

# **RHEOLOGICAL PROPERTIES (TERMINOLOGY)**

# Application

- Design/select equipment such as pumps, pipelines, extruders, mixers, heat exchangers etc.
- Rheological behavior relates to food texture and sensory data
- To determine ingredient functionality in product development
- Shelf life testing
- To obtain some information about atomic and molecular scale phenomena
- To obtain constitutive relations



*Standards Worldwide - Home*

## **ASTM Overview**

ASTM International, formerly known as the American Society for Testing and Materials (ASTM), is a globally recognized leader in the development and delivery of international voluntary consensus standards. Today, some 12,000 ASTM standards are used around the world to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence.

# BASIC CONCEPTS OF RHEOLOGY

**MECHANICAL PROPERTIES** are defined as those having to do with the behavior of the material under applied forces. Following this broad definition, such properties as stress strain behavior of a material under static and dynamic loading as well as flow characteristics of the material in air or in water, can be classified as mechanical properties

**Rheology** has been defined as "a science devoted to the study of deformation and flow." Therefore, when the action of forces result in deformation and flow *in the material, the mechanical properties will be referred-to as rheological properties. Moreover, rheology considers the time effect during the loading of a body.*

Three parameters of force, deformation and time

## ASTM STANDARD DEFINITION OF TERMS

### **Strain**

The unit change, due to force, in the size or shape of a body referred to its original size or shape. Strain is a non dimensional quantity, but it is frequently expressed centimetres per centimetre, m/m, mm/mm etc.

- a. **Linear (tensile or compressive) strain:** *The change per unit length due to force in an original linear dimension.*
- b. **Axial strain:** *Linear strain in a plane parallel to the longitudinal axis of the specimen.*
- c. **Transverse strain:** *Linear strain in a plane perpendicular to the axis of the specimen.*
- d. **Shear strain (angular strain):** *The tangent of the angular change, due to force, between two lines originally perpendicular to each other through a point in a body.*

# Stress

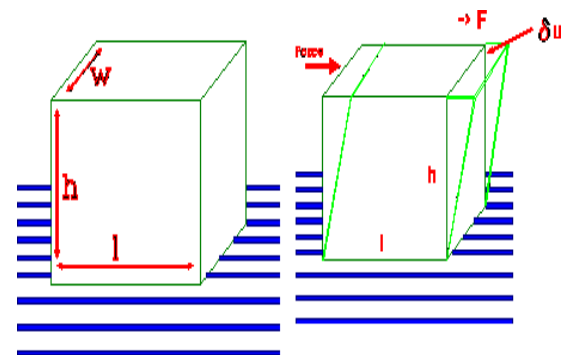
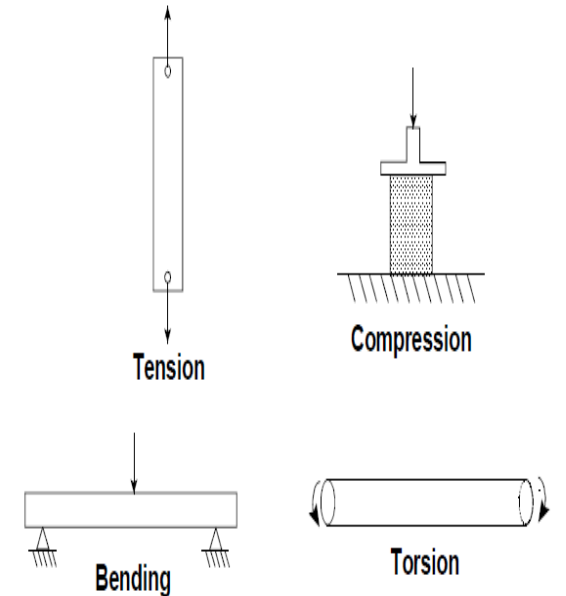
The intensity of a point in a body of the internal forces or components of force that act on a given plane through the point. Stress is expressed in force per unit of area (kilograms-force per square millimeter).

**Normal stress:** *The stress component perpendicular to a plane on which the forces act. Normal stress may be either:*

**1 Tensile stress:** Normal stress due to forces **directed away** from the plane on which they act, or

**2 Compressive stress:** Normal stress due to forces **directed towards the plane** on which they act.

**3. Shear stress** is the stress that is **tangential to the plane on which the forces act** tending to change the sample's shape. The two pulling (or pushing) forces are offset from each other.

