Mechanical Properties of Textile Fibres

Mechanical properties of textile materials can be classified into mainly three classes-

01. Tensile properties (behaviors shown by textile materials for applying load or tension):
    a) Breaking load
    b) Tensile strength
    c) Tenacity
    d) Breaking extension
    e) Initial modulus
    f) Work of rupture
    g) Work factor
    h) Work recovery
    i) Elastic recovery
    j) Creep (temporary creep & permanent creep)

02. Flexural properties (behaviors shown by textile materials when subjected to bending):
    a) Flexural rigidity
    b) Bending recovery
    c) Bending modulus

03. Torsional properties (behaviors shown by textile materials for applying torsional force):
    a) Torsional rigidity
    b) Breaking twist
    c) Shear modulus

04. Frictional properties (behaviors shown by textile materials due to causing the friction):

Tensile Properties of Textile Fibres

The behaviors shown by textile materials (fibre, yarn, fabric etc.) when it is subjected to load or tension, are known as tensile properties.

a) Breaking load:

The load required to break a specimen is termed as breaking load. Breaking load depends on fibre type, nature of fibre bonds, crystallinity, orientation etc. Breaking load is usually expressed by kilogram, gram, pound, Newton etc.

b) Tensile strength:

The term "Tensile" has been derived from the word "Tension". Tensile strength is very important property of textile materials which represents the ratio between force required to break a specimen and cross-sectional area of that specimen.

$$\text{Tensile strength} = \frac{\text{Force required to break a specimen}}{\text{Cross-sectional area}}$$

c) Tenacity:

Tenacity can be defined as the ratio between breaking load and linear density of specimen. Tenacity of a specimen may be expressed as the units of gram/tex, gram/denier, Newton/tex etc.

$$\text{Tenacity} = \frac{\text{Breaking load}}{\text{Linear density}}$$

d) Breaking extension:

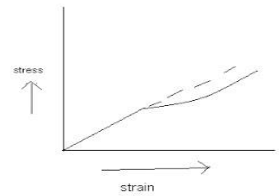
The load required to break a specimen is a useful quantity. Breaking extension of a specimen can be defined as the actual, percentage increase in length upto breaking. So, it can be said that, the length of a specimen which extends for applying load before breaking is known as breaking extension and it is usually expressed as the percentage.

$$\text{Breaking extension (\%)} = \frac{\text{Elongation at break x 100}}{\text{Original length of specimen}}$$

e) Initial modulus:

The tangent of angle between initial curve and horizontal axis is equal to the ratio of stress and strain. In engineering science, this ratio is termed as initial modulus but in textile science it is known as initial young's modulus. Initial modulus of textile materials depends on chemical structure, crystallinity, orientation of fibre etc.

Initial modulus, $\tan\alpha = \frac{\text{Stress}}{\text{Strain}}$; Tan α ↑↓ → extension ↓↑



f) Work of rupture:

The energy required to break a specimen or total work done for breaking a specimen is termed as work of rupture and is expressed by the units of joule, calorie etc. If applied force ‘F’ increases the length of a specimen in small amount by ‘dl’, then we have-

Work done = Force X Displacement
= F X dl

g) Work factor:

Work factor can be defined as the ratio between work of rupture and the product of breaking load and breaking elongation.

$$\text{So, Work factor} = \frac{\text{Work of rupture}}{\text{Breaking load x Breaking elongation}}$$

If the fibre obeys hook’s law, then the load-elongation curve would be a straight line and the work of rupture = ½ x Breaking load x Breaking elongation

So, in an ideal case, the work factor, Wf = 1/2, whereas, Wf >1 for top curve and Wf <1 for bottom curve.

h) Work recovery:

The ratio between work returned during recovery and total work done in total extension is known as work recovery.

$$\text{Work recovery} = \frac{\text{Work returned during recovery}}{\text{Total work done in total extension}}$$

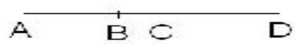
Total extension = Elastic extension + Plastic extension

Total work done in total extension = (Work done in elastic extension + Work done in plastic extension)

i) Elastic recovery:

The power of recovery from an immediate extension is called as elastic recovery. Elastic recovery of fibres depends on type of fibres, fibre structure, type of molecular bonds and crystallinity of fibres. Elastic recovery can also be defined as the elastic extension against total extension and expressed as the percentage.

$$\text{So, Elastic recovery (\%)} = \frac{\text{Elastic extension x 100}}{\text{Total extension}}$$



Here, AB = initial length of the specimen
AC = final length after recovery
BD = total extension
CD = elastic extension
BC = plastic extension

Total extension = Elastic extension + Plastic extension

So,
Elastic recovery (%) = (Elastic extension/total extension) ×100%
= (CD/BD) × 100%

So,
Plastic recovery = (plastic extension/total extension) ×100%
= (BC/BD) ×100%

j) Creep:

When load is applied on a textile fibre, an instaneous strain is occurred in the fibre and after that strain the fibre strain will be lower with passing time that means slow deformation will be occurred. This type of behavior of textile fibre is known as creep. The formation of crease marks on cloth depends on creep behaviors of fibres. Creep is usually classified into two classes-

