Fluid Mechanics

References

1. "Fundamentals of Fluid Mechanics", By Bruce R. Munson, Donald F. Young, and Theodore H. Okiish.
2. "Fluid Mechanics and applications" by Frank M. White
3. "Fluid Mechanics", By J.F Douglas, J.M.grasiore, and J.A. Swaffield.
4. "Fluid Mechanics Fundamentals and Applications" By Yunus A. Cengel, and John M. Cimbala.
5. "Fluid Mechanics and fluid power engineering" By D. S. Kumar .

Properties of fluids

* **Density :** mass per unit volume $\rho = \frac{m}{V}$

For water $\rho = 1000 \ kg/m^3$

* **Specific weight :** weight per unit volume

$$w = \frac{weight}{volume} = \frac{m * g}{V} = \rho g$$

For water $w = 1000 * 9.8 \ \frac{N}{m^3}$

* **Specific volume :** volume per unit mass

$$v = \frac{volume}{mass} = \frac{1}{\rho} \quad m^3/kg$$

For water $v = 0.001 \quad m^3/kg$

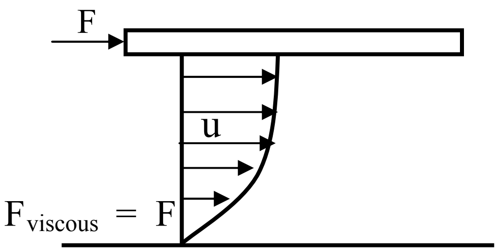
* **Specific gravity** : $SG = \frac{\text{Sp . weight of fluid}}{\text{Sp. weight of water}}$

$$= \frac{w_f}{w_w} = \frac{\rho_f \ g}{\rho_w \ g} = \frac{\rho_f}{\rho_w} \qquad \text{dimensionless}$$

For water $SG_w = 1$

**** Viscosity*** (μ): The property which causes friction between fluid and boundary or between fluid layers if they is velocity difference.

It's a property that represents the internal resistance of a fluid to motion or the "fluidity". The viscosity of a fluid is a measure of its "resistance to deformation."



μ = viscosity

= Absolute viscosity

= Dynamic viscosity

= Coefficient of viscosity

$$F_{viscous} \;\alpha\; A_{friction} \frac{du}{dy}$$

$$\boxed{F_{vis} = Const\,.\,A_{friction} \frac{du}{dy}}$$

$$\boxed{F_{vis} = \mu\, A_{friction\ moving} \frac{du}{dy}} \longleftarrow \text{Newton's law of viscosity}$$

μ = coefficient of viscosity depends on type of fluid and its temperature

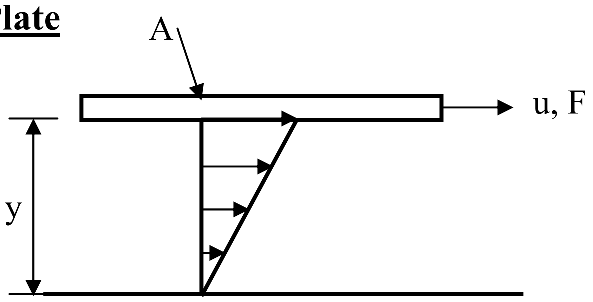
$$\mu = \frac{Fvis}{Afriction} * \frac{dy}{du}$$

for water $\mu = 0.001 \frac{N.S}{m^2}$

Units of $\mu = \frac{N.}{m^2} * \frac{m}{m/s} = P_a.s$

For a small thickness of fluid layer , velocity distribution car be assumed straight line. $\frac{du}{dy} = \frac{\Delta U}{\Delta y}$

