Types of Fluids

There are two types of fluid:

1. Newtonian fluids
2. Non- Newtonian fluids

1. Newtonian Fluids

Newtonian fluids are those in which the viscosity remains constant for all shear rates providing temperature and pressure conditions remain constant. Examples of Newtonian fluids are **water, glycerine and light oil**. In these fluids, **the shear stress is directly proportional to the shear rate**, as shown in Figure (3). **The rheogram curve of a Newtonian fluid is a straight line passing through the origin (0,0)**. The origin is the starting point on the graph of both the vertical and horizontal axes. The slope of the curve defines **viscosity** where **γ** is the shear rate and **τ** is the shear stress. Because **μ** (viscosity) does not change with rate of shear, it is the only parameter needed to characterize the flow properties of a Newtonian fluid. Most drilling fluids are not this simple.

$$\mu = \frac{\tau}{\gamma} \quad \text{---} \quad (24)$$

μ: Dynamic viscosity

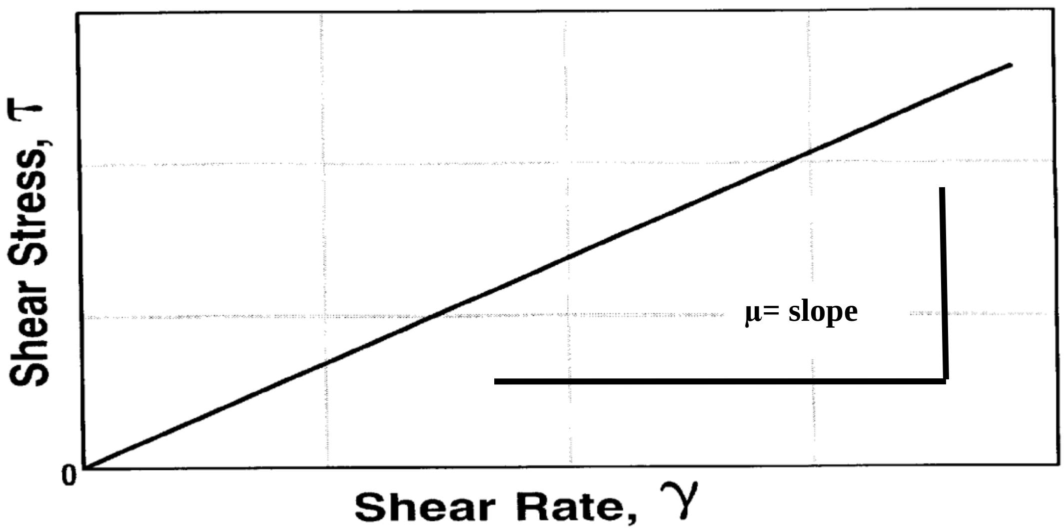

Fig. (3): Rheogram Showing Newtonian Fluid Behavior.

- **Properties of Newtonian Fluids:**

1. Flowing at very small forces.
2. Constant (μ) at specific temperature and pressure.
3. They don't have permanent **internal structure** (**thixotropic properties**).

Thixotropic fluid gel when it is static and return to the liquid phase upon a gelatin.

2. Non-Newtonian Fluids

Non-Newtonian fluids (most drilling fluids fit this general classification) do not show a direct proportionality between shear stress and shear rate, ex. most of **drilling fluids, cement, slurries etc.** The ratio of shear stress to shear rate (viscosity) varies with shear rate and the ratio is called "**effective viscosity**", but this shear rate must be identified for each effective viscosity value.

An example of a non-Newtonian shear stress/shear rate (slope of the dashed lines) shear rate relationship is shown in Figure (4). Note that the ratio of shear stress to shear rate differs at each shear rate.

The viscosity of non-Newtonian fluids is known as effective viscosity and the shear rate must be specified. Figure (4) shows that the effective viscosity **decreases** as the shear rate **increases**. This effect is called "**shear thinning**".

$$\tau = \mu_e \left(\frac{dv}{dr}\right)\left(\frac{dv}{dr}\right) \quad \text{----------------------------------} \quad (25)$$

