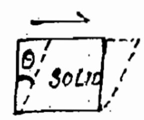
1. FLUID PROPERTIES

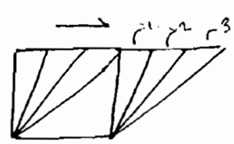
→ Substances in liquid and gaseous phase are refer to as fluid. They are capable of deforming continously under the action of shear stress, however small the shear stress might be.



θ → Shear Strain

$$\frac{\tau}{\theta} = G = \text{modulus of rigidity (In solid)}$$

* In case of solid shear stress is proportion to shear strain but in case of fluid shear stress is proportional to rate of shear strain.



Fluid

$$\boxed{\tau \propto \frac{d\theta}{dt} = \int d\theta = \int K \cdot \tau \, dt}$$

* CONTINUMM APPROACH :-

→ In fluid mechanics we assume continumm approach i.e we assume ~~low~~ no void space in the fluid. These helps in defining velocity, acceleration, etc. as a point function.

→ Continumm approach is invalid when mean free path is larger as compare to characteristics dimension of study.

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* IDEAL & REAL FLUID :-

→ Ideal fluid is a theoritical preposition / assumption made to simplify the analysis. No such fluid exist in reality.

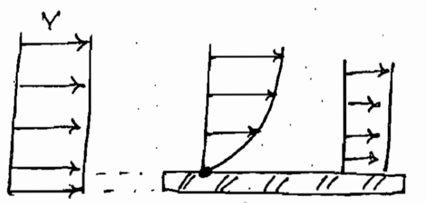
→ Ideal fluid does not have viscosity, surface tension and are in-compressible.

→ Real fluid which are not ideal are called real fluids.

* NO SLIP CONDITION :-

→ At the interface of a fluid and surface the fluid adhere to the surface due to a property of fluid called viscosity.

→ Thus if the surface is stationary, the fluid at the surface will be a stationary and if the surface is moving fluid at the surface will move with the same velocity.



** NOTE :-

* No waiting / wetting is due to surface tension it is not due to viscosity. Hence no wetting and no slip condition are different conditions.

* FLUID PROPERTIES :-

1.* Specific Gravity = $\boxed{G = \frac{\gamma_{fluid}}{\gamma_{water}}}$

$\gamma_{water} = 9.81\ KN/m^2$ = unit wt. of water = $\underset{\downarrow\ 1000\,kg/m^3}{\rho_w} \cdot g - 9.81\ m/s^2$

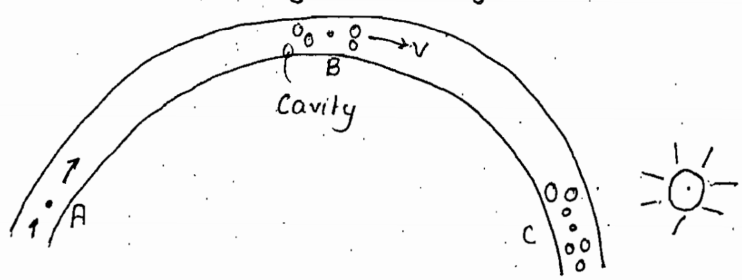
$G_{water} = 1$

$G_{mercury} = 13.6$

2. Vapour pressure & Caviation:-

- Saturation vapour pressure of a liquid is temperature dependent.
- Temperature increases, Saturation V.pressure increases & vice-versa.

→ If in the flow, absolute pressure is less than saturation vapour pressure then dissolved gases and vapour start comming out creating a cavity in the flow.



→ Saturation vapour pressure is the pressure exerted by vapour - when it is in phase equilibrium with the gases.

→ Saturation vapour pressure of a liquid is temp. dependent.

→ As temp. increases saturation vapour pressure increases & vice versa.

→ If in the flow, absolute pressure (i.e actual pressure) {$P_{atm} + P_{gauge} = P_{absolute}$} False below the sat. vapoure pressure dissolve gases and vapour start coming out in the form of bubbles creating cavity in the flow.

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→ These bubbles travel due to moment of flowing fluid and when they reach the high pressure region bubble colapse during rise to high presure waves which causes noise, vibration, surface pitting and fatigule failure.

→ Cavitation is generally obserbed in syphon and the inlet of centrifugal pump.

→ At the exit of reaction turbine.

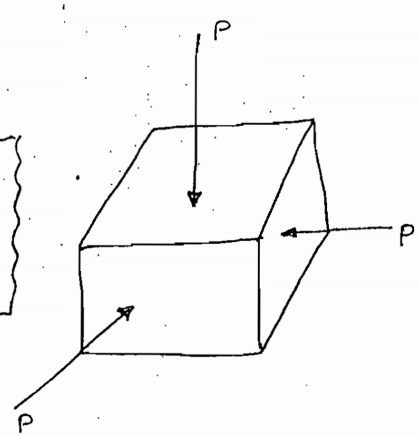
* Chances of cavitation increases with-

1. Increase in elevation,
2. With increase in velocity.
3. With increase in temperature.

3. Bulk modulus and Compressibility:-

- Bulk modulus = K
- Compressibility ⇒ $\beta = \frac{1}{K}$

$$\boxed{K = \frac{-(dp)}{\left(\frac{dv}{V}\right)}}$$



- K - Bulk modulus
- dp - Volumetric stress
- dv - volume changle
- V - Original volume

} Volumetric strain

$$m = \rho \cdot V$$

$$dm = 0$$

$$\rho\, dv + v\, d\rho = 0$$

$$-\frac{dv}{v} = \frac{d\rho}{\rho}$$

$$\therefore \left\{ K = \frac{dp}{\frac{d\rho}{\rho}} \right\} \Rightarrow \rho \left\{ \frac{dP}{d\rho} \right\}$$

→ Bulk modulus increases with increase in pressure and decreases with increase in temperature.

