Topic: Introduction

Date: March 2020

Fluid Mechanics

→ concerned with the behavior of liquids and gases at rest or in motion

→ fluid mechanics encompasses a vast array of problems that may vary from the study of

Range:
- → blood flow in the capillary (or capillaries) (which are only a few microns in diameters) — microfluidics
- to
- → the flow of crude oil through pipelines (long pipes around 4ft in diameter

→ fluid state of matter is predominantly found in nature and this in itself is reason enough to study its behavior in detail

→ Some examples where knowledge of fluid mechanics is essential in determining system performance

- → Heat exchangers & process equipment in power and chemical plants
- → Combustion chambers (IC Engines & furnaces)
- → Aerospace
- → Turbomachinery
- → Injection Molding, Casting, Material processing, etc

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Fluids

Matter can be classified as
- solids
- Liquids } fluids
- gases }

→ Basic difference between solids and fluids is in their stress–strain relationship besides their constituents

Solids — stress = f(strain)
- simple or complex

fluids

stress = f (Rate of strain)

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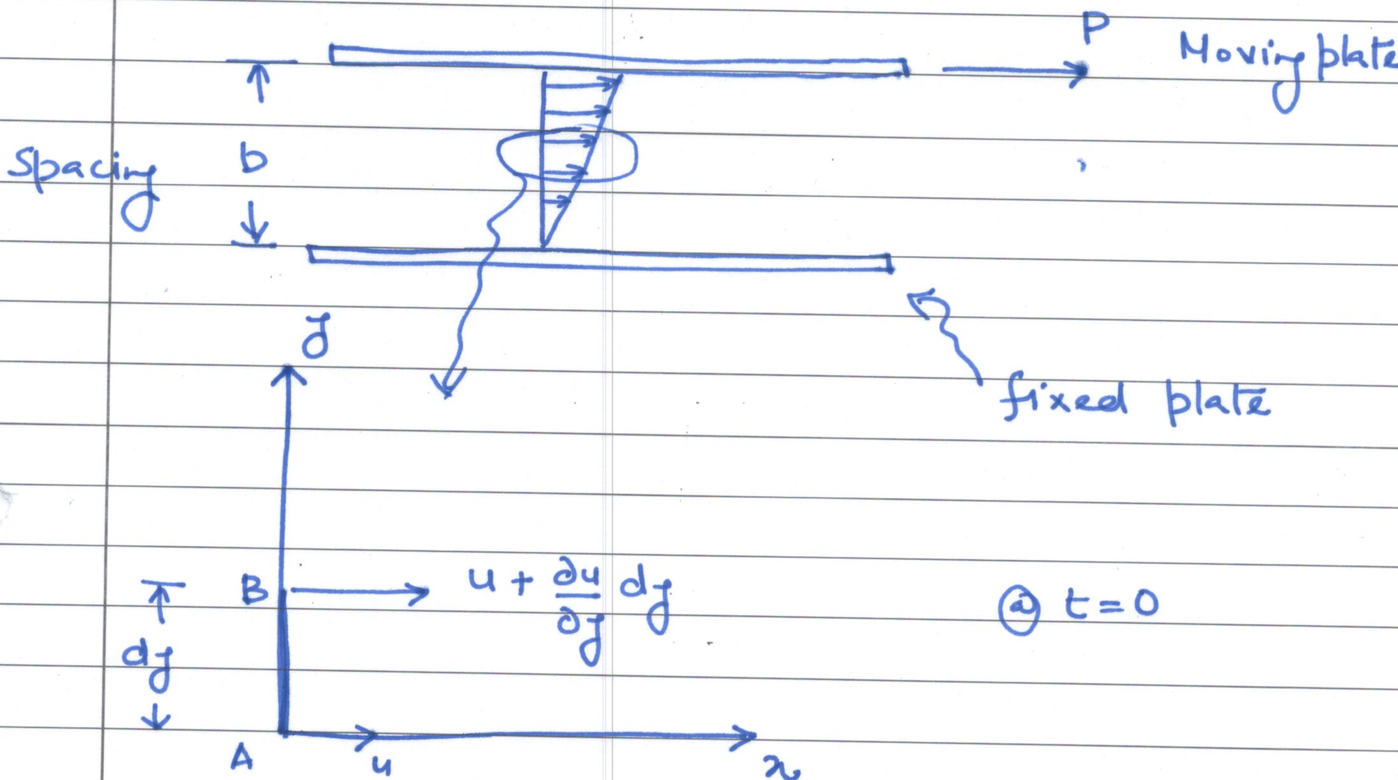
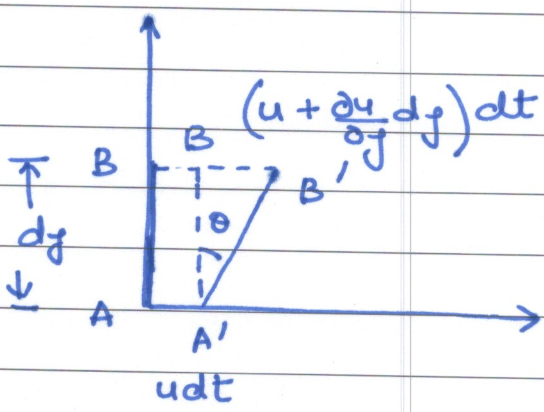
Hypothetical Experiment



