FDE 205 Fluid Mechanics

Fluid Dynamics

- Deals with the forces acting upon fluid in motion.

Definitions

- Mass Flow Rate ($\dot{m}$)(Kütle Akış Hızı) : It measures the mass of fluid that passes a given point per unit of time (kg/s)

$$\dot{m} = \frac{m}{t}$$

- Mass Flux (Φ)(Kütle Akısı) : is defined as the rate at which a certain property such as mass moves through a unit area(kg/s.m^2)

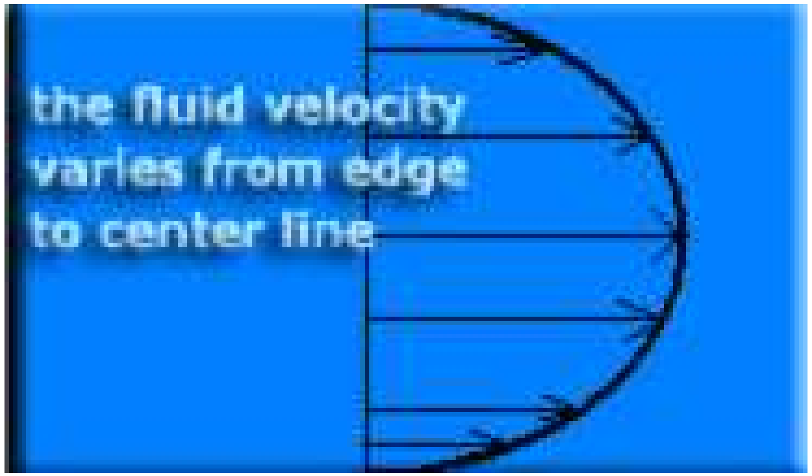
$$\Phi = \frac{m}{A \times t} = \frac{\dot{m}}{A}$$

- Volumetric Flow Rate (Debi) (Hacimsel Akış Hızı): It measures the volume of fluid that passes a given point per unit of time (m^3/s)

$$Q = \frac{V}{t}$$

- Average Velocity (Ortalama Hız): <ν>
  Fluid does not flow with the same velocity at different points of a pipe (m/s)

$$\langle \nu \rangle = \frac{Q}{A}$$



- Viscosity (Viskozite): μ

  Resistance to flow.

  Some fluids flow easier than the others inside a pipe.

  μ catchup> μ honey > μ oil> μ water

For Liquids → T↗→ μ ↘

For Gases → T ↗ → μ ↗

- Unit of viscosity:

Pa.s = N.s / m^2 = kg/m.s (SI unit)

lbm/ft.s (British units)

Poise = g/cm.s (cgs units) 1poise =100 cp

- Kinematic viscosity: (viscosity/density)

$$\gamma = \frac{\mu}{\rho}$$

- Control Volume (Kontrol Hacim):

  In some cases, it may be necessary to define a finite region fixed in space to apply the principles of conservation of momentum, energy and mass on a system. This region through which the fluid flows is defined as the control volume.

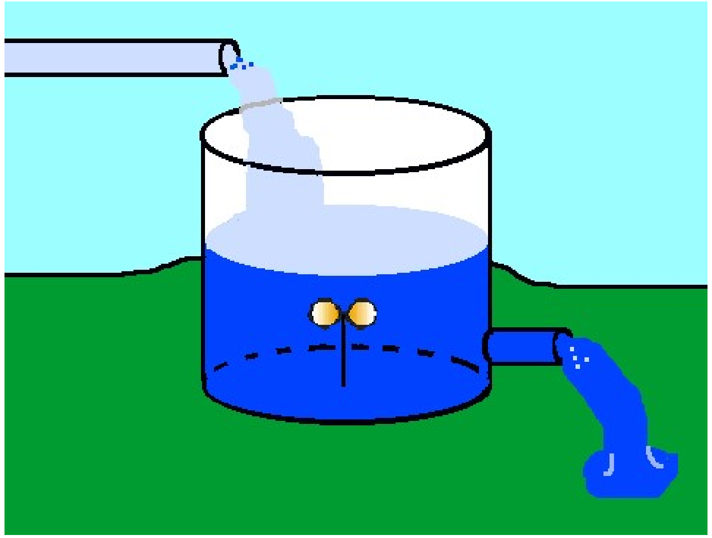
- Steady State (Kararlı Hal/ Yatışkın Hal):