* NOTE :-
- Liquids are generally incompressible except under very high pressure. Gases are generally compressible.
- Air is generally 15,500 time more compressible than water.

* ISOTHERMAL BULK MODULUS :-

$$P = \rho RT$$

$$dp = d\rho \cdot RT \; \{\text{Since temp. is constant}\}$$

$$K = \frac{\rho\, dp}{d\rho} = \frac{\rho \cdot d\rho\, RT}{d\rho} = \rho RT = p$$

$$\therefore K = p$$

$$\left\{ K_{ISOTHERMAL} = p \right\}$$

→ Isothermal bulk modulus is equal to pressure.

* ADIABATIC BULK MODULUS:-

$$PV^{\gamma} = \text{Constant} = C$$

$$\gamma = \text{adiabatic constant} = \frac{C_p \to \text{sp. heat at constant pressure.}}{C_v \to \text{sp. heat at const. vol.}}$$

$$P\left(\frac{m}{\rho}\right)^{\gamma} = C$$

$$P = C' \rho^{\gamma}$$

$$\therefore \boxed{K = \frac{\rho\, dp}{d\rho}}$$

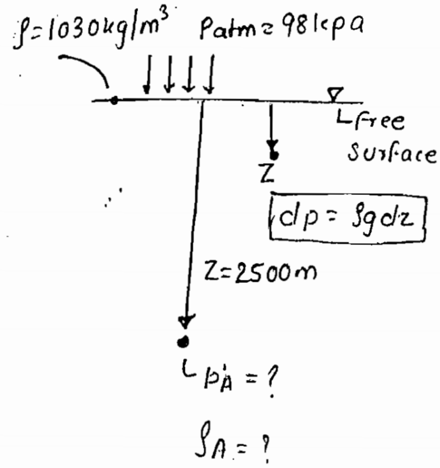
$$\frac{dp}{d\rho} = \gamma \rho^{\gamma - 1} \cdot C'$$

$$K = \gamma \cdot \rho^{\gamma} \cdot C'$$

$$K = \gamma p$$

$$\left\{ K_{adiabatic} = \underbrace{\gamma}_{\text{Adiabatic constant}} \cdot \overbrace{p}^{\text{Pressure}} \right\}$$

1 Que:- Density of sea water at free surface where pressure is 98 kPa is app. 1030 kg/m³ taking the bulk modulus of sea water to be $2.84\times10^{+9}\ N/m^2$ (Constant) and pressure variation with depth is given by $\{dp = \rho g\, dz\}$, determine the pressure and density at a depth of 2500 m neglect the effect of temperature?



Sol.

$$dp = \rho g\, dz$$

$$K = \frac{\rho\, dp}{d\rho}$$

$$\therefore K \cdot \frac{d\rho}{\rho} = \rho g\, dz$$

$$\int \frac{d\rho}{\rho^2} = \frac{g}{K}\int dz$$

$$-\frac{1}{\rho} = \frac{gz}{K} + c$$

at $z=0$, $\rho = \rho_0 = 1030\ kg/m^3$

$$\Rightarrow \frac{-1}{\rho_0} = c$$

$$\frac{-1}{\rho} = \frac{gz}{K} - \frac{1}{\rho_0}$$

$$\frac{1}{\rho} = \frac{1}{\rho_0} - \frac{gz}{K}$$

at $z = 2500\ m$

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$$\frac{1}{\rho_A} = \frac{1}{1030\,\frac{kg}{m^3}} - \frac{9.81\,\frac{m}{s^2} \times 2500\,m}{2.84 \times 10^9\,\frac{kg \cdot \frac{m}{s^2}}{m^2}}$$

$$\boxed{\rho_A = 1039.24\ kg/m^3}$$

Hence,

$$dp = \rho g\, dz$$

$$K = \rho \frac{dp}{d\rho}$$

$$\int dp = K \int \frac{d\rho}{\rho}$$

$$p = K \ln \rho + C$$

at, $\rho = \rho_0$, $p = p_0 = 98\,kPa$

$$p_0 = K \ln \rho_0 + C$$

$$p = K \ln \rho + p_0 - K \ln \rho_0$$

$$p = p_0 + K \ln \frac{\rho}{\rho_0}$$

$$p_A = p_A + K \ln \frac{\rho}{\rho_0}$$

$$P_A = 98\,kPa + 2.84 \times 10^6\,kPa \times \ln \frac{1039.24}{1030}$$

$$P_A = 25.461 \times 10^3\,kPa$$

$$\boxed{P_A = 25.461\ MPa}$$