

Chapter 2

Viscosity of Fluids

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Overview of Chapter 2

- Define viscosity, both dynamic and kinematic viscosity
- Identify units in the SI and English System
- Determine methods of measuring viscosity
- Learn about viscosity index

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Dynamic Viscosity

- Fundamental assumptions:
 - Thin layer of fluids between 2 surfaces
 - The fluid adjacent to each surface travels at the surface's velocity
 - For thin layers, the change in velocity is linear from zero to v (velocity of moving the surface)

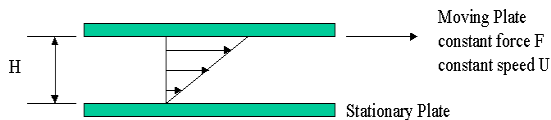
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Shear Stress in Fluids

- Shear stress τ (tau) is the force required to slide a unit area layer of substance over another.
- Units are in N/m^2 (SI) or lbf/ft^2
- $\tau = \eta (\Delta v / \Delta y)$
 - where v = velocity of surface and y = vertical thickness of fluid.

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➤ Viscosity: Due to interaction between fluid molecules, the fluid flow will resist a shearing motion. The viscosity is a measure of this resistance.



From experimental observation, $F \propto A(U/H) = A(dV/dy)$

$$\tau = \frac{F}{A} \propto \frac{dV}{dy}, \text{ where } \tau \text{ is shear stress}$$

$$\tau = \mu \frac{dV}{dy}, \text{ where } \mu \text{ is dynamic viscosity, The unit of } \mu \text{ is } \frac{\text{lb sec}}{\text{ft}^2} \text{ or } \frac{\text{N sec}}{\text{m}^2}$$

Kinematic Viscosity

- Some calculations use the ratio of dynamic viscosity to fluid density.
- Kinematic viscosity uses the Greek letter ν (nu) and $\nu = \eta / \rho$
- The derived units for $\nu = \text{m}^2/\text{s}$
- Stoke = $1 \text{ cm}^2/\text{s}$ (or $1 \times 10^{-4} \text{ m}^2/\text{s}$)
- Centistoke = $1 \text{ mm}^2/\text{s}$ (stoke/100) ⁶

Newtonian Fluids

- Newtonian Fluids are those fluids that behave in accordance with the the shear equation $\tau = \eta (\Delta v / \Delta y)$.
- Most common fluids are newtonian
 - Water, oil, gasoline, glycerine.
- The viscosity is a function of the condition of the fluid (mostly its

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Nonnewtonian Fluids

- These fluids change viscosity due to other factors, such as a change in velocity gradient, shear stress, time (thixotropic fluids like flour dough), and the application of electrical current.

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Viscous Coupling

- One of the earliest examples was Volkswagen's Syncro system.
- Inside a viscous coupler, there are many circular plates positioned very close to each other. Both drive shafts connect to roughly half of the plates in an alternating sequence. The sealed differential housing is fully contained with a high viscosity liquid, which has a strong tendency to "visco" those plates together.

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- In normal conditions, front and rear axles run at roughly the same speed so the plates and viscous liquid are relatively stable to each other. When tire slip occurs in one of the axles, that means the alternating plates run at different speeds, and a viscous liquid will try to visco them together. As a result, torque is transferred from the faster driveshaft through the liquid to the slower driveshaft. The greater the speed difference, the larger the torque transfer. As a result, the limited slip function is implemented.

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Viscosity and Temperature

- Typical fluids like oil decrease in viscosity as the temp increases.
- Appendix D shows SI and English graphs of dynamic viscosity versus temperature. Note the logarithmic scale due to large range.
- Note how gases act the opposite in general.

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Viscosity Index

- This is a measurement of how temperature affects the viscosity of a fluid.
- High VI indicates a small change in viscosity relative to temperature
- Low VI means viscosity changes greatly with change in temperature₂

Viscosity Index Values

- Viscosities of fluids are measured at 40° and 100° C and compared to standard fluids assigned with VI = 0 and 100.
- Higher VI oils are used where temperature variations are great – outdoor equipment, autos, trucks.

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Viscosity Measurement

- Rotating Drum Viscometer
 - Figure 2.4: Uses the shear equation to measure viscosity: $\tau = \eta (\Delta v / \Delta y)$
 - The meter can measure the drag (based on shear stress) and read out in viscosity units.

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Falling Ball Viscometer

- The time it takes a sphere to drop through a measured distance determines its terminal velocity (v) in a fluid, which can then be used to calculate the fluid viscosity by this equation: (using specific wts.)

- $$\eta = (\gamma_s - \gamma_f)D^2 / (18v)$$

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Saybolt Viscometer

- Determines the time required for 60 mL of sample to flow through a calibrated orifice under precisely controlled conditions. Saybolt Universal Seconds (SUS) is the standard measurement for lubricants, insulating oils, and lighter fuel grades.

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Paint Cup Viscometer

- Relative measurement to check viscosity of paint used in a dipping process.
- Cup has a hole in bottom, time the number of seconds that full flow comes out the bottom.

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SAE Viscosity Grades

- SAE created a rating system for engine oils
- W rated oils based on cold cranking and pumping conditions
- Straight grades based on high temperature conditions
- Multigrade oils (10W-30) must meet both conditions
- Note SAE 90 weight oil (for gearboxes).¹⁹

ISO Viscosity Grades

- Another set of viscosity grades for standardization by ASTM
- ISO VG has 20 grades, based on kinematic viscosity at 40° C.
- Grade based on nominal centistokes rating. See Table 2.6

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Fluid Power Systems

- Types of fluids in use:
 - Petroleum oils (automotive)
 - Water-glycol fluids (fire resistant)
 - High water-based fluids (HWBF)
 - Silicone fluids (high temp – brakes)
 - Synthetic oils (higher specifications)

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Primary Characteristics of Fluids

- Proper viscosity
- Lubricating capability
- Chemical stability
- Compatibility with system material
- Resistance to bacterial growth
- Ecological acceptability & Safety
- High bulk modulus

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Homework – Chapter 2

- Problems, page 49:
- 18, 25, 32 thru 35, 55, 57, & 61

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