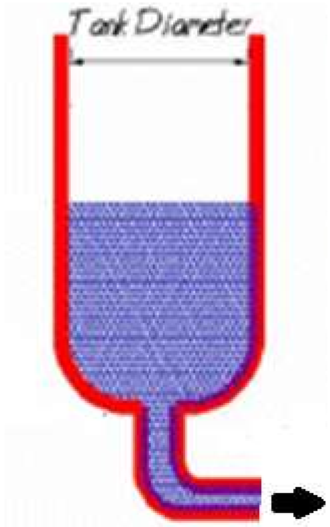
  A system in a steady state has properties that are unchanging in time.

- Unsteady state (Kararsız Hal/Yatışkın Olmayan Hal):

  A system in an unsteady state has properties that are changing in time.

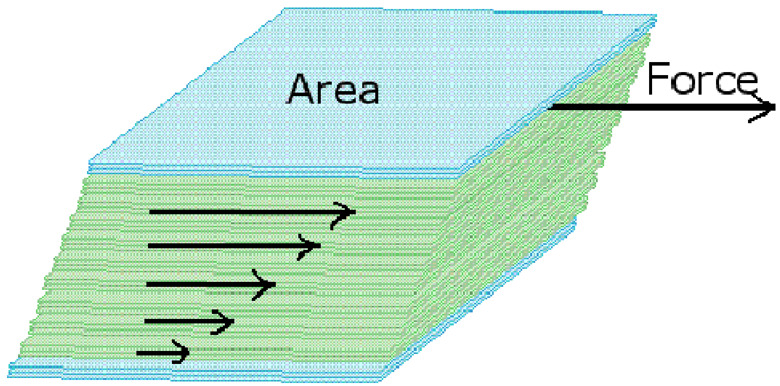
Steady state ?

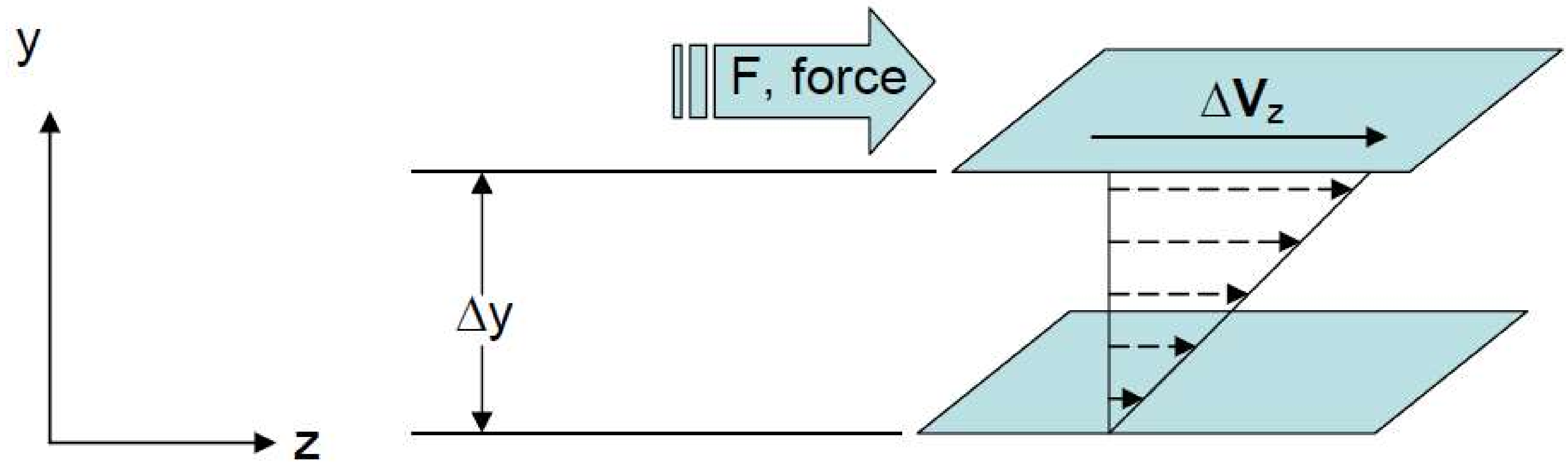




Newton’s Law of Viscosity

- If the force is normal to the surface of the fluid : Normal stress: Pressure
- If the force parallel to the surface: Shear Stress (Kayma gerilimi)→ τ (tau)





- Bottom plate is stationary.
- Top plate is moving with Vz
- The layer of water adjacent to the top plate is carried along at the velocity of plate.
- The layer just below that is at a slightly slower velocity.
- Each layer moves at a slower velocity.