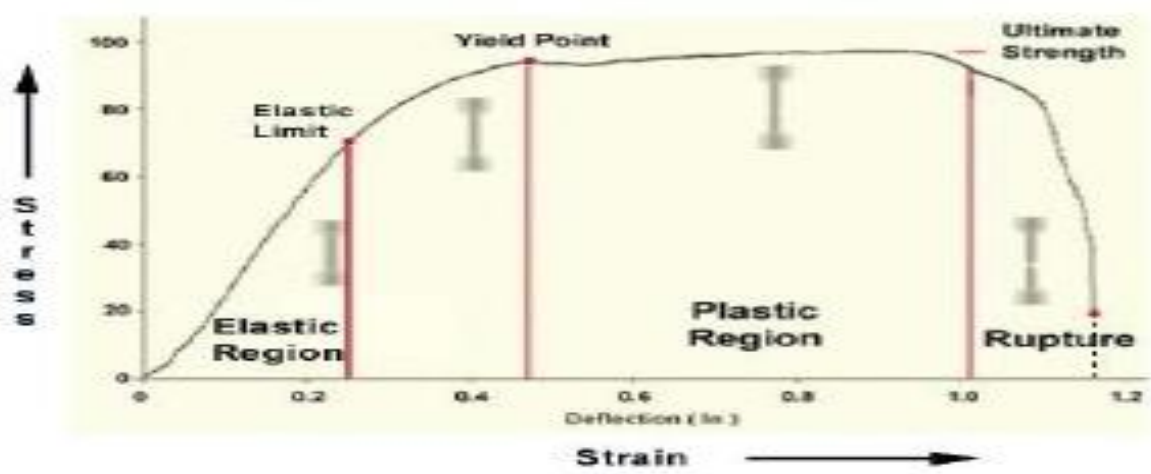
i) <u>Temporary creep:</u>

This type of creep is temporarily occurred in fibre. So, after removing load it is possible for textile fibre to recover it's original shape. Here, elastic deformation is occurred and fibre does not break, only molecular chains of fibre get stretched.

ii) Permanent creep:

This type of creep is permanently occurred in fibre. So, after removing load it is not possible for textile fibre to recover it's original shape. Here, plastic deformation is occurred and molecular chains of fibre break, hence the whole fibre breaks.

Stress-strain curve:



A **yield strength** or **yield point** is the material property defined as the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Stress at yield point is known as yield stress and strain at yield point is known as yield strain.

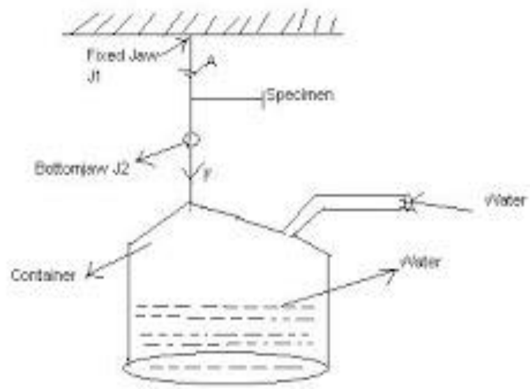
Factors affecting the results of Tensile Testing:

- Materials and it's conditions:
  - The chemical treatment to which it has been subjected
  - The mechanical treatment that it has received
  - Amount of moisture that it contains
  - Temperature in the testing atmosphere
- Arrangement & Dimension of the specimen
- Nature & Timing of the test

Methods or Principles of Tensile Experiment:

01.Constant rate of loading (CRL):

A specimen is gripped between two jaws-top jaw which is fixed and bottom jaw which is moveable. The load on specimen is initially zero, but increase at constant rate. By adding constant rate of water in a container which is attached to the bottom jaw, may increase the load gradually. Thus, constant rate of flow gives the constant rate of loading. The function of this applied force is to extend the specimen until it eventually breaks down. Thus, loading causes the extension.



02.<u>Constant rate of elongation (CRE):</u>

A specimen is gripped between two jaws-top jaw which is fixed and bottom jaw which is moveable to downward direction at a constant velocity by means of a screw mechanism. Initially the tension on specimen is zero. But, when the bottom jaw moves downwards at a constant rate, the specimen is extended and an increasing tension is developed until the specimen finally breaks down. In this case, the extension causes loading.

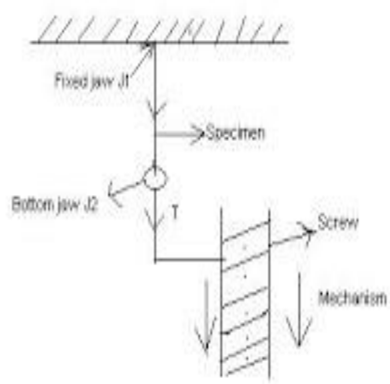


FIG. CRL METHODS

Types of Tensile Testing Instruments:

- Cambridge extensometer
- Scott inclined plane tester
- Cliff tester
- Pressly fibre strength tester
- Instron tensile strength tester
- Lea strength tester

Tensile properties of fibres:

Fibre	Tenacity (N/tex)	Breaking extension (%)	Work of rupture (mN/tex)	Initial modulus (N/tex)
Cotton	0.19-0.45	5.6-7.1	5.1-14.9	3.9-7.3
Jute	0.31	1.8	2.7	17.2
Silk	0.38	23.4	59.7	7.3
Nylon	0.47	26	76	2.6
Polyester	0.47	15	53	10.6
Wool	0.11-0.14	29.8-42.9	26.6-37.5	2.1-3.0
Viscose	0.18-0.27	15.2-27.2	18.8-30.6	4.8-6.5