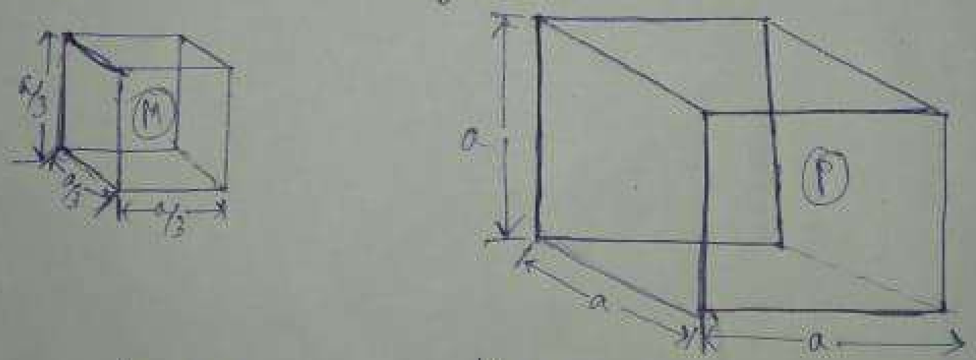
Fluids

Pressure	L	K. (relative roughness)
μ	D	modulus of Elasticity (E)
ρ	T	σ (surface tension).

1> Full length experimentation
2> predict the performance of one machine from the result obtained from another m/c.
3> Computer simulation

Sym. Similarity b/w two systems governs by.

- Geometric similarity $\longrightarrow$ similarity of shape.
- Kinematic similarity $\longrightarrow$ Similarity of motion.
- Dynamic similarity $\longrightarrow$ Similarity of forces.



Scale factor : = $\dfrac{\text{linear dimensions of the model}}{\text{linear dimensions of the prototype}}$

$$\boxed{\frac{1}{\text{scale factor}} = \text{model ratio}}$$

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...re roughness)
... Elasticity (E)
...tension).

...m the

...shape.
...motion.
...of forces.

...of the model
...of the prototype

Similarity of motion:

Scale factor or length ratio $= \frac{l_m}{l_p} = \frac{u_m \times t_m}{u_p \times t_p} = \frac{u_m}{u_p} \times \frac{t_m}{t_p}$

= velocity ratio × time ratio.

$$\boxed{\text{Velocity Ratio} = \frac{\text{length ratio}}{\text{time ratio}}}$$

Dynamic Similarity → similarity of forces:

the force at any point acted on the prototype which must be a definite proportion of the force acts at the same point of the model.

Many forces are involved in fluid flow phenomenon. but let us consider the most common forces act on the fluid elements

- Viscous force → F_v
- Surface Tension force → F_e.
- Gravitation force → F_g.
- 1st Pressure force → F_p.
- Elastic force → F_e

$$\boxed{F_p + F_v + F_{cr} + F_c + F_e = F_r}$$

$$-F_i = F_p + F_v + F_{cr} + F_c + F_e.$$

$$\Rightarrow \boxed{F_i + F_r = 0}$$

:- Fluids :-

$$F_i + F_v + F_p + F_g + F_c + F_E = 0$$

let us consider a cubical fluid element of length l, velocity u density ρ and time of applied force t.

Then inertia of force = mass x acceleration =

$$\rho \times l^3 \times \frac{u}{t}$$

$$= \rho \times l^3 \times \frac{u}{l/u}$$

$$\Rightarrow \boxed{\rho l^2 u^2}$$

~~viscous force = shear stress x surface area~~

$= \mu \cdot \frac{u}{l} \times l^2 = \boxed{\mu u l}$

pressure force = difference of pressure x area

$= \boxed{\Delta p \times l^2}$

Gravity force = $\boxed{\rho P \times g}$

Capillary force = surface tension x length

$= \boxed{\sigma \times t}$??

Elastic force = modulus of elasticity x area

$= \boxed{E \times l^2}$

Dynamic similarity of flow with viscous ~~force only~~.

incase of bounded flow

F_i, F_p & F_v only acts.

Convention is that for this type of flow, we consider only the ratio between the inertia force and viscous force, thus ~~Inertia force~~

$$\left|\frac{\text{Inertia force}}{\text{viscous force}}\right| \propto \frac{\rho l^2 u^2}{\mu u l} = \boxed{\frac{\rho l u}{\mu}}$$

~~Reyno~~

Reynolds number

Dynamic Similarity of flow with gravity force only.

incase of bounded flow the pipe must be completely filled by the water/fluid

$$\frac{[\text{Inertia force}]}{[\text{Gravity force}]} \propto \frac{\rho l^2 u^2}{\rho l^3 g} \simeq \underbrace{\frac{u^2}{lg}}_{(\text{Froude NO})^2}$$

In generator Froude NO. is specified as.

$$\boxed{F_r = \frac{u}{\sqrt{lg}}}$$

Dynamic Simild — F_r is one of the parameter to measure critical flow, supercritical flow
($F_r = 1$) ($F_r > 1$)

Ex

Subcritical flow
($F_r < 1$)

Dynamic Similarity of flow with surface tension force only.

$$\frac{|\text{Inertia Force}|}{|\text{Surface Tension Force}|} \propto \frac{\rho l^2 u^2}{\sigma l} \rightarrow (\text{Weber no})^2$$

Generally Weber. no is denoted by

$$= u\left(\sqrt{\frac{\rho L}{\sigma}}\right)$$

Dynamic similarity with Elastic force only.

If the velocity of fluid is almost greater than $\frac{1}{3}$rd of the velocity of the sound it is affected by compressibility factor.

$$\frac{|\text{Inertia force}|}{|\text{Elastic force}|} = \frac{\rho u^2 l^2}{E l^2} = \underbrace{\frac{\rho u^2}{E}}_{\text{Cauchy's No.}}$$

In an isentropic flow of fluid *

reversible adiabatic process where the entropy will remain constant.

* the bulk modulus of elasticity is given as $E_s = \gamma P = \gamma \rho R T$.

again $\sqrt{\gamma R T}$ = c velocity of sound.

Thus $\frac{E_s}{\rho} = \gamma R T = c^2$

Thus Cauchy's NO $= \frac{u^2}{E/\rho} = \frac{u^2}{c^2}$

$= (\text{Mach NO})^2$

Mach NO = 1 sonic
Mach NO < 1 subsonic
Mach NO > 1 supersonic
0.9 < Mach NO < 1.1 Transonic.

Hypersonic:
Mach NO > 3.5.

Dynamic Similarity of flow with force only:

$$\frac{[\text{Pressure Force}]}{[\text{Inertia Force}]} \propto \frac{\delta P l^2}{\rho l^2 u^2} \rightarrow \underbrace{\frac{\Delta P}{\rho u^2}}_{\text{Euler's No}}$$