After a small interval of time dt @ t=dt



$$AA' = u\,dt$$

$$BB' = \left(u + \frac{\partial u}{\partial y} dy\right) dt$$

In a small time interval dt an imaginary line AB in the fluid has rotated through an angle θ

for small angles

$$\theta \sim \tan\theta$$

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$$\theta \sim \tan\theta = \frac{BB'}{A'B} = \frac{\left[u + \frac{\partial u}{\partial y}dy - u\right]dt}{dy}$$

$$\theta = \frac{\partial u}{\partial y} dt$$

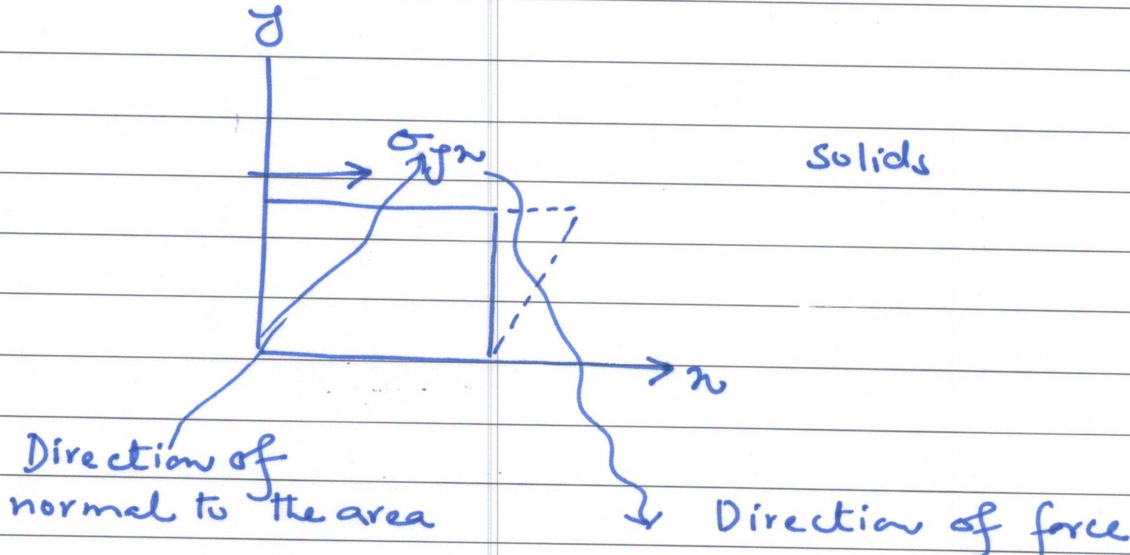
Strain, $\theta = \frac{\partial u}{\partial y} dt$

Rate of strain $= \frac{\partial u}{\partial y}$

Stress in the fluids $= f\left(\frac{du}{dy}\right)$

for solids

→ shearing stress causes a strain in case of solids



VISCOUS FLOW THEORY

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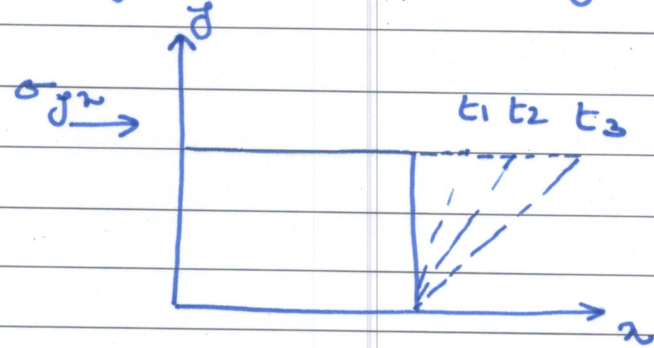
→ In case of fluids the shearing stress goes on changing the shape as long as it remains



→ fluids are incapable of resisting stress
→ infact the fluids flow
→ fluids continuously deform under the action of shearing stresses
→ solids can resist the shearing stress