Newton's Law of Viscosity

- Experimentally for many fluids the force(F) is directly proportional to the velocity (ΔV) and to the area (A), inversely proportional to the distance Δy.

(kayma gerilimi)
(shear stress) $\vec{\tau}_{yz}$

viscosity

Hız gradyanı
(shear rate)
(kayma hızı)

$$\frac{F}{A} = -\mu \frac{\Delta V_z}{\Delta y}$$

Newton's Law of Viscosity

As Δy approaches zero, by definition of derivative:

$$\tau_{yz} = -\mu \frac{\partial \upsilon_z}{\partial y}$$

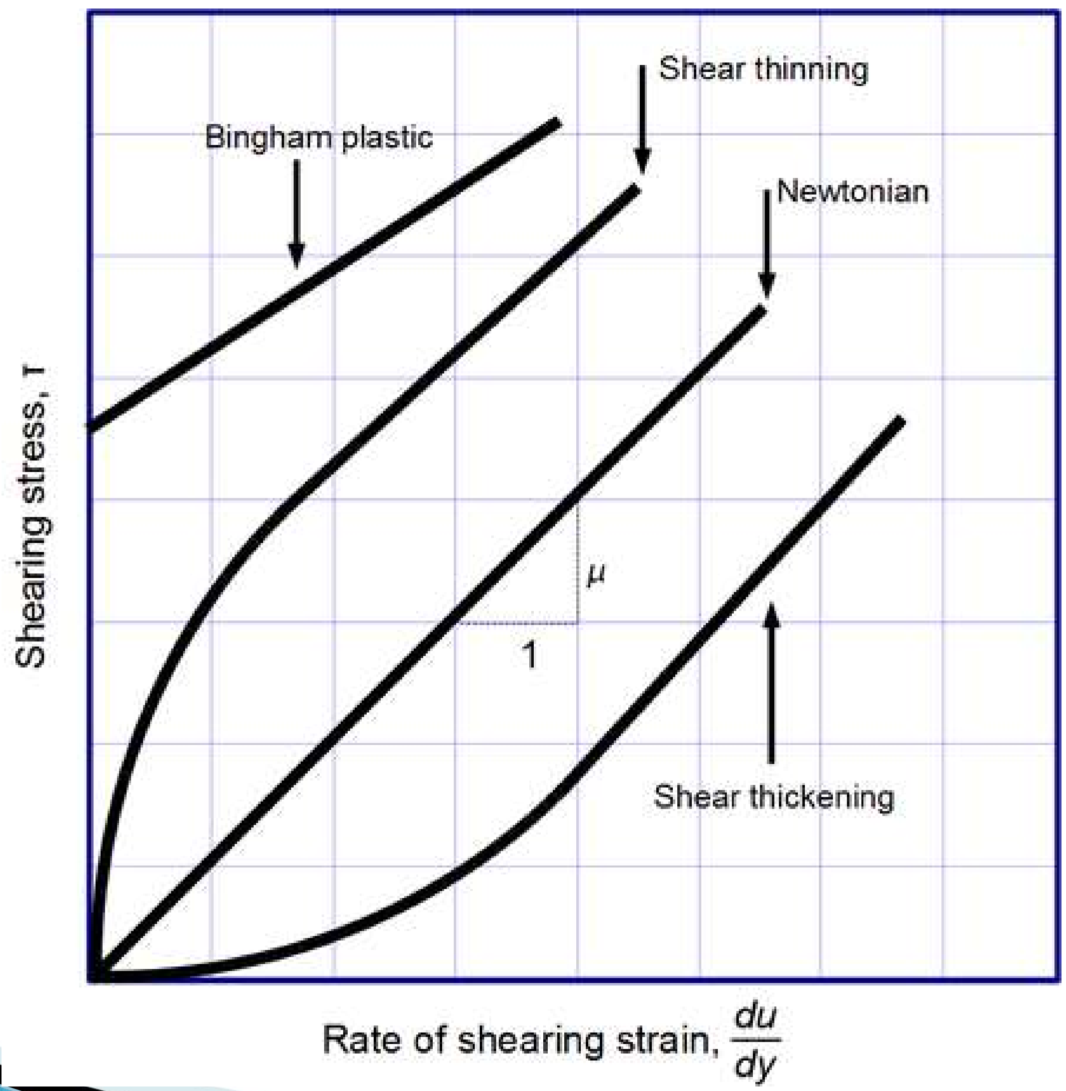
z→ direction of force (kuvvetin uygulandığı yön)
y → direction of normal (kuvvetin uygulandığı yüzeye dik olan yön)