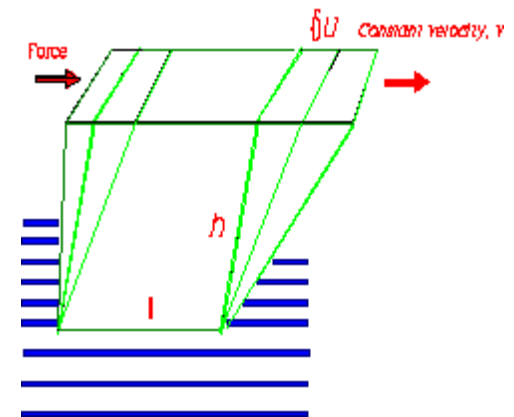


## Shear Rate

This type of deformation (lower fixed upper moving) is defined as a 'shear deformation'. The deformation  $\delta u$  and  $h$  are used to define the:  
**Shear Strain =  $\delta u/h$**

The shear strain is simply a ratio of two lengths (displacement / gap) and so has no units. It is important since it enables us to quote pre-defined deformations without having to specify sizes of sample etc.

The rate of change of strain is referred to as the **SHEAR STRAIN RATE** often abbreviated to **SHEAR RATE** and is found by the rate of change of strain as a function of time i.e. the differential SHEAR STRAIN / differential TIME.



### ***Tensile strength***

The maximum tensile stress that a material is capable of sustaining. Tensile strength is calculated from the maximum load during a tension test carried to rupture and the original cross sectional area of the specimen.

### ***Compressive strength***

The maximum compressive stress which a material is capable of sustaining. Compressive strength is calculated from the maximum load during a compression test and the original cross sectional area of the specimen.

### **Strength**

The resistance to applied force (kg/cm).

### **Ultimate strength**

The stress corresponding to the rupture point (kg/cm<sup>2</sup>).



## Pressure

A measure of the mean normal stress on a point of body ( $\text{kg} / \text{cm}^2$ )

## Deformation

Deformation or distortion is the **relative displacement of points within a body. Deformation like stress is a vector quantity. In general, deformation is accompanied either by change of volume or by change of shape. The change of shape is brought about by shear stresses. Material can be deformed by uniaxial compression, uniaxial tension, shear, and bulk compression:**

### ***Elastic Limit***

The greatest stress which a material is capable of sustaining without any permanent strain remaining upon complete release of the stress.

### ***Proportional Limit***

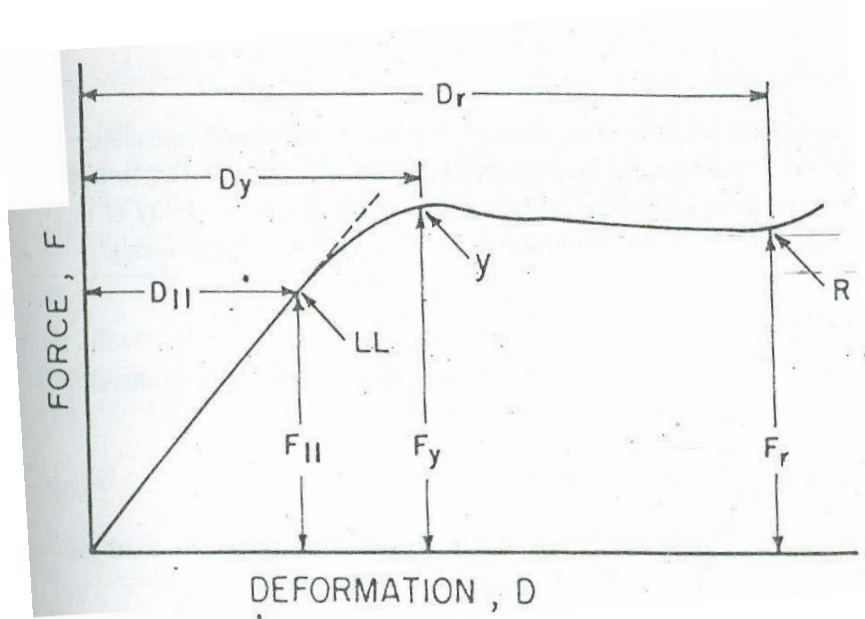
The greatest stress which a material is capable of sustaining without any deviation from proportionality of stress to strain (Hooker's law).