→ Shearing stresses generate velocity gradients

$$\sigma_{yx} = f\left(\frac{\partial u}{\partial y}\right)$$

for a certain category of fluids

$$\sigma_{yx} \propto \frac{\partial u}{\partial y}$$

$$\sigma_{yx} = \mu \frac{\partial u}{\partial y}$$

μ — coefficient of proportionality is called coefficient of viscosity

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Solids : $\sigma_{yx} = f$ (strain)

fluids : $\sigma_{yx} = f$ (Rate of strain)

$= f(\partial u / \partial y)$

Literally 'fluid state' means an unstable state with respect its shape under the action of forces or stresses

Relationship

(I) $\sigma_{yx} = f(\partial u / \partial y)$

can have different forms depending upon the nature of the fluid

→ A large number of fluids have a linear relationship of the type

(2) $\sigma_{yx} = \mu \dfrac{\partial u}{\partial y}$

} Such fluids are called Newtonian fluids)

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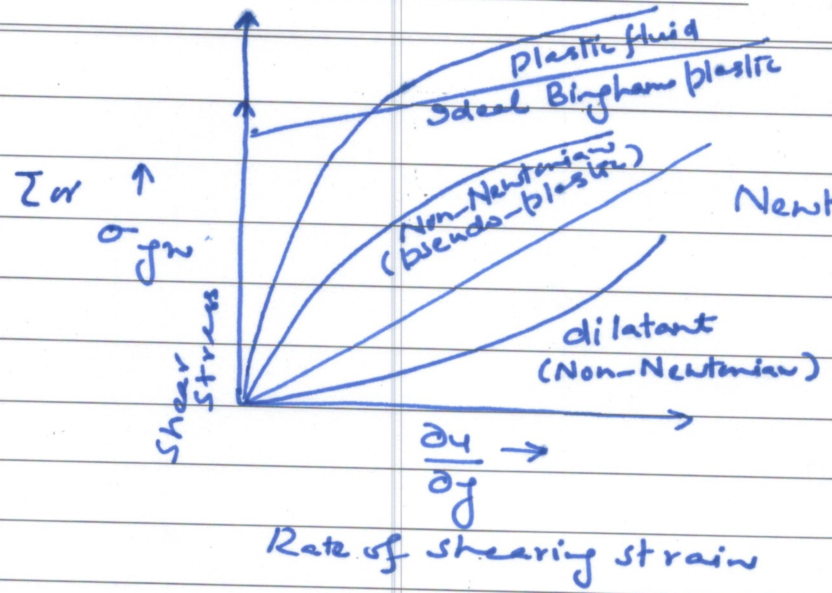
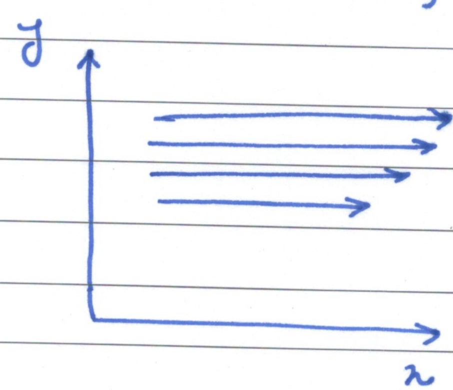


Discussion of the coefficient of viscosity

→ Viscosity – Resistance to flow or deformation or to the creation of velocity gradients or to the creation of relative motions



→ More viscosity means tendency to bind the particles or to keep the particles bound together

→ parameters that tend to bind the particles together

- → cohesion (intermolecular forces)
- → molecular momentum exchange

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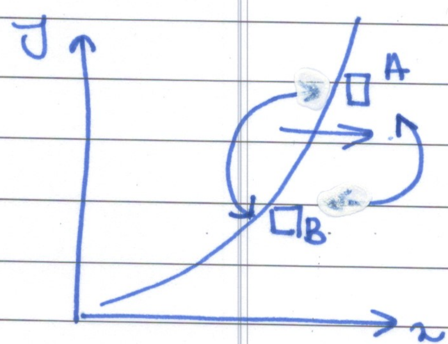
Molecular momentum exchange of random molecular motion tend to slow down the particles of element A and tend to make the particles of element B move faster



→ Hence there is a tendency to reduce relative motion between A and B and hence tendency to bind them together

→ So molecular momentum exchange is another cause for viscosity

Liquids — cohesion is major cause of viscosity

$T \uparrow$, $\mu \downarrow$

Increase in temperature — Viscosity decreases

Gases — molecular momentum exchange cause of viscosity

$T \uparrow$, $\mu \uparrow$

Increase — Increase