

Viscosity

Introduction

Have you ever wondered why honey flows more slowly than water? Or why some motor oils are described as "thicker" than others? The answer for this lies in a fundamental property of fluids called viscosity.

Viscosity plays a crucial role in everything from car engines to cooking and even human circulation. But what exactly is viscosity, and why does it matter? In this article, we'll explore the concept of viscosity, its mathematical explanation, real-world applications, and common misconceptions.

Definition & Explanation of Viscosity

Viscosity is a measure of a fluid's resistance to flow. Or simply, it describes how "thick" or "thin" a liquid is. A fluid with high viscosity, like honey, resists motion, while a fluid with low viscosity, like water, flows easily.

To understand viscosity, let's take an example of difference between stirring a cup of coffee and a jar of honey. We can observe that the coffee moves with ease, while the honey offers resistance. This resistance arises due to the internal friction between layers of the fluid as they move past each other.

Mathematical Definition of Viscosity

Viscosity is denoted by η (eta) and is defined by Newton's Law of Viscous Flow:

$$\tau = \eta \frac{du}{dy}$$

where:

- τ = Shear stress (force per unit area)
- η = Viscosity coefficient
- du/dy = Velocity gradient (rate of change of velocity with respect to depth)

Types of Viscosity

1. **Dynamic Viscosity (Absolute Viscosity):** It measures the actual internal resistance of a fluid to flow. It indicates how thick or thin the fluid is.
2. **Kinematic Viscosity:** It is the ratio of dynamic viscosity to the fluid's density, reflecting how a fluid flows under the influence of gravity.

Newtonian vs. Non-Newtonian Fluids

Newtonian Fluids: These have a constant viscosity regardless of applied force (e.g., water, air), which means their flow behaviour remains constant.

Non-Newtonian Fluids: Their viscosity changes when force is applied (e.g., ketchup, blood, cornstarch in water), which means their flow behaviour can vary under different conditions.

Applications of Viscosity

1. Motor Oil & Lubrication

Engines require oil with specific viscosity to reduce friction and wear. The right viscosity ensures efficient performance and fuel economy.

2. Food Industry

The viscosity of chocolate, sauces, and syrups affects their texture and how they coat food.

3. Medical Applications

Blood viscosity impacts circulation and cardiovascular health. Abnormal viscosity levels can lead to medical conditions like high blood pressure.

4. Aerospace & Manufacturing

Paints, inks, and coatings must have the correct viscosity for smooth application and durability.

Example Calculations on Viscosity

Example 1: Calculating the Shear Stress in a Fluid

A fluid has a dynamic viscosity of $0.5 \text{ Pa}\cdot\text{s}$, and the velocity gradient is 2 s^{-1} . Find the shear stress.

Using the formula: $\tau = \eta \, du/dy$

$$\tau = (0.5)(2)$$

$$\tau = 1 \text{ Pa}$$

Thus, the shear stress is 1 Pascal.

Example 2: Comparing Flow Rates of Two Fluids

Honey has a viscosity of $5 \text{ Pa}\cdot\text{s}$, while water has a viscosity of $0.001 \text{ Pa}\cdot\text{s}$. Which fluid flows more easily?

Since water has a much lower viscosity than honey, it offers less resistance to flow and moves more easily. Therefore, water pours quickly, while honey drips slowly.

Comparison of Viscosity with Related Concepts

Property	Viscosity	Density	Surface Tension
Definition	Resistance to flow	Mass per unit volume	Force per unit length at a liquid's surface
Unit	Pa·s (Pascal-second)	kg/m ³	N/m (Newton per meter)
Example	Honey (high viscosity), Water (low viscosity)	Lead (high density), Air (low density)	Water forming droplets

Conclusion

Viscosity is a fundamental property of fluids that affects everyday life in surprising ways—from the oil in our cars to the flow of blood in our veins. Understanding viscosity helps engineers, chefs, doctors, and scientists optimize processes and improve efficiency. Next time you pour syrup on pancakes or see lava flowing from a volcano, take a moment to appreciate the science behind viscosity!

Frequently Asked Questions (FAQs)

1. **Does temperature affect viscosity?**

Yes! As temperature increases, viscosity usually decreases. That's why honey flows faster when warmed.

2. **How is viscosity measured?**

Instruments like viscometers and rheometers measure viscosity by analysing fluid resistance under different conditions.

3. **Why does ketchup flow slowly from the bottle?**

Ketchup is a shear-thinning non-Newtonian fluid, meaning its viscosity decreases when shaken or squeezed.

4. **What is the SI unit of viscosity?**

The SI unit of dynamic viscosity is **Pascal-second (Pa·s)**, while kinematic viscosity is measured in **square meters per second (m²/s)**.

5. **What is the difference between viscosity and density?**

Viscosity measures a fluid's resistance to flow, while density measures the mass per unit volume of a substance.

6. What is the viscosity of air?

The viscosity of air at room temperature is approximately 1.81×10^{-5} Pa·s.

7. What is the viscosity of water?

The viscosity of water at room temperature (20°C) is about 1.002 mPa·s (or 0.001002 Pa·s).

8. What is the viscosity index?

The viscosity index is a measure of how much a fluid's viscosity changes with temperature; a higher index indicates less change in viscosity with temperature fluctuations.