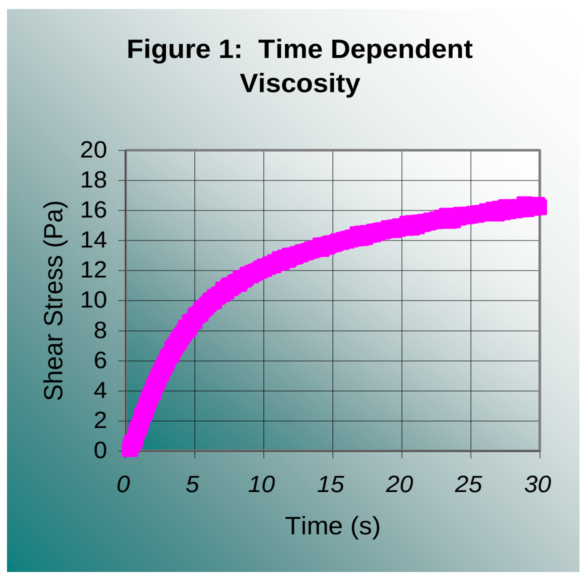
Is the viscosity behavior time dependent??

Many common household products exhibit complex rheology. In addition to being non-Newtonian, they frequently exhibit time dependent shear effects. One example is thixotropy, where the viscosity decreases with time during the progression of a step shear rate measurement. On the other end of the spectrum is rheopexy, whereby the viscosity increases at constant shear rate. Each of these properties can have a significant influence in the manufacture and consumer handling of these products. Examples include dentifrice, body washes, paints, caulks, puddings, etc. Your typical household is a warehouse of complex rheology features.

In rheological studies, time dependent shear effects are determined using constant shear rate measurements. This is certainly the easiest approach but can be time consuming. The shear rate selected depends on the objective of the measurement. There is also a general qualitative industry preference for running "thixotropic loop" tests whereby the shear rate is ramped from rest to a maximum value in a specified time period, and then the shear rate is decelerated from the maximum value to a minimum, or to the rest state, also in a predetermined time period. In the following text, examples will be provided for each of these test methods with pros and cons of each.

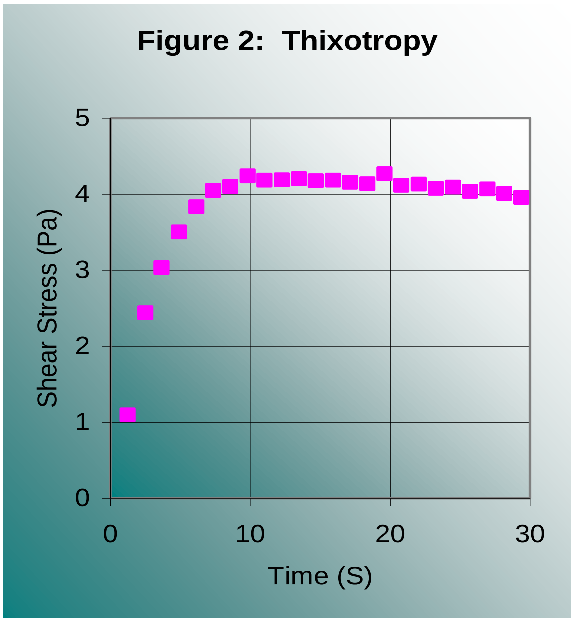
In Figure 1, we have selected a retail sample of skin care lotion and evaluated the viscosity behavior at a low constant shear rate of .05 s^{-1}. We show the response of the fluid during the first thirty seconds of the test, and we definitely see that the shear stress is increasing for the entire 30 s time interval. This product is not thixotropic, as the viscosity is increasing as we would expect to see for a rheopectic specimen.



In studies of time dependent shear effects, one would evaluate this type of behavior at various shear rates. This method would then establish the independent effect of both shear rate and time on the viscosity behavior of a given material. These are not easy measurements to make with structured fluid systems, including emulsions and dispersions, but can be quite revealing. And there are always interesting results that can be found when one is looking at the stress growth phenomena of dispersions at low shear rates.

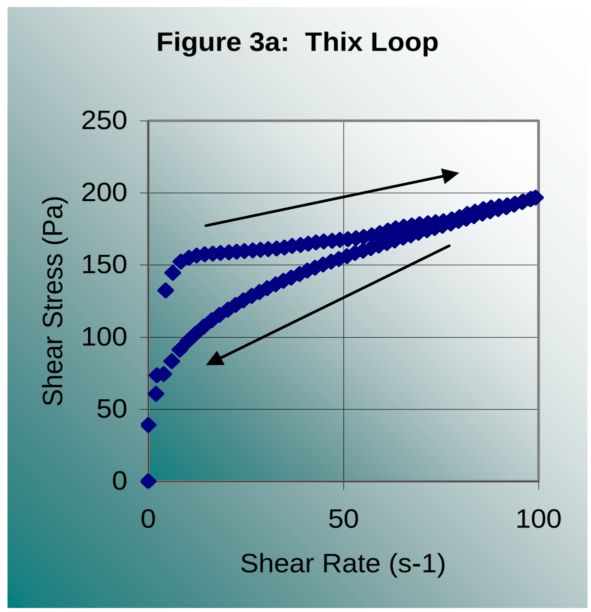
An example of thixotropy is shown in Figure 2. At the same shear rate and for the same time duration, this sample reaches a maximum shear stress and then begins to decrease.

At this low shear rate, and at the inception of flow, this is fairly typical behaviors of complex structured dispersed systems.



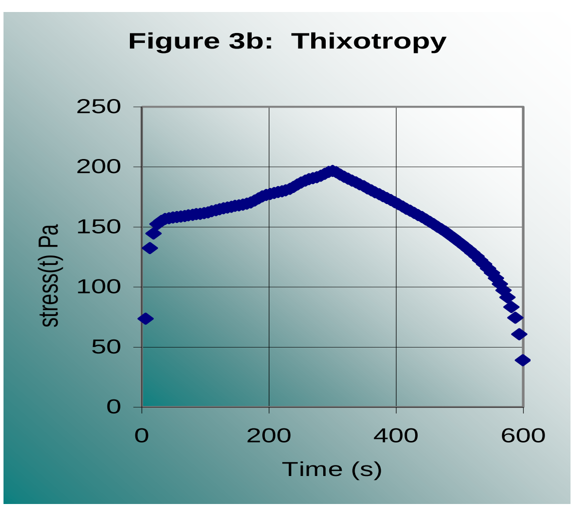
Thixotropic loops are common QC and R&D type tests in many different industries. This test ramps the shear rate up and down in a predetermined time period. This test couples the combined shear stress or shear rate and time dependent shear effects. Nevertheless, it also can be quite revealing about the flow behavior of a fluid system.

Figures 3a and 3b are examples of a "thix" loop measurement for a commercial household product.



In Figure 3a we show the shear stress as a function of shear rate. These are two curves on the figure, one for the "up" curve and one for the "down" curve. This loop gives an idea of the thixotropy of the sample. In this example, the total test covers 10 minutes, with five minutes for each cycle of the thixotropic loop.

An alternative view of this test is shown in Figure 3b. Here we show the shear stress as a function of time.



In both figures we can see that the viscosity is a strong function of shear rate and time of shear. In addition, these samples may well also exhibit a yield stress value.

Characterizing the viscosity behavior of non-Newtonian fluids with shear effects is one of our specialties and we have a strong interest in these systems. For information on characterizing your fluid system, please contact us at your convenience and visit www.FluidDynamics.com.