Important engineering properties such as physical and rheological properties of cereals, pulses and oilseeds

The knowledge of physical properties such as shape, size, volume, surface area, test weight, density, porosity, angle of repose, etc., of different grains is necessary for the design of different equipment for handling, processing and storage of grains.

1 Physical Properties

1.1 Shape and size

Shape of the grain is connected with the geometrical form of the grain. Size of the grain refers to the characteristics of an object which in term determine how much space it occupies and, within limits, can be described in terms of length, width, and thickness. The Shape and size together with other characteristics of the grains is important in the design of the seed grader. These factors determine the free flowing or bridging tendencies of the seed mass, and therefore, determine the suitable handling and feeding equipment. Sphericity and equivalent diameters are also used to describe the shape and size, respectively for the grains.

The sphericity (φ) of the fruits can be calculated using the following formula.

$$\phi = \frac{abc^{1/3}}{a}$$

where, (a) = major diameter ; (b) = intermediate diameter; (c) = minor diameter
The geometrical mean diameter (GMD) can be calculated as follows:

$$GMD = (abc)^{1/3}$$

1.2 The bulk density

The bulk density (ρb) considered as the ratio of the weight of the grain in kg to its total volume in m^3. The bulk density of grains is measured using 1 liter measuring cylinder and electronic balance. The bulk density of the food grains changes with the change in the moisture content. Hence, the moisture content of the food grains at which the bulk density was measured also to be reported. The bulk density can be calculated using the following formula

$$\rho b = \frac{W_s}{V_s}$$

where, ρb= bulk density, kg/m3,
Ws = weight of sample, kg and
Vs = volume of the sample i.e., 1000 cc or 10^{--3}

1.3 True density

The true density (ρt) defined as the ratio of mass of the sample (W) to its true volume. The true density (ρt) is determined using a Multivolume Pycnometer (Helium gas displacement method). Multivolume Pycnometer's Helium displacement method provides a rapid means for precisely determining the true volume of pores, porous materials, and irregularly shaped food grains. The true density of the grains is found to be decreased with an increase in moisture content as the increase in true volume of the grains is higher compared to the increase in moisture content of the grains. Since, the true density varies with the moisture content of the food grains, the moisture content of the food grains also to be reported. True density can be calculated using following formula.

$$\text{True density } \rho_t = \frac{\textit{Total mass of the grain, kg}}{V_{sample}}$$

1.4 Porosity

Properties such as bulk density, true density and porosity of grains are useful in design of various separating, handling, storing and drying systems. Resistance of bulk grain to airflow is a function of the porosity and the kernel size. The porosity (ε) defined as the percentage of void space in the bulk grain which is not occupied by the grain can be calculated from the following relationship:

$$\varepsilon = \frac{\rho t - \rho b}{\rho t} \times 100$$

where, ε = porosity
ρb= bulk density, kg/m^3
ρt = true density, kg/m^3

1.5 Angle of Repose

The flowing capacities of different grains are different. It is characterized by the angle of natural slope. The angle of repose is the angle between the base and the slope of the cone formed on a free vertical fall of the grain mass to a horizontal plane.

1.6 Coefficient of friction

The frictional properties of granular materials are important in designing of storage bins, hoppers, chutes, pneumatic conveying system, screw threshers and conveyors, forage harvesters, etc, The ratio between the force of friction (F), and the force normal to the surface of contact (N), is known as the coefficient of friction (μ).

Mathematically,

coefficient of friction , $\boldsymbol{\mu = F/N}$

where, F = Frictional force (Amount of total Weights added + Suspended Pan)

N = Normal Load (Weight of the material + Circular Ring)

2 Rheological Properties

Rheology has been defined as "a science devoted to the study of deformation and flow." Therefore, when the action of forces results 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. Rheologically then, mechanical behavior of a material is expressed in terms of the three parameters of force, deformation and time. Examples of rheological properties are time-dependent stress and strain behavior, creep, stress relaxation, and viscosity.

2.1 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 centimeters per centimeter, m/m, mm/mm etc.

2.2 Stress

It is defined as 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 (Kg/mm^2)

2.3 Compressive strength

It is 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 sample.

2.4 Elastic Limit

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

2.5 Modulus of elasticity

It is the ratio of stress to corresponding strain below the proportional limit.

2.6 Poisson's ratio

The absolute value of the ratio of transverse strain to the corresponding axial strain resulting from uniformly distributed axial stress below the proportional limit of the material.

$$v = -\frac{d\varepsilon_{trans}}{d\varepsilon_{axial}}$$

2.7 Tensile strength

The maximum tensile stress that a material is capable of sustaining

$$\sigma = F/A$$

- σ is the tensile stress
- F is the force acting
- A is the cross-sectional area