1- Flat Plate



$$\tau \;\alpha\; \frac{du}{dy}$$

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

$$F = \mu\, A \frac{du}{dy}$$

as : τ : shear stress

μ : viscosity

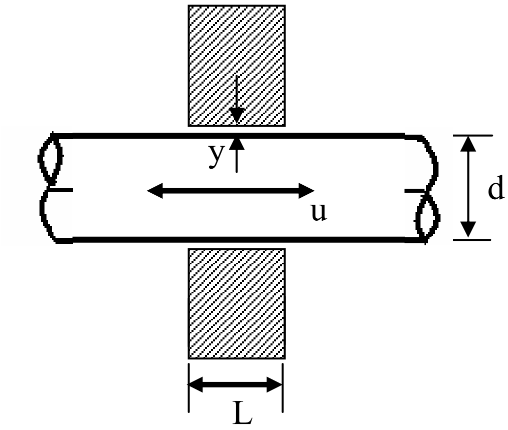
$\frac{du}{dy}$: rate of shear strain

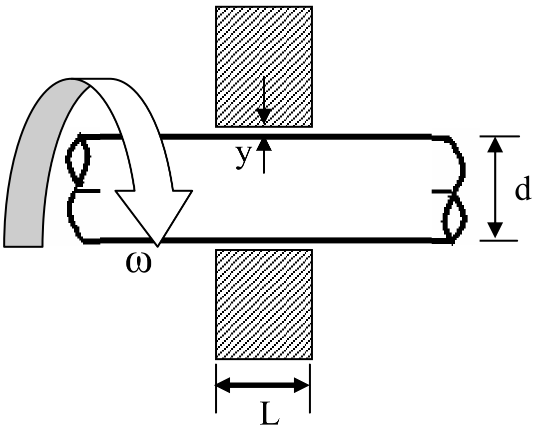
F : viscous force

2- Moving Shaft

$F = \mu A \frac{V}{y}$

Where $A = \pi d L$





3- Rotating Shaft

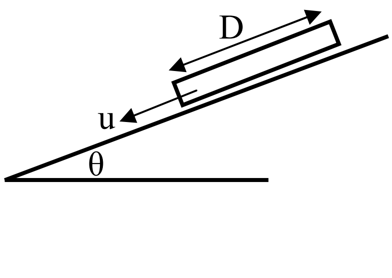
$F = \mu A \frac{u}{y}$

$u = \omega r$

$r = \frac{d}{2}$

4 - Sliding Disk

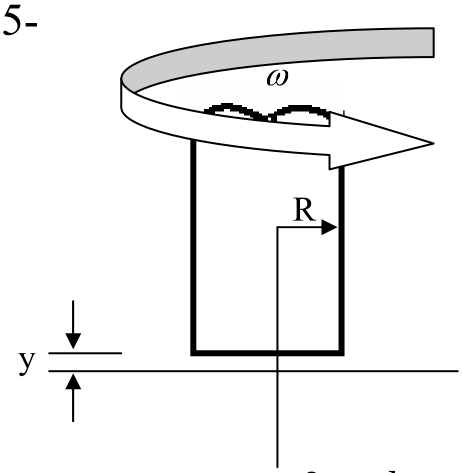
$A = \frac{\pi}{4} D^2$

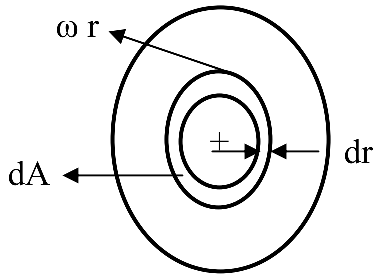


If N is given $\therefore \quad \omega = \dfrac{2\pi N}{60}$ as N : rpm & ω : rad /sec

& $\omega = 2\pi(rps)$ If rps $\xrightarrow{convert}$ ω rad /sec

5-





dA = $2\pi\ rdr$ & u = ωr

dF = $\mu(2\pi\ rdr) * \dfrac{\omega r}{y}$

F $= \dfrac{\mu.2\pi\omega}{y} \displaystyle\int_0^R r^2 dr$

$$\boxed{F = \frac{2\pi\omega\mu}{3y} R^3}$$

dT = r.dF

$= r * \dfrac{\mu\ 2\pi\ rdr\ \omega r}{y}$

$\displaystyle\int_0^T dT = \frac{2\pi\mu\omega}{y} \int_0^R r^3 dr$

$$\boxed{T = \frac{2\pi\mu\omega}{4y} R^4}$$

Power = T * ω

= F * r * ω

= F * v

*** Kinematic viscosity** (υ): is defined as the ratio of dynamic viscosity of water to density

$$\upsilon = \frac{\mu}{\rho} = \frac{Pa.S}{kg/m^3} = \frac{kg.m.s\ m^3}{s^2 m^2\ kg} = (m^2/s)$$

υ = 0.01 cm^2/s

= 0.01 stoke as Stoke = cm^2/s

= 1 centi stokes

*** Newtonian & Non – Newtonian:**

$$\tau = \frac{F_{vis}}{A} = \mu \frac{du}{dy}$$

as τ : Shear stress

$\frac{du}{dy}$: rate of shear strain

If $\tau \ \alpha \ \frac{du}{dy}$ $\therefore$ μ = const. $\therefore$ It is a Newtonian fluid

μ = const. ⟶ Newtonian fluid

μ = ↑↓ ⟶ Non-Newtonian