

Mustansiriyah University
College of Engineering
Materials Engineering Department
B.Sc. Second Class

Engineering Fluid Mechanics

Lecture 4-1

Non-Newtonian Fluids

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Non-Newtonian Fluids

For non-Newtonian fluids a plot of shear stress (τ) against shear rate ($\dot{\gamma}$) does not give a straight line. Plot of (τ) against ($\dot{\gamma}$) are experimentally determined using a viscometer.

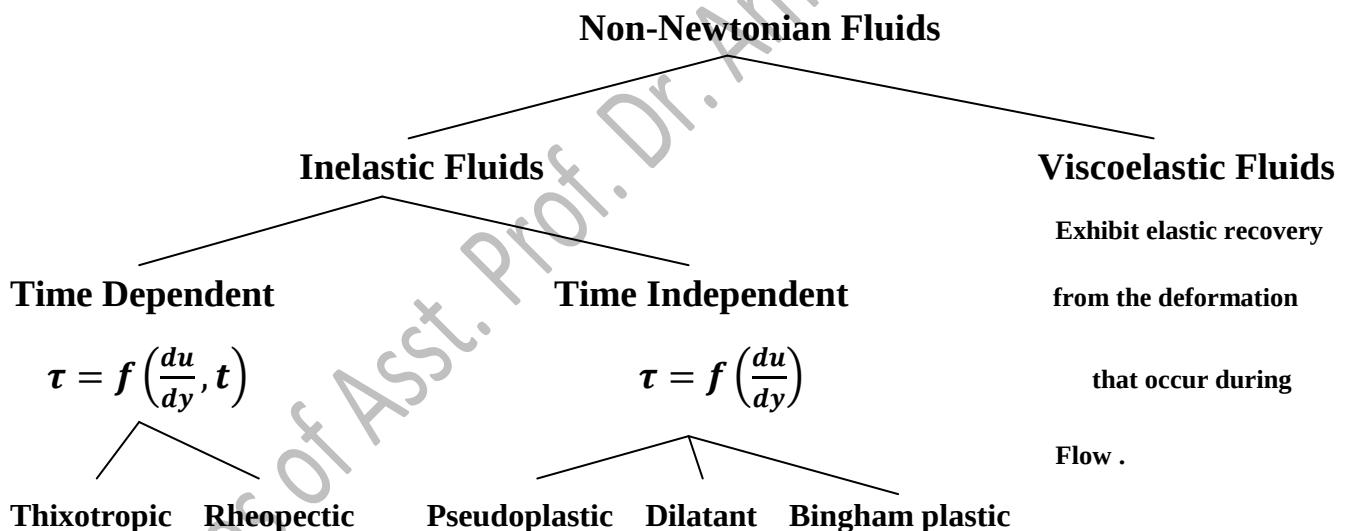
The term viscosity has no meaning for a non-Newtonian fluid unless it is related to a particular shear rate ($\dot{\gamma}$). An apparent viscosity μ_a can be defined as follows:

$$\mu_a = \frac{\tau}{\dot{\gamma}}$$

The simplest and most commonly used mathematical model to represent the rheological behavior of non-Newtonian fluid is the power law equation

$$\tau = K \left(\frac{du}{dy} \right)^n = K(\dot{\gamma})^n$$

Where K is called the consistency coefficient (or flow consistency index) and n the power law index (or flow behavior index).



Rheology: the study of the deformation and flow of matter. The aim is to establish relationships between stress and deformation for non-Newtonian materials where neither Newton's law nor Hook's law suffice to explain their mechanical behavior.

Example-1:

- Derive an expression for the apparent dynamic viscosity μ_a of a power law fluid.
- Derive an expression for the rate of change of apparent dynamic viscosity of a power law fluid with change in shear rate ($\dot{\gamma}$).
- Calculate the apparent dynamic viscosity μ_a of a power law fluid if the consistency coefficient $K = 1.5 \text{ (N/m}^2 \text{) s}^{0.5}$, the power law index $n = 0.5$, and the shear rate $\dot{\gamma} = 100 \text{ s}^{-1}$.
- Calculate the rate of change of μ_a with change in ($\dot{\gamma}$) for the data in part (c).

Solution:

The power law fluid represented by the equation $\tau = K(\dot{\gamma})^n$, where $\dot{\gamma} = \frac{du}{dy}$.

a) $\mu_a = \frac{\tau}{\dot{\gamma}}$

$$\mu_a = \frac{K(\dot{\gamma})^n}{\dot{\gamma}}$$

$$\mu_a = K(\dot{\gamma})^{n-1}$$

b) $\frac{d\mu_a}{d\dot{\gamma}} = (n-1)K(\dot{\gamma})^{n-2}$

$$\frac{d\mu_a}{d\dot{\gamma}} = \frac{(n-1)K(\dot{\gamma})^n}{(\dot{\gamma})^2}$$

$$\frac{d\mu_a}{d\dot{\gamma}} = -\frac{(1-n)K}{(\dot{\gamma})(\dot{\gamma})^{1-n}}$$

c) $\mu_a = K(\dot{\gamma})^{n-1}$

$$\mu_a = 1.5 \frac{\text{N.s}^{0.5}}{\text{m}^2} \times (100 \text{ s}^{-1})^{0.5-1} = 0.15 \text{ N s/m}^2$$

d) $\frac{d\mu_a}{d\dot{\gamma}} = (n-1)K(\dot{\gamma})^{n-2}$

$$\frac{d\mu_a}{d\dot{\gamma}} = (0.5-1) \times 1.5 \frac{\text{N.s}^{0.5}}{\text{m}^2} \times (100 \text{ s}^{-1})^{0.5-2} = -7.5 \times 10^{-4}$$

Example 2: A power law fluid of density 961 kg/m^3 flows in steady state with a mean linear velocity of 1.523 m/s through a tube 2.67 m long with an inside diameter of 7.62 cm . For a pipe consistency coefficient K_p of $4.46 (\text{N/m}^2) \text{ s}^n$, calculate the apparent viscosity in $\text{N}\cdot\text{s/m}^2$, the Reynolds number, and the pressure drop in N/m^2 in the tube for power law index of 0.75 .

Solution:

Lectures of Asst. Prof. Dr. Amer Hameed Majeed