τ_{yz} → The shear stress in y direction due to force applied in z direction (vector) (also known as momentum flux)

Types of Fluid

- Fluid types can be categorized as newtonian and non-newtonian.
- Newtonian Fluids are those which follow Newton's Law of Viscosity. (e.g. Water)
- If a fluid does not follow the law, then it is a non-newtonian fluid.
- If we plot shear stress vs shear rate graph?

Types of Fluid



- Bingham plastic: these are simplest because they differ from Newtonian only in that the linear relationship does not go through the origin.
- E.g. Margarine, chocolate mixtures

- Pseudoplastic fluids (shear thinning)(*kayma hızı ile incelen)*: The majority of non-Newtonian fluids are in this category, including mayonnaise, concentrated fruit juice.
- Burada incelme, akışkanın akmaya karşı gösterdiği dirençte gevşemeyi ve zayıflamayı, kalınlaşma ise koyulaşma ve güçlenmeyi yansıtan derişim terimi olarak kullanılmaktadır.

- Dilatant (shear rate thickening): Their flow behaviour shows an increase in viscosity with increasing shear rate. (Dilatant akışakanlarda ise tam tersine bir davranış bulunduğundan *kayma hızı ile kalınlaşan* akışkanlar da denilmektedir.)
- E.g. Gelatinized starch

Power Law (Üstlülük Yasası)

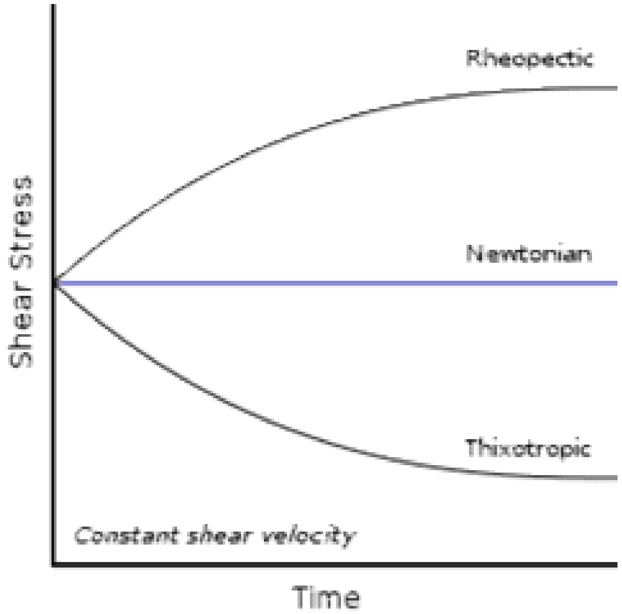
- Newtonian Law can be generalized with Power law equation

$$\tau_{yx} = -K\left(\frac{dv_x}{dy}\right)^n$$

- n: flow behavior index (akış davranışı göstergesi)
- K: consistency index (kıvam göstergesi)
- n<1pseudoplastic
- n>1dilatant fluids
- n=1newtonian fluids (K=μ)

Time Dependent Fluids

- When some fluids are subjected to constant shear rate they become thinner or thicker with time.



Kek hamuru

Örnek 2.4.1

- There is a fluid (ethanol) between two parallel plates, at 273 K, with a viscosity of 1.77 cp. The distance between two parallel plates is 0.5 cm. The velocity of lower plate is 10 cm/s.
- Calculate the shear stress.