1. Rheology

Rheology is the study of the deformation and flow of matter. The study of rheology is important because it allows the drilling fluid to be specifically analyzed in terms of fluid flow profile, viscosity, hole cleaning ability, pressure loss, and equivalent circulating density - in general, wellbore hydraulics.

Velocity Profile

Figure (1) depicts a fluid flowing up an annulus. A force exists in the fluid which resists fluid flow. This force, **shear stress**, is analogous to the friction arising when one fluid layer moves past another. **The fluid velocity increases progressively away from zero at the walls to a maximum near the center of the annulus**. This occurs because it is easier for each fluid layer to move past another fluid layer than to move past the walls. The rate at which a fluid layer moves past another is called "**shear rate**".

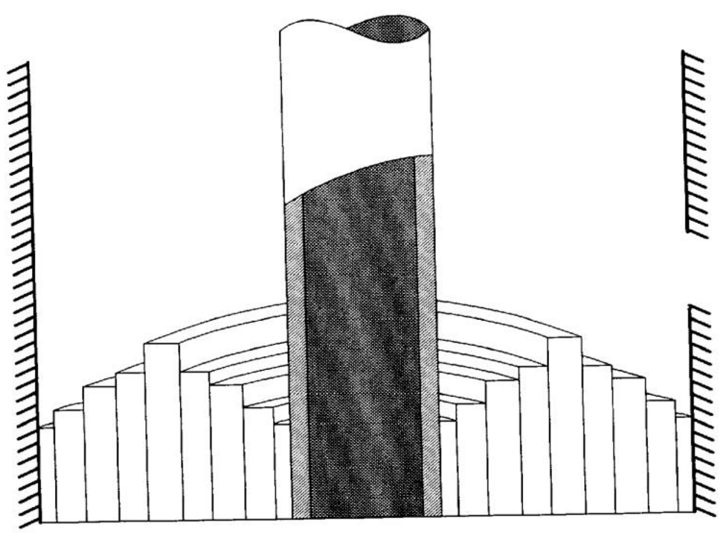

Fig. (1): Flow in an Annulus.

The concept of shear stress and shear rate is further developed in Figure (2).

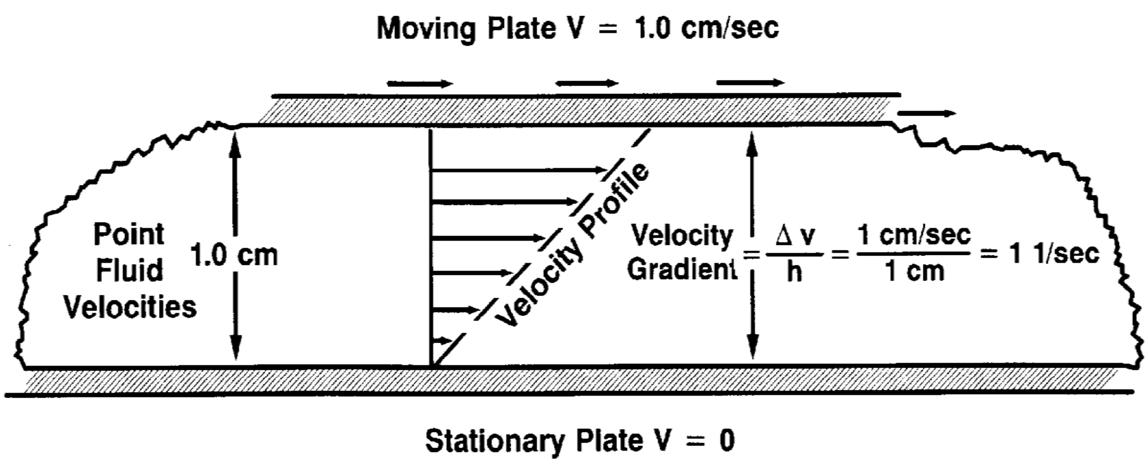

Fig. (2): Concept of Velocity Gradient Shear Rate and Shear Stress.

- **Shear Stress (τ)**

Shear stress is the force required to sustain a particular type of fluid flow. In laminar flow, shear stress is the frictional drag existing between individual laminae.

$$\tau = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} \quad \text{--} \quad \textbf{(20)}$$

This is expressed as lb/100 ft^2, or as $Dynes/cm^2$.

Note: 1 Dyne/cm^2 = 4.79 lb/100ft^2.

Shear Stress (τ), Ib/100ft^2 = 1.065 × ϕ

- **Shear Rate (γ)**

This is the relative velocity of one lamina moving by adjacent lamina, divided by the distance between them.

$$\gamma = \frac{\text{Velocity}}{\text{Distance}} = \frac{\text{cm/sec}}{\text{cm}} = \frac{1}{\text{sec}} = \text{sec}^{-1}$$ -- **(21)**

This is expressed in sec^{-1} (reciprocal seconds).

Note: Shear Rate (γ), 1Sec^{-1} = 1.703 x RPM. (Where RPM is on a Fann VG meter.)

- **Viscosity (μ)**

Viscosity is the representation of a fluid's internal resistance to flow, defined as the ratio of shear stress to shear rate. Viscosity is expressed in poise.

$$\mu = \frac{\text{Shear stress}}{\text{Shear rate}} = \frac{\tau}{\gamma}$$ -- **(22)**

As previously defined:

$$\mu = \frac{\text{Dyne.sec}}{\text{cm}^2} = \text{poise}$$ --- **(23)**

A poise is a very large number and therefore, viscosity is typically reported in centipoise

(100 centipoise = 1 poise).