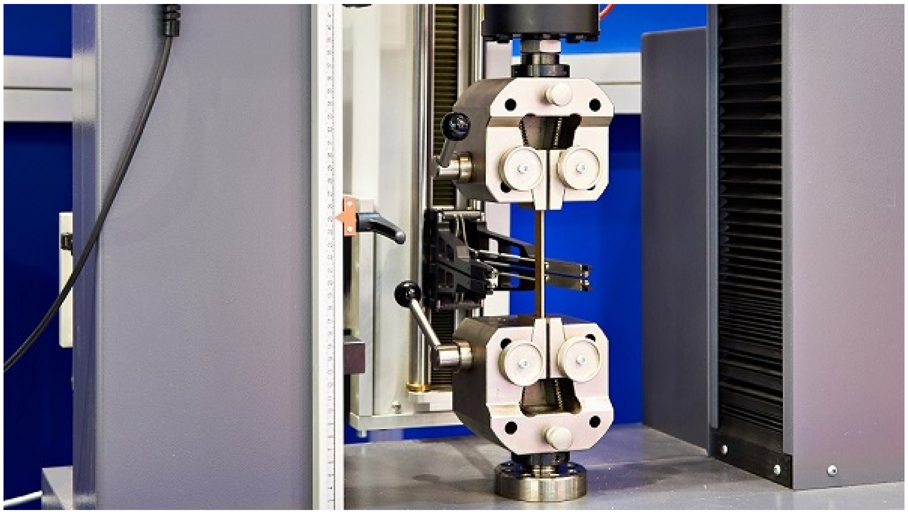
Modulus of Elasticity



What are stress and strain?

Definition of stress

Stress is defined as the **force per unit area of plastic**. The units of stress are N/m^2 or Pa.

$$\sigma = F/A$$

where,

σ is the stress (in Newtons per square meter or, equivalently, Pascals),

F is the force (in Newtons, commonly abbreviated N), and

A is the cross-sectional area of the sample.

Definition of strain

Strain is defined as **extension per unit length**. And, since it is a ratio of lengths, the strain has no units.

$$\varepsilon = \Delta L/L0; \Delta L = L - L0$$

where,

ε is the strain

L0 is the original length of a bar being stretched,

L is its length after it has been stretched, and

ΔL is the extension of the bar, the difference between these two lengths.

What is Young's modulus?

Young's modulus is the **ratio of stress to the strain** applied to the material. The force is applied along the longitudinal axis of the specimen tested. It is the measure of the stiffness of an elastic material.

The formula of Young's modulus is:

$$E = \sigma/\varepsilon$$

where,

E is the Young's modulus

σ is the stress and

ε is the strain

Other names include tensile modulus, elastic modulus, or modulus of elasticity.

The physics behind young's modulus

When a stretching force (tensile force) is applied to an object, it extends. Its behavior can be obtained using stress-strain curve in the elastic deformation region. This is known as **Hooke's Law**. The extension that a force produces depends upon the:

material

dimensions of the object (e.g., length, thickness, etc.)

What are the units of Young's modulus?

SI unit of Young modulus is Pascal (Pa). It is also equal to newton per square meter (N/m^2).

The practical units used in plastics are:

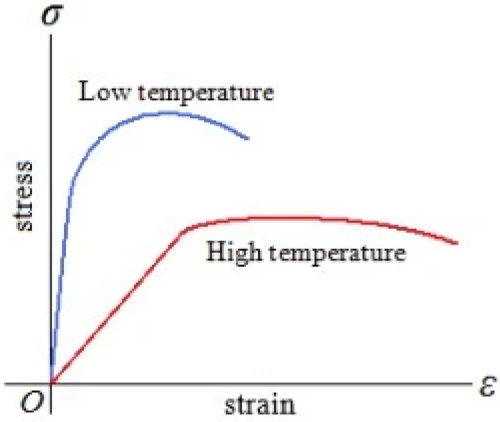
- Megapascals (MPa or N/mm^2)
- Gigapascals (GPa or kN/mm^2)

In the United States customary units, it is often expressed as pounds (force) per square inch (psi).

What are the factors affecting Young's modulus?

The modulus is closely related to the **binding energies of the atoms**. Binding forces and modulus of elasticity are higher for high melting point materials. Young's modulus depends on the orientation of a single crystal material.

The **higher temperature in the material** increases atomic vibration. This in turn decreases the necessary energy to separate the atoms from one another. This generally decreases the stress needed to produce a given strain.



Relation between tensile properties and temperature (Source: Engineering Archives)

Presence of impurity atoms, alloying atoms, non-metallic inclusions, secondary phase particles, dislocations (shifts or mismatches in the lattice structure), and defects (cracks, grain boundaries, etc.). All of these things can serve to either weaken or strengthen a material.

- Anything that impedes the motion of dislocations through the lattice tends to increase the modulus. This will thus the yield strength.
- Anything that facilitates dislocation movement or localized stress will decrease strength. An increase in temperature eases dislocation movement. Cracks and inclusions rise localized stress. For example, promoting early onset of failure.

actions right from the start.

Which plastics have high or low modulus?

- Polymers with High Modulus - View Product List
- Polymers with Low Modulus - View Product List

What is the modulus values of plastics vs. others?

The modulus of elasticity of plastics is much smaller than that for metals, ceramics, and glasses. For example:

- The modulus of elasticity of nylon is 2.7 GPa (0.4 x 106 psi)
- The modulus of glass fibers is 72 GPa (10.5 x 106 psi)
- The Young's modulus of composites such as glass fiber-reinforced composites (GFRC) or carbon fiber-reinforced composites (CFRC) lies between the values for the matrix polymer and the fiber phase (carbon or glass fibers) and depends upon their relative volume fractions.

What are the applications of Young's modulus?

Elastic modulus is an important mechanical property for:

1. **Material selection** for various purposes. This depends upon how the polymer reacts under different types of forces. For example, high-stiffness materials should have a higher Young's modulus.
2. **Product design** for specific industries. Used in several engineering as well as medical applications.
3. **Performance analysis** determines the batch quality and consistency in the manufacture. This in turn reduces material costs.

What are the test methods to calculate Young's modulus?

In general, "tensile test methods" measure the modulus of elasticity of materials. The common methods used are:

- **ASTM D638** - Standard Test Method for Tensile Properties of Plastics
- **ISO 527-1:2012** - Determination of tensile properties. General principles

These methods determine the tensile properties of plastics and plastic composites. This is done under defined conditions that can range from:

- pretreatment,
- temperature,
- humidity, and
- machine speed

The test specimens are in the form of a standard dumbbell shaped.

For ASTM D638, the test speed is determined by the material specification. For ISO 527, the test speed is typically 5 or 50 mm/min for measuring strength and elongation, and 1 mm/min for measuring modulus.

Apart from Young's modulus, the tensile test results can also calculate:

- Tensile strength (at yield and at break)
- Tensile modulus
- Strain
- Elongation and percent elongation at yield
- Elongation and percent elongation at break

Which instrument is used to determine Young's modulus?

An extensometer determines the elongation and tensile modulus. It is a device that measures the changes in the length of an object. It evaluates the stress-strain curve values.

The two main types of extensometers are contact and non-contact.

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