriers to gas (CO_2) permeability. Most polymers are poor barriers to CO_2 permeability. Metal and plastic may impart some taste to the beer. Glass and plastic are clear which is an advantage for most products. Polymer and aluminum have much lower mass than glass. All three are recyclable. Polymer and aluminum are safe materials in terms of cuts.
b) The aluminum can is cast and then drawn. The top of the can is generally made in a separate operation of rolling and stamping. The can might be coated with a polymer to protect the contents from contamination by the metal. The formation of metal cans is basically a batch or semi-continuous operation. A plastic bottle is made by blow molding in a semicontinuous operation. Glass bottles are cast from the melt. The rate of production is probably much higher for plastic bottles.
c) Significant cost advantages exist for the lower weight materials, aluminum and plastic, due to lower shipping and stocking costs. In terms of raw materials glass is basically made from sand but high temperature processing makes the cost similar to polymers. Aluminum is the most expensive of the three.
d) Aluminum cans have a negative aesthetic feel. Glass and Polymer are better accepted aesthetically. In terms of safety, aluminum and polymer are about equal. Glass is inherently dangerous due to sharp pieces when broken.

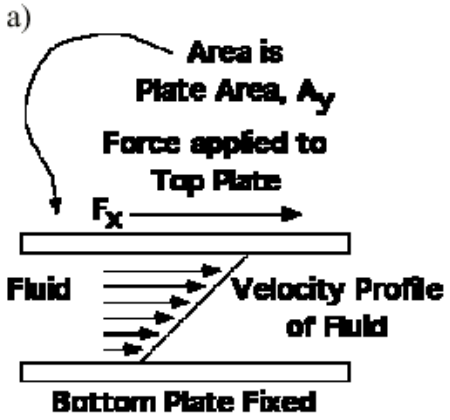
2) a) Metal melt has a low viscosity and Newtonian. Glass has a high viscosity and Newtonian. Polymer shows a Newtonian plateau at low rates of strain and a power-law decay at moderate shear rates.
b) High viscosity of glass melt is due to ionic associations, metal melt is a simple fluid with no ionic associations. The polymer melt is dominated by entanglement of the polymer chains and by deformation of the chains and disentanglement of the coils with moderate rates of strain.

c) Since the power-law decay depends strongly on the molecular weight the viscosities can only be compared at low shear rate in the Newtonian plateau regime.

3) a) The viscosity is highly non-linear in molecular weight. Typically, at low molecular weights a linear regime is observed. For moderate and high molecular weights the viscosity increases with a power of 3.4 in molecular weight. The molecular weight distribution should be raised to the 3.4 power to estimate the dominance of parts of the molecular weight distribution on processing.
b) The highest molecular weights will dominate the processing behavior.

4)

a)



$\tau_{xy} = F_x/A_y$

$\gamma_{xy} = dx/dy$ $\quad \tau_{xy} = \eta \dot{\gamma}_{xy}$

$\dot{\gamma}_{xy} = dv_x/dy$

$v_x = dx/dt$, so $dv_x/dy = (dx/dy)/dt = \gamma_{xy}/dt$

b) For parallel plate flow the shear rate is constant across the gap regardless of the shear rate dependence of the viscosity.

c) In cylindrical Couette flow the shear rate varies across the gap.