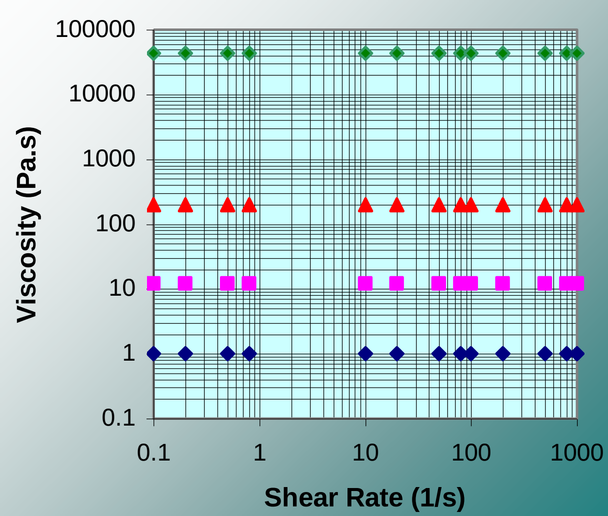
Is it Newtonian or non-Newtonian?

One of the important characteristics of a fluid is its viscosity dependence on shear rate. If the fluid exhibits a constant viscosity, independent of shear rate, the fluid is classified as Newtonian. Example plots of viscosity as a function of shear rate is shown in Figure 1, where the viscosity is constant, independent of shear rate.

In Figure 1, for the four fluids tested, we observe Newtonian behavior in the shear rate range of .1 to 1000 s^{-1}. The plot is a typical representation of viscosity/shear rate behavior for Newtonian fluids under isothermal conditions.

Figure 1: Newtonian Fluids



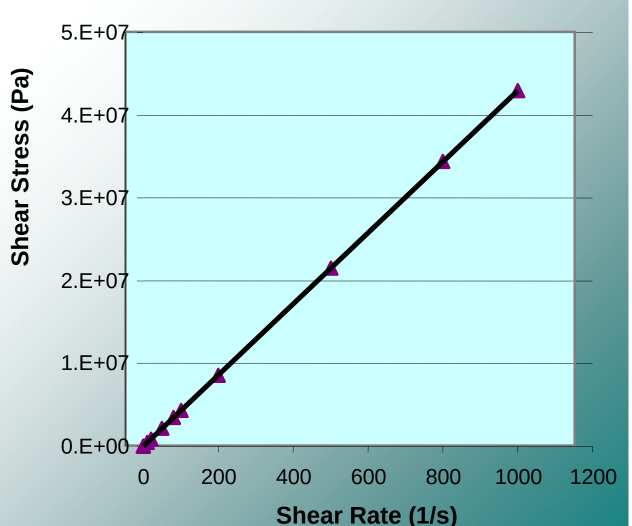
Viscosity is defined as the proportionality between the shear stress and the shear rate:

$$\tau = -\eta \, (d\gamma / dt) \qquad \textbf{Eq. 1}$$

τ = shear stress
$(d\gamma/dt)$ = rate of deformation tensor
η = viscosity

For a Newtonian Fluid, the shear shear stress:shear rate relationship is linear, and an example is shown in Figure 2. The slope of the line is the Newtonian viscosity value.

