MEC2015 : FLUID MECHANICS

Lecture 1-2

Fluid Properties

- Fluid vs. Solid, Continuum
- Viscosity
- Surface Tension : Capillary Rise/Fall
What is Fluid Mechanics?

Fluid (流體) Mechanics (力學)

Fluid mechanics is the study of fluids and their effect on boundaries in contact with them either in motion or at rest.

유체역학은 정지 또는 운동상태에 있는 유체에 관한, 그리고 유체가 유체와 접하고 있는 경계면에 미치는 영향들에 관한 학문이다.
Fluid mechanics is the study of fluids and their effect on boundaries in contact with them either in motion or at rest.

**What is Fluid Mechanics?**

1. **Eulerian** - Control Volume
2. **Lagrangian** - Following the mass (System)

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**Dept. Mechanical Robotic & Energy Engineering**

**FLUIDS Engineering LAB**
Fluid (流體) vs. Solid (固體)

Solid
(Liquid, Gas)

Fluid
Can

Solid
Can Not

Resist Shear Force (Stress)

\[ \tau = \frac{F}{A} \]

\[ \tau = G\gamma = G \tan(\delta\theta) \]

\[ \tau \propto \frac{\delta\theta}{\delta t} \propto \frac{du}{dy} = \mu \frac{du}{dy} \]
A valid model for MOST of Engineering situations!

Except:
- Extremely small scale
  
  distance between gas molecules @ STP \( \sim 10^{-7} \text{m} \)
  
  \( 1 \text{ mm} \overset{\rightarrow}{\sim} 10^7 \text{ molecules} \)

- Extremely low pressure
  
  @ 0.001 bar
  
  \( 1 \text{ mm} \overset{\rightarrow}{\sim} 10^4 \text{ molecules} \)
Viscosity (粘度)

\[
\tau \propto \frac{\delta \theta}{\delta t} \propto \frac{du}{dy} = \mu \frac{d\theta}{dt} = \mu \frac{du}{dy}
\]

\[
\mu \quad \text{kg} / (\text{m} \cdot \text{s}) \; ; \; 1 \text{ Poise} = 1 \text{ g/(cm} \cdot \text{s})
\]

\[
v = \frac{\mu}{\rho} \quad \text{m}^2 / \text{s} \; ; \; 1 \text{ St} = 1 \text{ cm}^2 / \text{s}
\]
Shear Stress ~ Viscosity, Velocity Gradient

\[ \tau = \mu \frac{du}{dy} \]

\[ \tau = \mu \frac{dv}{dx} \]

\[ \tau = \mu \frac{dv_\theta}{dr} \]
Shear Stress ~ Viscosity, Velocity Gradient

\[ \tau = \mu \frac{d\theta}{dt} = \mu \frac{du}{dy} \]

What is the velocity profile \( u(y) \)?

\[ \frac{du}{dy} = \frac{\tau}{\mu} = \text{constant} \quad \therefore \quad u = c_1 y + c_2 \]

(1) \( u(y = h) = c_1 h + c_2 = V \)
(2) \( u(y = 0) = c_2 = 0 \)

\[ \therefore \quad u = V \frac{y}{h} \]

No-Slip Condition (粘着 조건)

\[ V_{\text{Fluid}}(\vec{x}_0) = V_{\text{Solid}}(\vec{x}_0) \]
Surface Tension: $\text{N} / \text{m}$

\[
\begin{align*}
(2RL) \times \Delta p &= 2 \times (\sigma L) \\
(\pi R^2) \times \Delta p &= 2\pi R \times \sigma \\
\Delta p &= \sigma \left( \frac{1}{R_1} + \frac{1}{R_2} \right)
\end{align*}
\]
Surface Tension ~ Capillary Rise/Fall

Contact Angle (接觸角)

고체 ⇒ 액체 ⇒ 기체

\( 0 < \theta < \frac{\pi}{2} \) : wetting
\( \frac{\pi}{2} < \theta < \pi \) : non-wetting

Capillary Rise (毛細管 現象)

\[ F_\text{하} = \left( (\pi R^2 h) \rho \right) g = F_\text{상} = \left[ \sigma (\cos \theta) \right] (2\pi R) \]

\[ h = \frac{2\sigma \cos \theta}{\rho g R} \]

\[
\begin{align*}
0 < \theta & < \frac{\pi}{2} : h > 0 \quad \text{Rise} \\
\frac{\pi}{2} & < \theta < \pi : h < 0 \quad \text{Fall}
\end{align*}
\]
Announcement

HW Format!!!

Homework:
HW#1 Due Sept. 13 before Lecture

Next Lecture
Ch. 1.11 Velocity Field
Ch. 4.7 Stream Function