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GENERAL CONSIDERATIONS

Fluids: Simple or Structured

Fluid materials, by definition, are systems which flow when subjected to stress. How they respond to an input stress is the heart of rheological testing and may be a complex issue. There are many types of fluids: pure substances, mixtures, dispersions and solutions, falling into the categories of either simple or structured fluids. Each has its own unique behavior when subjected to stress. In general, when a material has a uniform phase, such as a solution or pure substance, it is referred to as a simple fluid. Materials which contain more than one phase, such as solid particles dispersed in a liquid, gas particles in foam or an emulsion of immiscible liquids are considered structured fluids since their rheological behavior is in general dominated by the interactions of the constituents.

Structured Fluids

Many of the materials we use each day are structured fluids. Most foods, cosmetics, pharmaceuticals and paints contain particles or droplets of an immiscible fluid suspended in a carrier liquid. A number of soft semisolid materials also fall under the category of structured fluids since they have a multiphase structure and exhibit complex flow behavior. Some examples would be cheeses, lipstick, caulk, and bread dough.

Many factors affect the stability of structured fluids. The viscosity of the liquid phase in dispersions usually plays an important role on the flow properties of the material. Dispersions have wide variations in performance depending on particle size, shape, concentration, and any attraction with the continuous phase in which they are suspended. When there is a repulsive electrostatic or steric force between particles they tend not to settle rapidly, instead forming a network structure which will stabilize the suspension if undisturbed. Shearing or even Brownian motion can destroy this delicate structure and break down the fluids viscosity.

Structured fluids do not obey a simple linear relationship between applied stress and flow (Newtonian fluid behavior) as shown in Figure 1 for suspensions of latex particles with increasing volume fraction in water.

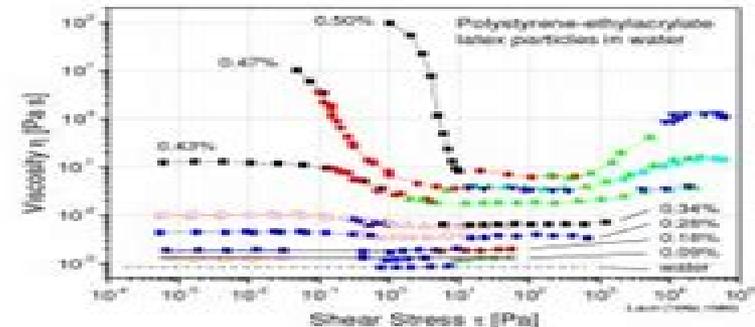


Figure 1: Viscosity of a structured fluid as a function of shear rate and particle concentration?

Nearly all these materials have a viscosity that drops at higher rates of shear velocity resp. stress. This is the phenomenon of shear thinning which becomes progressively larger as the volume concentration of solid particles increases. At high concentration of solid content, the low shear rate viscosity region disappears completely, the material is yielding. Some materials show after the shear thinning region with increasing rate or stress, an increase of the viscosity, usually due to structure rearrangements as a result of the applied shear. This is referred to as flow induced shear thickening.

Characteristic flow parameters and functions

Bingham Flow

Eugene Bingham, a colloid chemist, first coined the term "rheology". He also showed that for many real fluids a critical level of stress must be attained in order to initiate flow. Below this critical stress, τ_y , the material behaves as a solid, absorbing the stress energy without flowing. Once the threshold of critical stress has been reached, the material yields to flow, hence the term, yield stress. The yield stress is the reason, why you need to shake or tap a bottle to make the ketchup flow. Materials which exhibit Newtonian flow beyond the yield bear the name Bingham Fluids.

Elastic Flow

Most materials do not exhibit Newtonian flow after the yield, but have a viscosity that decreases (shear thinning) until a plateau is reached. Lipsticks, drilling muds and toothpaste are good examples of shear thinning non-Newtonian materials.

Understanding Rheology Of Structured Fluids Ta Instruments

Rachel Sandford



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