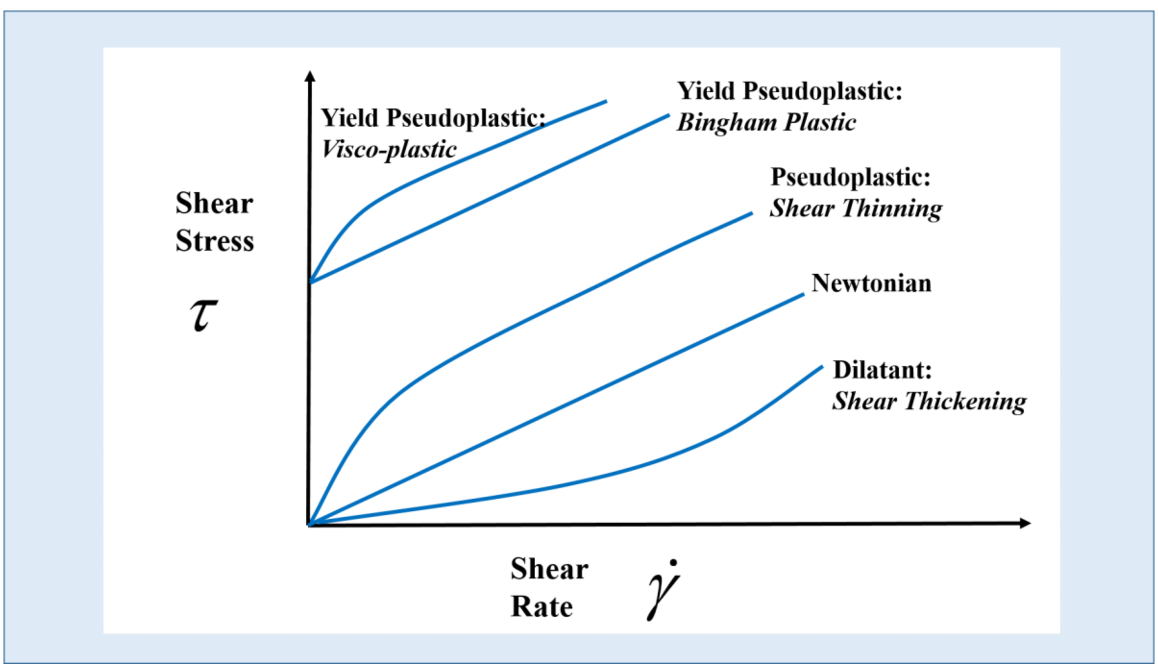

Fig. (4): Effective Viscosity of a Non-Newtonian Fluid.

Properties of Non-Newtonian Fluids are:

1. Variable viscosity which depends on shear rate,
2. Have permanent structure (forming gel structure at static).

Non-Newtonian fluids are classified into four major categories:

1. Those with properties independent of time
2. Those with properties dependent on time

The first two categories are of principal concern to drilling fluids. There is a further subdividing of these categories as follows:

1. Time Independent, Non-Newtonian Fluids, as shown in Figure 5.

- Bingham plastic fluids
- Pseudoplastic fluids
- Dilatant fluids

2. Time Dependent, Non-Newtonian Fluids

- Thixotropic fluids
- Rheopectic fluids

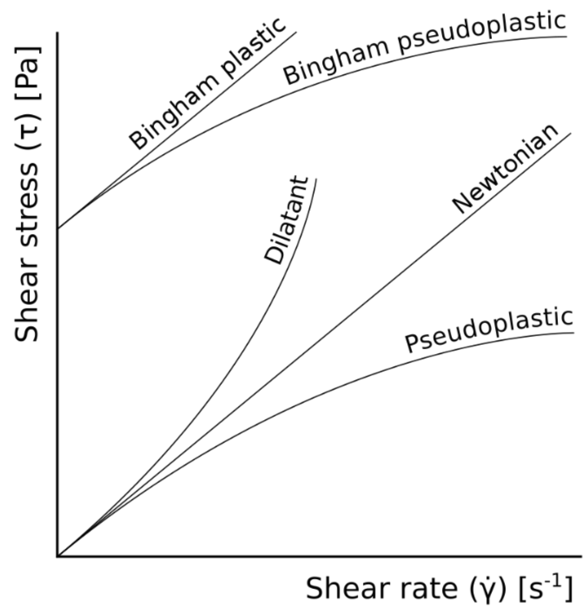

Fig. (5): Time Independent, Non-Newtonian Fluids.

- **Bingham Plastic Fluids**

These fluids yield a straight-line relationship between shear stress and shear rate that does not pass through the origin. A finite shear stress is required to initiate flow. The value of this shear stress is called the "**Yield Point**" Figure (6).

The Bingham Plastic Model is the most widely used mathematical rheological model in the oil field. All data are generated from the 600 and 300 readings on a VG Meter. The model assumes that the fluid evaluated acts in a linear manner on the shear rate - shear stress curve, but has a positive yield stress Figures (7 and 8).

