Rheology

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What is Rheology

- Rheology is the study of deformation and flow.
- Oil and water flow in familiar, normal ways, whereas mayonnaise, peanut butter, and chocolate flow in complex and unusual ways.
- In rheology, we study the flows of unusual materials.
- When you open a partly used jar of mayonnaise, the top surface retains the shape created by the last person who made a sandwich.
- Well, compare that observation with the behavior of honey. The top surface of honey in a jar is always smooth. Within a few seconds of serving yourself from a honey jar, the surface is flat again

Importance of Rheology in Pharmacy

- In preparation, development and evaluation of pharmaceutical dosage forms e.g., suspensions, emulsions, pastes, suppositories, tablets coating, …., etc.

- Mixing and Flow of materials, Packaging into containers and their removal prior to use in respect to Pouring from bottle, extrusion from tube, passage from syringe

Classification of Materials according to the types of flow

1) Newtonian Systems

They obey Newton's law of flow.

Example: Water, Ethanol, Benzene.

2) Non-Newtonian Systems

They fail to follow Newton's law of flow.

Examples: Colloidal Solutions, Emulsions, Liquid Suspensions, Gels and Ointments.

Newtonian system

They have constant viscosity where

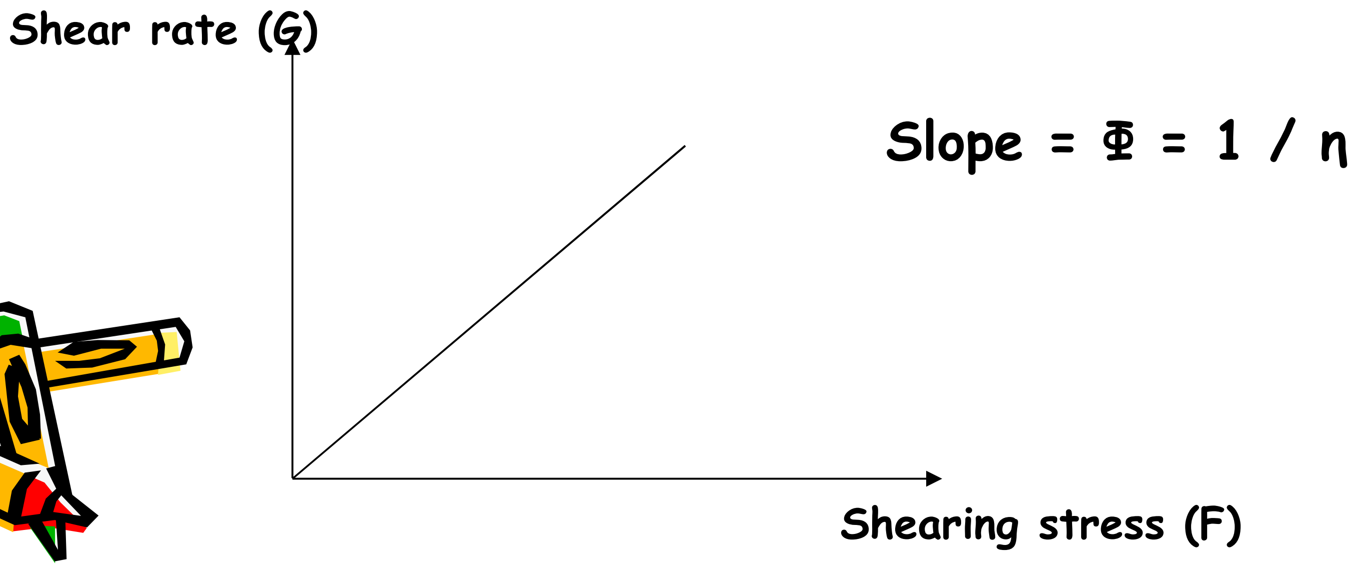
$$\eta = F / G.$$

- When we plot a rheogram of G against F, then a straight line is obtained passing through the origin, the slope of which is equal to the reciprocal of viscosity, a value referred to as **the fluidity Φ**,

$$\Phi = 1 / \eta$$

- Newtonian systems like water, simple organic liquids, true solutions and dilute suspensions and emulsions.

Rheogram of a Newtonian liquid



NON-NEWTONIAN SYSTEMS

- Do not follow the simple Newtonian relationship i.e., when F is plotted against G the rheogram is not a straight line passing through the origin i.e., viscosity is not a constant value.
- Such as colloidal dispersions, concentrated emulsions and suspensions, ointments, creams, gels, etc.
- These rheograms represents three types of flow:

1. Plastic
2. Pseudoplastic
3. Dilatant.

1. Plastic Flow:

Such materials are called Bingham bodies

- The curve is linear over most of its length corresponding to that of a Newtonian fluid.
- However, the curve does not pass through the origin but rather intersects the shearing stress axis (or will if the straight part of the curve is extrapolated to the axis) at a particular point referred to as the *Yield value* or *Bingham Yield value.*

- Contrary to a Newtonian liquid that flows under the slightest force, a Bingham body does not flow until a definite shearing stress equal to the **yield value** is applied.