### ***Yield point***

The first stress in a material, less than the maximum attainable stress, at which an increase in strain occurs without an increase in stress.

## Bioyield point

A point, such as  $y$  on the stress-strain or force-deformation curve at which there occurs **an increase in deformation with a decrease or no change of force**. In some agricultural products, the presence of this bioyield point is an indication of initial cell rupture in the cellular structure of the material. The bioyield point may occur at any point beyond the point LL, where the curve deviates from the initial straight line portion.



A possible force-Deformation curve for an agricultural product.  
LL linear limit;  $y$ , "Bioyield point"; R, rupture point

## Rupture point

A point on the stress-strain or force-deformation curve at which the axially loaded specimen ruptures under a load. In biological materials, rupture may cause puncture of shell or skin, cracking, or fracture planes.

A "bioyield point" in these materials corresponds to a failure in the microstructure while a "rupture point" corresponds to a failure in the macrostructure of the specimen.

In a force-deformation curve, the point of rupture of the specimen may occur at any-point on the curve beyond the bioyield point.

In a "brittle" material, rupture may occur in the early portion of the curve. In a "tough" material, rupture may take place after considerable plastic flow at such point as R.

## **Elasticity**

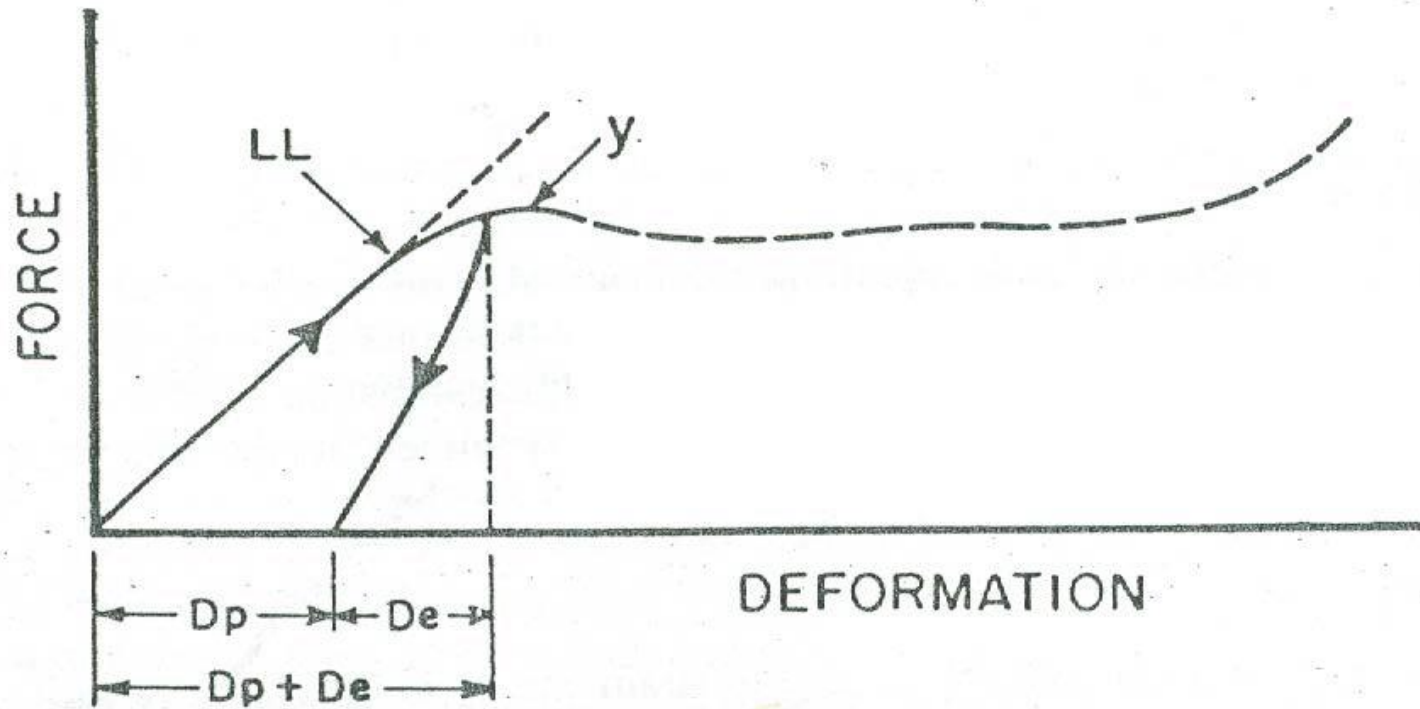
The capacity of a material for taking elastic or recoverable deformation. In those portions of the curve before the point LL is reached, elongations are, in large part at least, recoverable, and are a measure of elastic deformation.

