Lecture: Rheology

Course: Industrial Pharmacy

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1. Introduction

Rheology is the science that studies the flow and deformation of matter. In pharmacy, it helps understand how liquid, semisolid, and solid materials behave under applied forces — essential for formulation design, processing, and quality control.

2. Importance of Rheology in Pharmacy

1. Mixing and pouring of liquids.
2. Filling and packaging of semisolids and suspensions.
3. Spreadability of creams and ointments.
4. Suspension stability and sedimentation control.
5. Injectability and syringeability of parenteral products.
6. Patient acceptability (texture and flow).

3. Basic Rheological Concepts

1. Deformation: Change in shape when stress is applied.
2. Flow: Continuous deformation under shear stress.
3. Viscosity (η): Resistance to flow; ratio of shear stress to shear rate ($\eta = \tau / \gamma$).

4. Classification of Flow Behavior

A. Newtonian Flow

Follows Newton's law of viscosity. Viscosity remains constant, independent of shear rate. Shear stress (τ) is directly proportional to shear rate (γ): $\tau = \eta\gamma$. Examples: Water, glycerin. Represented by a straight line on a rheogram.

B. Non-Newtonian Flow

1. Plastic Flow: Behaves as a solid until a yield value is exceeded; then flows. Examples: Toothpaste, ointments, gels.
2. Pseudoplastic Flow: Viscosity decreases with increasing shear rate (shear-thinning). Examples: Polymer solutions, emulsions.
3. Dilatant Flow: Viscosity increases with increasing shear rate (shear-thickening). Examples: High solid suspensions like starch.

5. Thixotropy

A time-dependent reversible decrease in viscosity upon shearing. On standing, viscosity returns to original value. Seen in pseudoplastic systems like gels and creams. Important in formulation stability — ensures easy spreading yet maintains consistency.

6. Rheological Models

1. Newtonian Model: $\tau = \eta\gamma$
2. Bingham Plastic Model: $\tau = f + \eta_p\gamma$ (f = yield value)
3. Power Law (Ostwald-de Waele): $\tau = K\gamma$■ (K = consistency index, n = flow index; $n < 1 \rightarrow$ pseudoplastic; $n > 1 \rightarrow$ dilatant)

7. Measurement of Rheological Properties

1. Capillary Viscometers: Measure time for a liquid to flow through a narrow tube (for Newtonian fluids).
2. Falling Sphere Viscometers: Measure time taken for a ball to fall through a liquid column (Stokes' Law).
3. Rotational Viscometers: Measure torque to rotate spindle (for non-Newtonian systems).
4. Cup-and-Bob Rheometer: Measures complex fluids with thixotropy or plasticity.

8. Pharmaceutical Applications of Rheology

1. Suspensions: Prevent sedimentation and ensure redispersion.
2. Emulsions: Maintain droplet uniformity and stability.
3. Ointments and Creams: Optimize spreadability and consistency.
4. Tablet Coating Solutions: Control film thickness and smoothness.
5. Injectables: Ensure syringeability and process uniformity.
6. Processing: Pumping, mixing, and packaging efficiency.

9. Factors Affecting Rheology

1. Temperature: Viscosity decreases as temperature increases.
2. Particle size and shape.
3. Concentration of dispersed phase.
4. Intermolecular interactions and polymer entanglement.
5. Presence of surfactants or viscosity modifiers.

10. Summary

Rheology is a vital aspect of industrial pharmacy, helping predict and control material behavior during manufacturing and storage. Understanding flow properties ensures product stability, process efficiency, and patient acceptability.