- Below the yield value the system acts as an elastic material.

- Plastic systems resembles Newtonian systems at shear stresses above the yield value.

- The slope of the rheogram is termed **mobility**, analogous to fluidity in Newtonian systems and its reciprocal is known as the ***Plastic viscosity***, U.

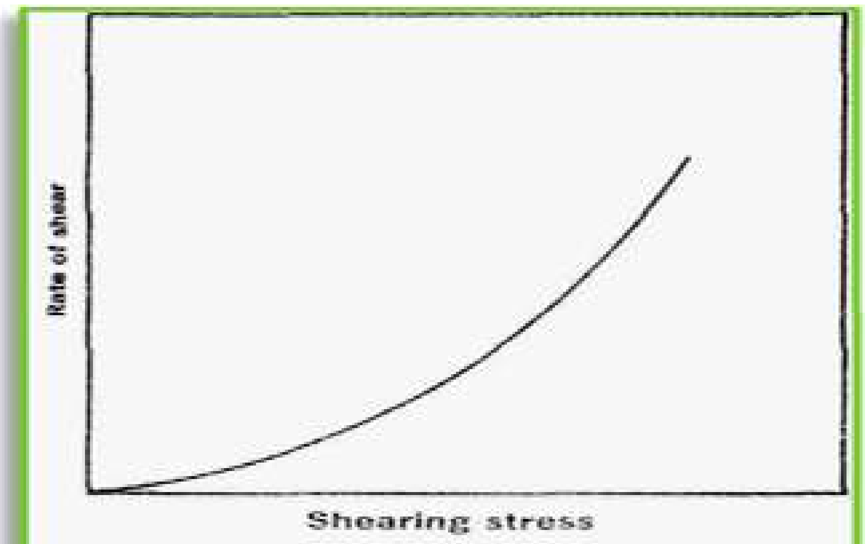
$$U = \frac{(F - f)}{G}$$

- Plastic flow is associated with the presence of **flocculated particles in concentrated suspensions**, however ointments and creams are common examples for that system.
- A yield value exists because of the contacts between adjacent particles (brought about by van der Waals forces), which must be broken down before flow can occur.
- Consequently, the yield value is an indication of force of flocculation: The more flocculated suspension, the higher will be the yield value.
- Plastic systems are **shear-thinning systems**

2. Pseudoplastic Flow:

- A large number of pharmaceutical products, including natural and synthetic gums, e.g., liquid dispersions of tragacanth, sodium alginate, methyl cellulose, and Na CMC show pseudoplastic flow.

- As a general rule pseudoplastic flow is exhibited by **polymers in solution**, in contrast to plastic systems which are composed of flocculated particles in suspension



(c) Simple pseudoplastic flow

- Curve for a pseudoplastic material begins at the origin consequently, in contrast to Bingham bodies, there is no yield value.

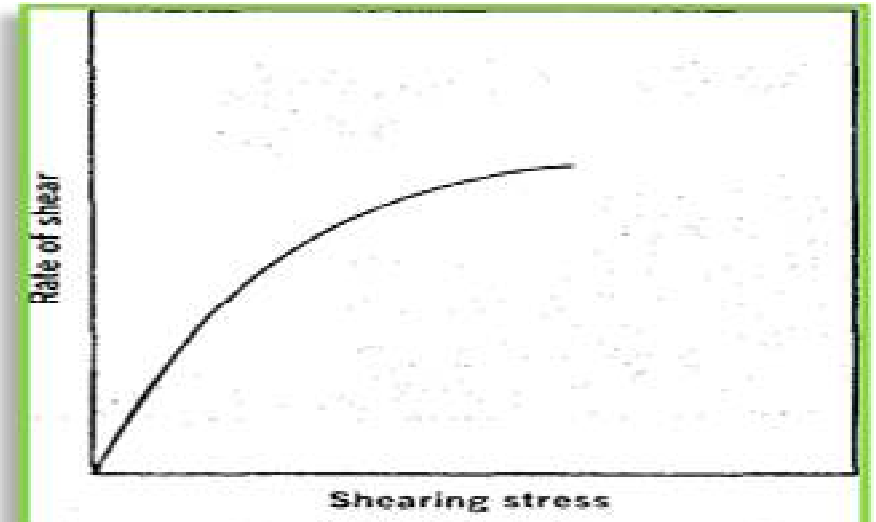
- Since no part of the curve is linear, one can not express the viscosity of a pseudoplastic material by any single value.