The equation for the Bingham Plastic model is:

$$\boldsymbol{\tau = pv\left(\frac{\gamma}{300}\right) + Yp} \quad \textbf{(26)}$$

Where

Plastic Viscosity (PV) = θ_{600} - θ_{300} -- **(27)**

Yield Point (YP) = θ_{300} - PV -- **(28)**

Common terms associated with the Bingham plastic model are: **Plastic Viscosity (PV), Apparent Viscosity (μ_a), Yield Point (YP) and gel strengths**. Most drilling fluids, as seen in Figure (7), do not conform exactly to the Bingham plastic model or to any universal model, but drilling fluid behavior can usually be approximated with acceptable accuracy.

The Bingham Plastic model assumes that the curve Figure (9) is approximated by a straight line. This is seldom true for drilling fluids, especially at low shear rates found in the annulus, Table (1).

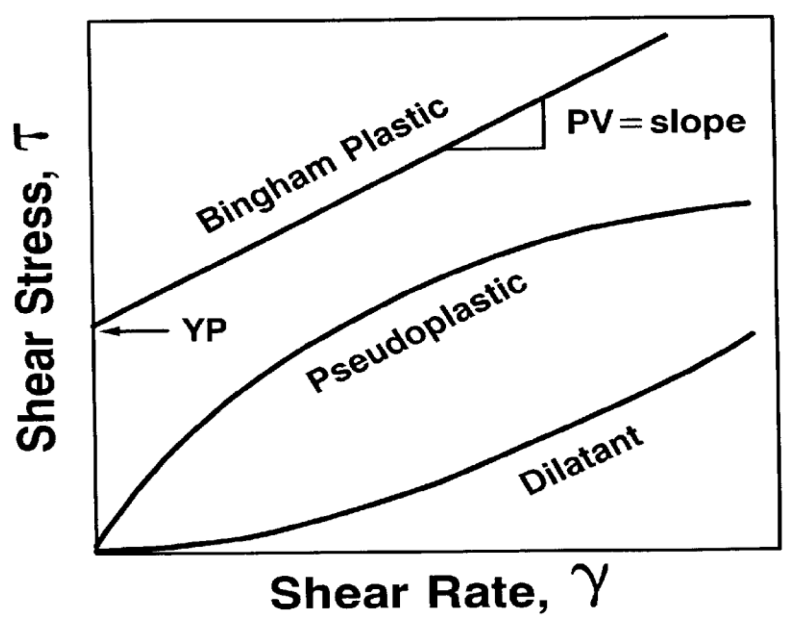

Fig. (6): Rheogram Showing Bingham Plastic, Pseudoplastic and Dilatant Fluids Behavior.

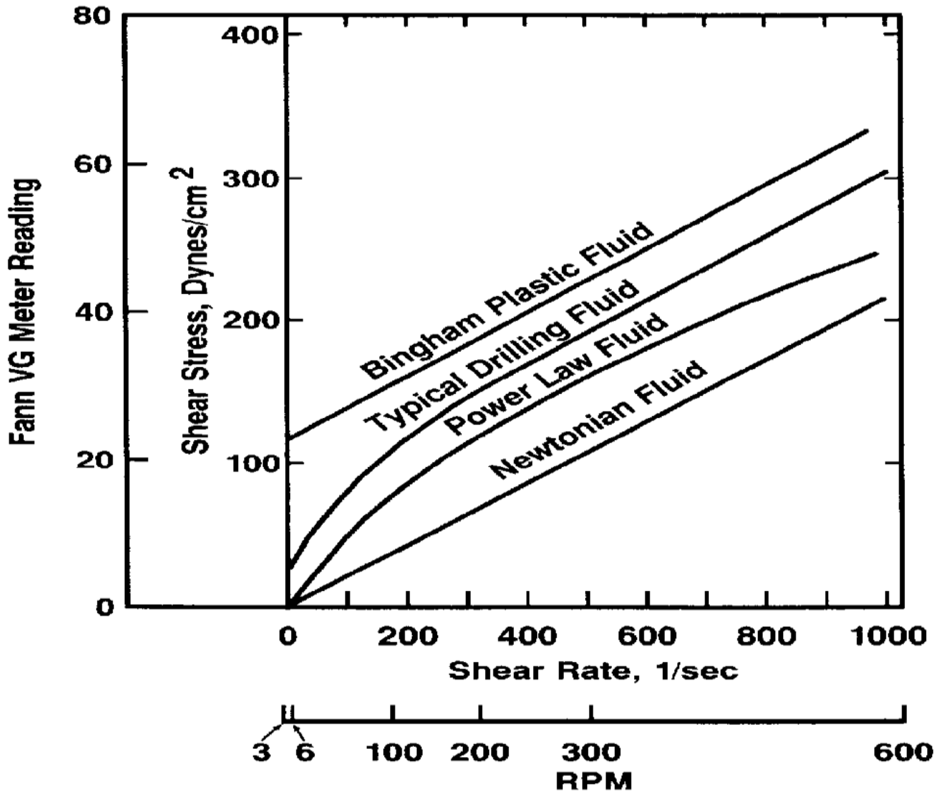

Fig. (7): Shear Stress - Shear Rate Curves.

