Application Note to the Field	Pumping Non-Newtonian Fluids with Liquiflo Gear Pumps
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Newtonian vs. non-Newtonian Fluids:

Fluids fall into one of two categories: Newtonian or non-Newtonian. A *Newtonian* fluid has a constant viscosity at a particular temperature and pressure and is independent of shear rate. A *non-Newtonian* fluid has viscosity that varies with shear rate. The *apparent viscosity* is a measure of the resistance to flow of a non-Newtonian fluid at a given temperature, pressure and shear rate.

Newton's Law states that *shear stress* (τ) is equal the *dynamic viscosity* (μ) multiplied by the *shear rate* (γ): $\tau = \mu \gamma$. A fluid which obeys this relationship, where μ is constant, is called a Newtonian fluid. Therefore, for a Newtonian fluid, shear stress is directly proportional to shear rate. If, however, μ varies as a function of shear rate, the fluid is non-Newtonian.

In the **SI system**, the unit of shear stress is pascals ($Pa = N/m^2$), the unit of shear rate is hertz or reciprocal seconds (Hz = 1/s), and the unit of dynamic viscosity is pascal-seconds (Pa-s). In the **cgs system**, the unit of shear stress is dynes per square centimeter (dyn/cm^2), the unit of shear rate is again hertz or reciprocal seconds, and the unit of dynamic viscosity is poises ($P = dyn\text{-}s\text{-}cm^{-2}$). To convert the viscosity units from one system to another, the following relationship is used: 1 cP = 1 mPa-s.

Pump shaft speed is normally measured in RPM (rev/min). This speed is related to the rate of shear in Hz (rev/s) by the following relationship: 1 Hz = 60 RPM. For example, a pump operating at 1750 RPM would be equivalent to a pump speed and shear rate of 1750 RPM x 1 Hz/60 RPM = 29.2 Hz. (This is a typical full-load motor shaft speed of a 4-pole, 3-phase induction motor based on a motor synchronous speed of 30 Hz and operating from a power supply frequency of 60 Hz.)

Some examples of Newtonian fluids are: water, solvents, dilute solutions, and most mineral oils at temperatures above their cloud points. Some examples of non-Newtonian fluids are: greases, polymer-thickened oils, tomato ketchup, quicksand, emulsions, suspensions, paints, printing inks, some starches, drilling muds, and mineral oils at temperatures below their cloud points.

Viscosity Measurement:

The viscosity of a fluid is typically determined at atmospheric pressure by testing with various types of viscometers and rheometers. A rheometer is used for fluids that cannot be defined by a single viscosity value and therefore require more parameters to be set and measured. Such is the case for non-Newtonian fluids. When measuring viscosity, the temperature of the fluid must be closely controlled since the viscosity is highly dependent on temperature. For this reason, a viscosity value must always be specified at a particular temperature. In the case of a non-Newtonian fluid, the apparent viscosity must be specified at a particular temperature and shear rate.

Pump Selection:

A Newtonian fluid would have an as-tested viscosity which could generally be used as-is for pump selection purposes without further consideration.

Pump selection for a non-Newtonian fluid is not as straightforward. A non-Newtonian fluid may have a viscosity that is either inconsistent (as with a mixture of immiscible fluids such as oil and water) or not what it appears to be (as with a suspension). It is, for example, possible to have a colloidal suspension that will have a viscosity that is apparently higher than it actually is. In such a case, it is necessary to take both the *apparent* viscosity and the actual or *working* viscosity, into account. This is because the slip characteristics of the pump depend on the working viscosity while the torque and power requirements depend on the apparent viscosity. It is easy to picture a handful of mud where it looks and feels quite viscous, and yet the water runs out between your fingers. The viscosity of the water (working viscosity) is what would be used to calculate slip and that of the mud (apparent viscosity) to calculate required power.

The procedure Liquiflo uses for handling the above situation is as follows:

1) Determine the Liquiflo gear pump model based on the working viscosity, differential pressure and flow rate. The calculated pump speed for the selected model will produce the desired flow rate, accounting for the higher slip of the lower viscosity number.

2) Calculate the torque and power for the higher apparent viscosity, for the same pump model and operating speed selected in step 1. These higher numbers for torque and power are what are used to select the pump materials and motor.

3) Select materials of construction as for the lower viscosity with respect to wear (bearing material, shaft coatings, metal versus plastic gears, etc.) and the higher viscosity with respect to torque (choose gears strong enough to withstand the higher torque, magnets strong enough to transmit it, etc.).

For any questions or assistance with pump selection, please contact the Liquiflo Applications Group or your local Liquiflo distributor.

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