- The viscosity of a pseudoplastic substance decreases with increasing rate of shear (**shear-thinning systems**).

- As the shearing stress is increased, the normally-disarranged molecules begin to align their long axes in the direction of flow.

3. Dialatant Flow:

- Dilatant systems exhibit an increase in resistance to flow (viscosity) with increasing rates of shear, "**shear thickening systems**".
- Such systems actually increase in volume when sheared and are hence termed dialatant. When the stress is removed, a dialatant system returns to its original state of fluidity.



(d) Dilatant flow

- Dilatant flow is the reverse of that possessed by pseudoplastic systems.

- Substances possessing dilatant flow properties are invariably **suspensions** containing a high concentration (about 50 percent or greater) **of small, deflocculated particles.**

- Particulate systems of this type which are **flocculated** would be expected to possess **plastic,** rather than dilatant flow characteristics.

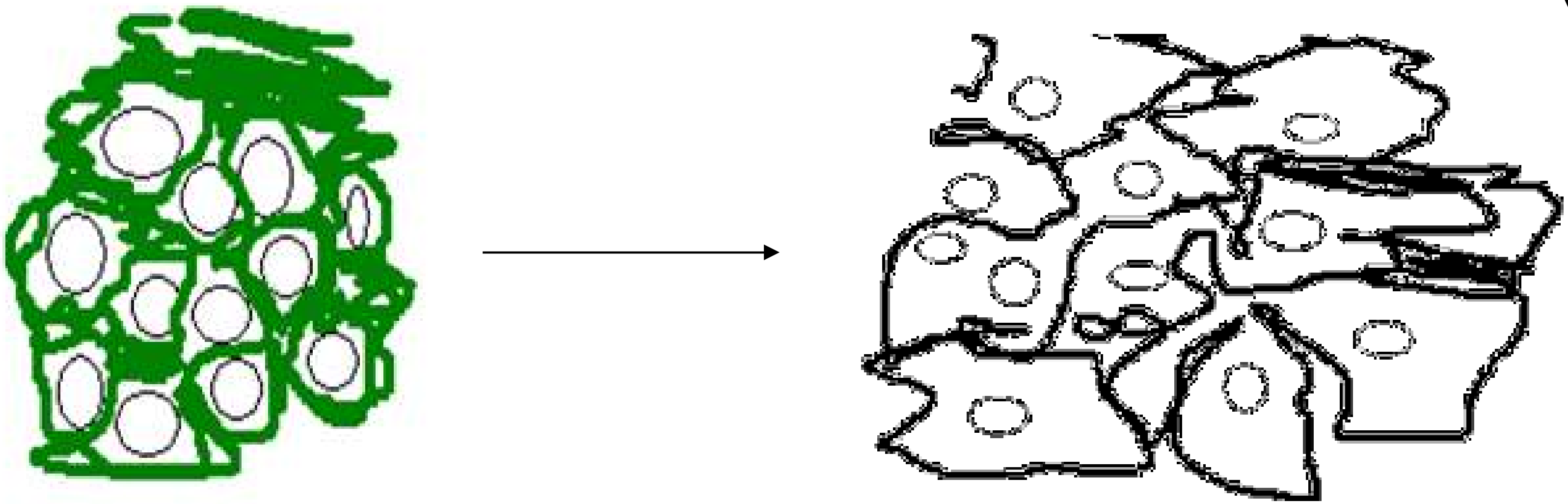
Dilatant behavior may be explained as follows:

- **At rest**, the particles are closely packed with the interparticle volume, or voids being at a minimum.

- The amount of vehicle in the suspension is sufficient, however, to fill this volume and permits the particles to move relative to one another at low rates of shear.

- Thus, one may pour a dilatant suspension from a bottle since under these conditions it is reasonably fluid.

- As the shear stress is increased, the bulk of the system expands or dilates, hence the term dilatant.
- The particles, in an attempt to move quickly past each other, take on an open form of packing. Such an arrangement leads to a significant increase in the interparticle void volume.
- The amount of vehicle remains constant and at some point, becomes insufficient to fill the increased voids between the particles.
- Accordingly, the resistance to flow increases because the particles are no longer completely wetted or lubricated by the vehicle.
- Thus, the suspension will set up as a firm paste.



Closed packed particles
minimum void volume
sufficient vehicle
low viscosity

open packed particles
increase void volume
insufficient vehicle
high viscosity

Thank You