## **Plasticity**

The capacity of a material for taking plastic or permanent deformation. Since deformations from the bioyield point to the point of rupture are not all recoverable, the unrecoverable part can be taken as a measure of plastic deformation.

## **Degree of elasticity**

The ratio of elastic deformation to the sum of elastic and plastic deformation when a material is loaded to a certain load and then unloaded to zero load



Degree of elasticity from a loading-unloading curve.

De = elastic or recoverable deformation;

Dp = plastic or residual deformation;

Degree of elasticity =  $De / (De + Dp)$

## Toughness

The work required to cause rupture in the material. This can be approximated by the **area under the stress-strain or force-deformation curve up to the point selected as the rupture point**. If in estimating toughness, a force-deformation curve is used, the size of the specimen and the loading surface area should be specified.

## Resilience

The capacity of a material for storage of strain energy in the elastic range. Thus **the area under the unloading curve** is a measure of resilience of the material. As in the case of toughness, when a force-deformation curve is used, the size of the specimen and the loaded area should be specified.

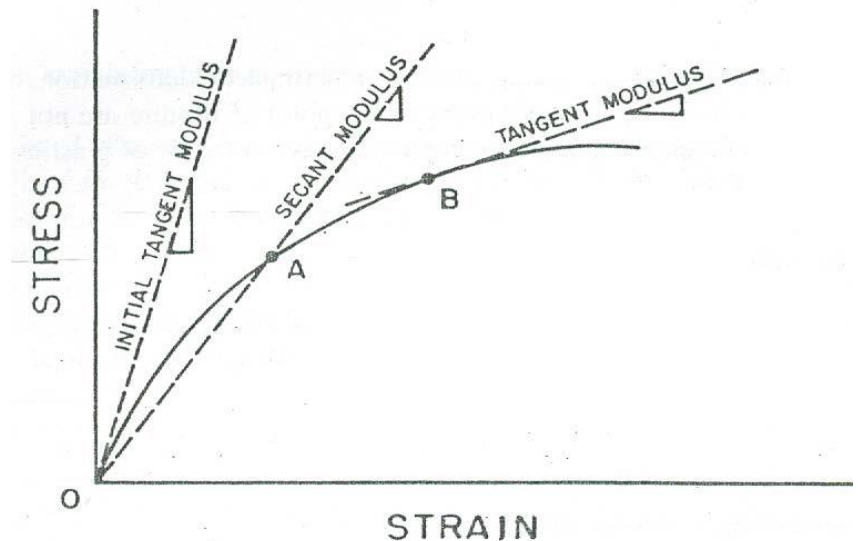
# Stiffness

Stiffness or rigidity is indicated by the **slope** of the initial straight line portion of the curve. The **ratio of stress to strain** in this more or less elastic region of the curve may be referred to as the "modulus of elasticity" or "Young's modulus" ( $\text{kg/cm}^2$ ).

In the case of nonlinear stress-strain behavior, stiffness or "apparent modulus" can be defined in terms of

1. Initial tangent modulus,
2. Secant modulus,
3. Tangent modulus.
4. Chord modulus

The slope of the chord drawn between any two specified points on the stress - strain curve.



Methods for defining the modulus in non-linear stress-strain diagrams



### **Deviatoric stress component**

The stress which is responsible for change in shape.

### **Isotropic stress component**

The stress which is responsible for change in volume.

### **Viscoelasticity**

A combined solid-like and liquid-like behavior in which the stress-strain relationship is time dependent.

### **Newtonian liquid**

An ideal fluid in which the relationship between shear stress and shear rate is a straight line passing through the origin.

### **Viscosity**

Resistance to flow indicated by coefficient of viscosity.

**THANK YOU**