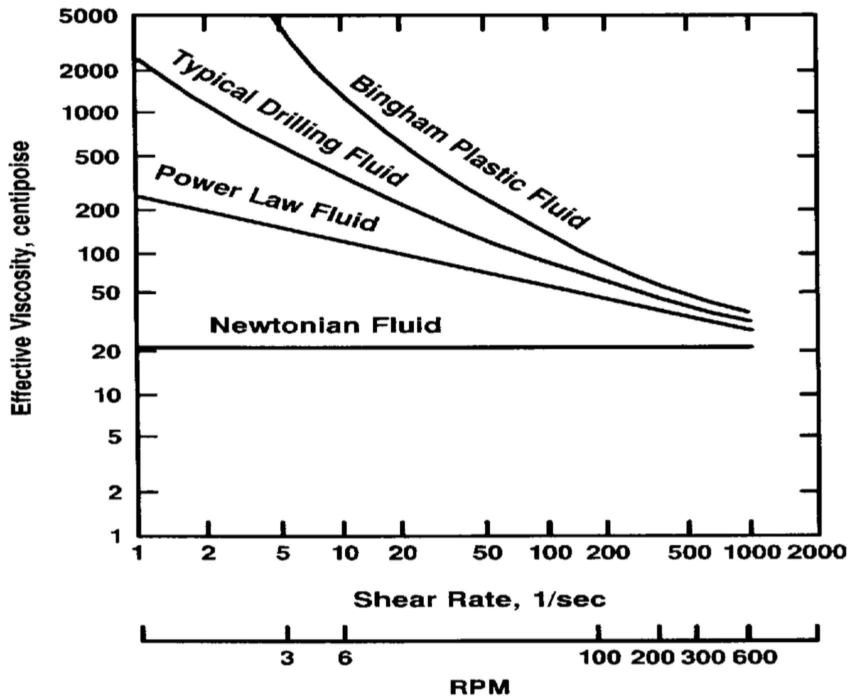

Fig. (8): Viscosity - Shear Rate Curves.

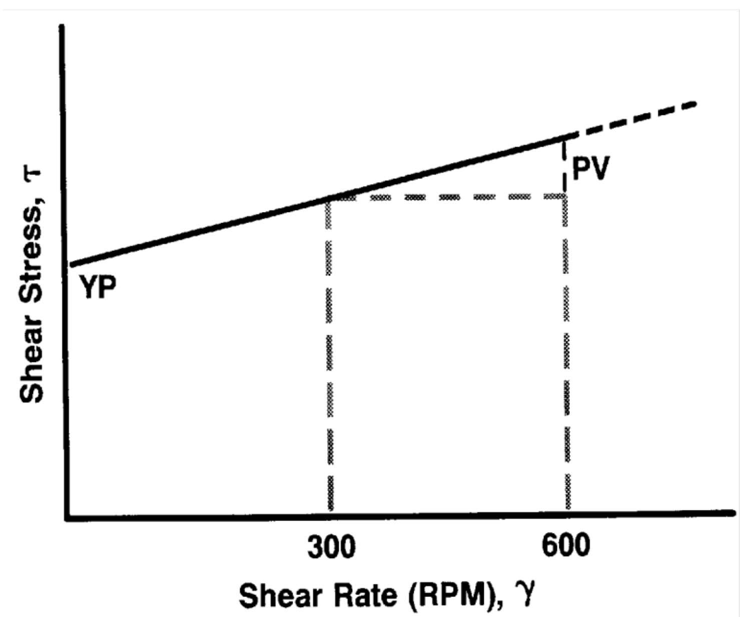

Fig. (9): Bingham Plastic Model Parameters.

Table (1): Shear Rates in a Circulating System

Location	**Shear Rate, sec^{-1}**
Drill Pipe	100 - 500
Drill Collars	700 - 3000
Bit Nozzles	10000 - 100000
Annulus	10 - 500
Mud Pits	1 - 5