Quiz 4 2001 Processing

You are working for Dow Chemical on LDPE used for film applications. A Professor from the University of Twente gives a seminar on constitutive equations for simple fluids as analyzed using a corotational frame and a special memory function, $\Omega(t)$.

a) **-What** is a simple fluid?
-Should a soap/water solution be modeled as a simple fluid? Why?
-Should a LDPE polymer melt be modeled as a simple? Why?
-Is ketchup a simple fluid? Why?
-Is motor oil a Simple fluid? Why?

b) Your boss asks the speaker why he didn't use a codeformational reference frame to remove translational flow effects.
-Is this a good question? Why?
-What is a corotational reference frame?
-What is a codeformational reference frame?

c) The model uses an equation that includes the memory function $\Omega(t)$ in a series of integrals, the first of which includes the strain rate tensor and the second of which includes the square of the strain rate tensor. You are interested in modeling die swell and flow instabilities.
-Can the proposed constitutive equation be of potential use to you? Why?
-Is this a viscoelastic model? Why?

d and e) **-Sketch** a log-log plot for the typical behavior of viscosity and the coefficient for the first normal stress coefficient. For the following flow scenarios:

i) Show the region on the log-log plot of interest to the flow described.

ii) Give a common example of such a fluid from your experience at home, at work or in class.

iii) Give a physical model for the behavior (can be of the hand-waving type, i.e. why does this behavior occur).

iv) Give the importance of the behavior to processing. (For this you might want to refer to an extruder as was done in class and note the section of the extruder where this behavior might be observed.) Some of the behaviors may not be common to polymer processing.

d) An identical small bead (low mass) is placed in two fluids and it slowly falls at the same rate in both vessels. For the same two fluids the fluid is allowed to drain through a tube and the fluid flows 4 times **faster** out of one of the tubes!

e) One of the fluids swells as it exits the tube.

Answers Quiz 4 2001

a) A simple fluid is a fluid where the elements of the fluid act independently. This is not true of ionic fluids such as soap and ketchup. It is generally a good simplification for polymer melts and motor oil.

b) This is a poor question since the corotational frame already includes removal of translational flow effects. The corotational frame is a frame that flows with the fluid elements, a codeformational frame travels with and deforms with the fluid element.

c) It can be of potential use since it includes second order effects that lead to normal stresses. This is probably a viscoelastic model since the memory function generally displays a time dependence associated with viscoelastic response, i.e. non-Hookean and non-Newtonian response.

d) i)This is shear thinning behavior which could be described with a power-law model:

$$\eta(d\gamma/dt) = m\,(d\gamma/dt)^{n-1}$$

n is generally near 0.5, i.e. less than 1.

The first flow is at low shear rate in the Newtonian Plateau region and the second at high shear rate in the power-law fluid region.

ii) Shampoo flows this way.

iii) Structuring of the fluid by orientation in the direction of flow reduces viscosity with higher shear rate.

iii) High-shear rate processing conditions such as in the die of an extruder.

e.) i) The CEF equation would be used to empirically model this system.

$$\psi_1 = \Psi_1 \dot{\gamma}^2$$

$$\psi_2 = \Psi_2 \dot{\gamma}^2$$

The swelling becomes more dramatic at high shear rates but exists across the spectrum of strain rates for a typical polymer .

ii) Shampoo displays this behavior as to most polymer melts under high shear rate.

iii) Structuring of the fluid by orientation under high shear leads to an entropic normal force response.

iv) Die swell from the die of an extruder. Also pressure build up in the extruder barrel.