HYDRAULICS - FREE SURFACE FLOWS

1.1 Introduction

A fluid is any substance that deforms continuously when subjected to shear stress, no matter how small the shear stress is.

Shear force is the force component tangent to the surface. Average shear stress is the shear force per unit area.

Fluids can be classified as ideal fluids and real fluids.

Ideal fluids are those which are incompressible with zero viscosity and, shear stress is always zero. Ideal fluid is hypothetical.

Fluids with viscosity are known as real fluids.

Example: Water, Milk, and Honey etc.,Then real fluids are classified as Newtonian and non-Newtonian. Box 1.1.

Examples of non-Newtonian fluids are

Thixotrophic substance (thixotrophic jelly paints), ideal plastic, Bingham plastic (sewage sludge), pseudo plastic (clay, milk, cement), dilatant substance(quick sand) etc. Fig 1.1.

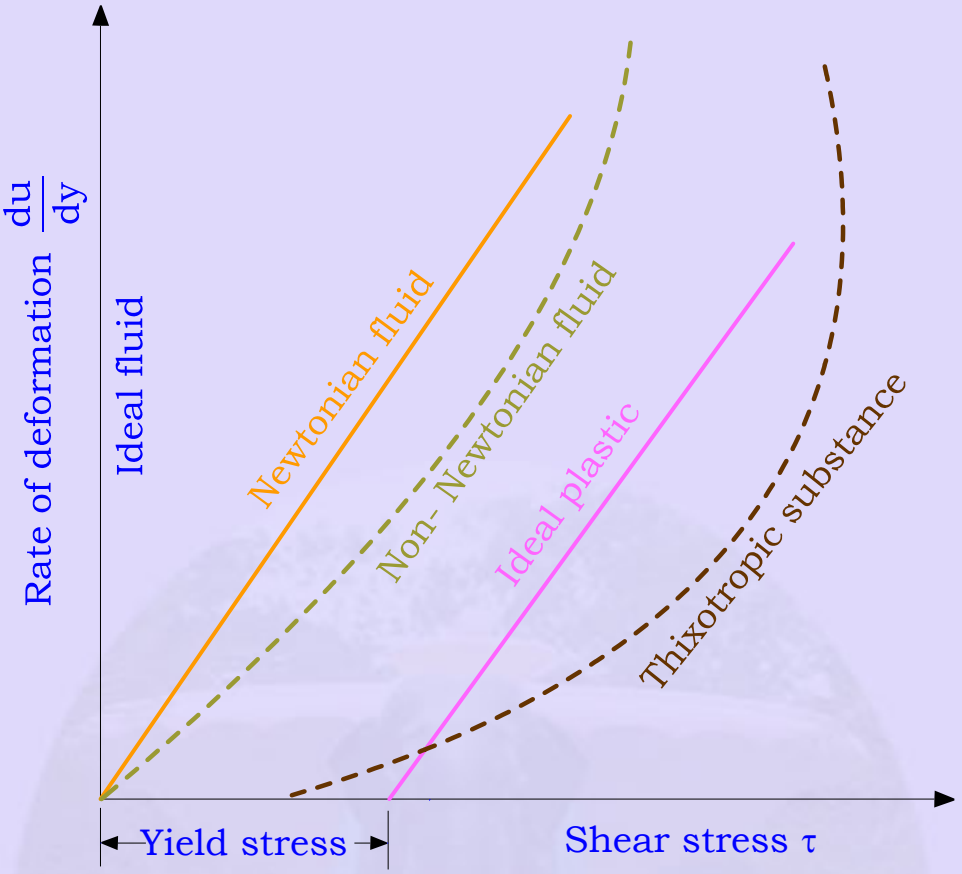

Figure 1.1 Rheological diagram

Box 1.1 Newtonian fluids follow the law of viscosity

$$\tau = \mu \frac{du}{dy} \qquad 1.1$$

in which τ, is the Shear stress, μ is the viscosity co-efficient and $\frac{du}{dy}$ is the velocity gradient in y direction.

Viscosity μ is a fluid property and is known as dynamic viscosity. The equation 1.1 is known as Newton's law of viscosity.

The kinematic viscosity υ is given by the ratio of dynamic viscosity to mass density of fluid ρ.

$$\upsilon = \frac{\mu}{\rho} \qquad 1.2$$

Dimensions and units

Coefficient of Dynamic viscosity

$\mu = \left[M L^{-1} T^{-1} \right]$ $Ns\,m^{-2}$ *or* kg m^{-1} s^{-1} *or* Poise

10 poise = 1 kg m^{-1} s^{-1}, Pa s (Pascal seconds)

Example: Water: 1.14 x 10^{-3} kg m^{-1} s^{-1};

Air : 1.78 x 10^{-5} kg m^{-1} s^{-1}

$\upsilon = \frac{\mu}{\rho} = \left[L^2\ T^{-1} \right]$ $m^2 s^{-1}$, 10^4 Stokes =1 $m^2 s^{-1}$

[Example: water 1.14 x 10^{-6} $m^2 s^{-1}$ at 15° C , air 1.46 x 10^{-5} $m^2 s^{-1}$]

However viscosity depends on temperature.

Physical properties of water at atmospheric pressure and S.I units are given

Mass Density of water : Mass per unit Volume.

$\rho = [ML^{-3}]$; kg m^{-3}, ρ=1000 kg m^{-3}

Mass density of air = 1.23 kg m^{-3}

at atmospheric pressure of 1.013 x 10^5 N m^{-2} and temperature 288.15 K.

weight per unit volume is known as specific weight

$\gamma = \rho g$ N m^{-3}

$\gamma_{\text{of water}}$ = 9.81 x 10^3 N m^{-3}

$\gamma_{\text{of air}}$ = 12.07 N m^{-3}

In free surface flows water is the dominating fluid. Water is a basic element and supports the life system.

Proper control and management of water is required for sustaining the life on earth. Hydraulics forms a part of water resources engineering. The free surface flows deals with the movement of surface water in rivers, stream, canals etc. In order to understand the mechanism of free surface flows, the different classification of them is to be understood.