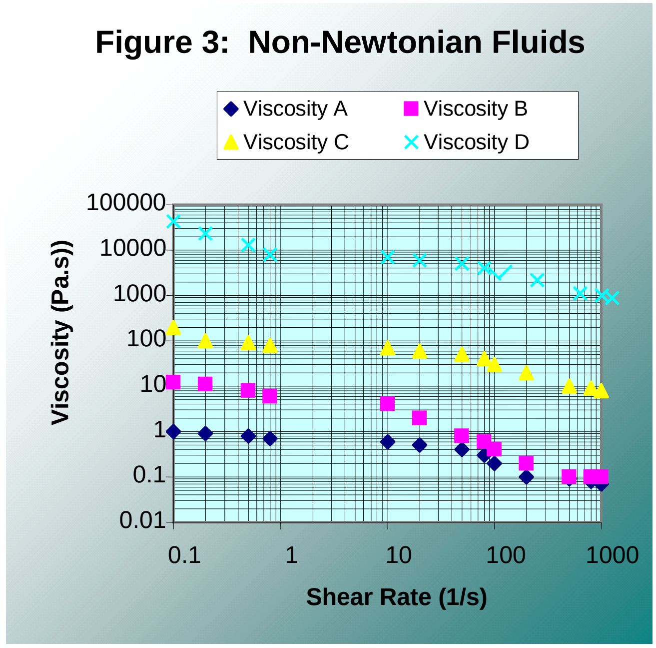
Figure 2: Newtonian Fluid Example



Non-Newtonian fluids are shear rate dependent. These fluids do not exhibit a single viscosity value, since the viscosity is dependent on the shear stress or shear rate that the fluid is experiencing. There may also be other fluid flow characteristics that are important to define and understand, including time dependent shear effects, such as thixotropy or rheopexy.

Figure 3 shows the shear rate dependence of several fluids, again under isothermal conditions. These fluids are non-Newtonian and pseudoplastic, meaning that the viscosity decreases with increasing shear rate within the tested shear rates from .1 to 1000 s^{-1} at constant temperature.

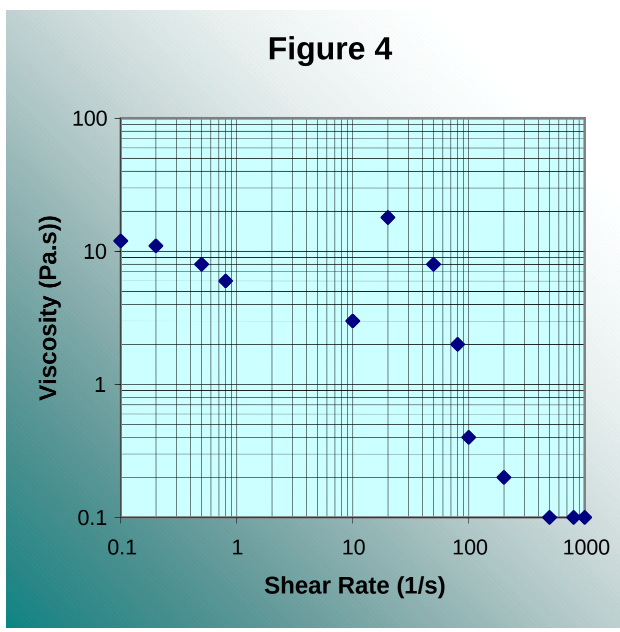
Fluids exhibit many different types of shear rate dependence and here we are only looking at shear thinning behavior. We can see that the viscosity is decreasing as the shear rate is increasing. While these experiments were conducted under controlled shear rate conditions, similar tests can be completed whereby the viscosity is measured as a function of shear stress.



There are fluid systems that exhibit phenomena called dilatancy. In this instance, the viscosity will increase with increasing shear rate. While this is perhaps not as common as pseudoplasticity, it has very important consequences in fluid handling and processing.

Dilatancy can occur within a limited shear rate range. For example, fluids can be both pseudoplastic and dilatant, depending on the shear rate regime. We are showing an example of such behavior in Figure 4:

In this example, the fluid is showing pseudoplastic shear thinning behavior in the shear rate range of .1 to 1 s^{-1}. At a shear rate of 20 s^{-1}, the viscosity abruptly increases, an example of dilatant behavior. With increasing shear rate, the viscosity decreases again and pseudoplasticity is observed in the shear rate range of 20 to 1000 s^{-1}.



We will discuss time dependent shear effects separately.

For information on characterizing your fluid system, please contact us at your convenience or visit www.RheologyCentral.com.