Chapter - three

Yarn count, yarn twist and tensile testing

Yarn Count Testing

- Different end –uses need yarns of different thickness
- Measuring the diameter of a yarn is difficult ,because not all yarns have a circular cross-section ,& some are easily deformed during measuring
- The accepted way to indicate the thickness of a yarn or of material from other stages in yarn processing ,is to give the count or linear density
- A length of the material is measured out, then weighed

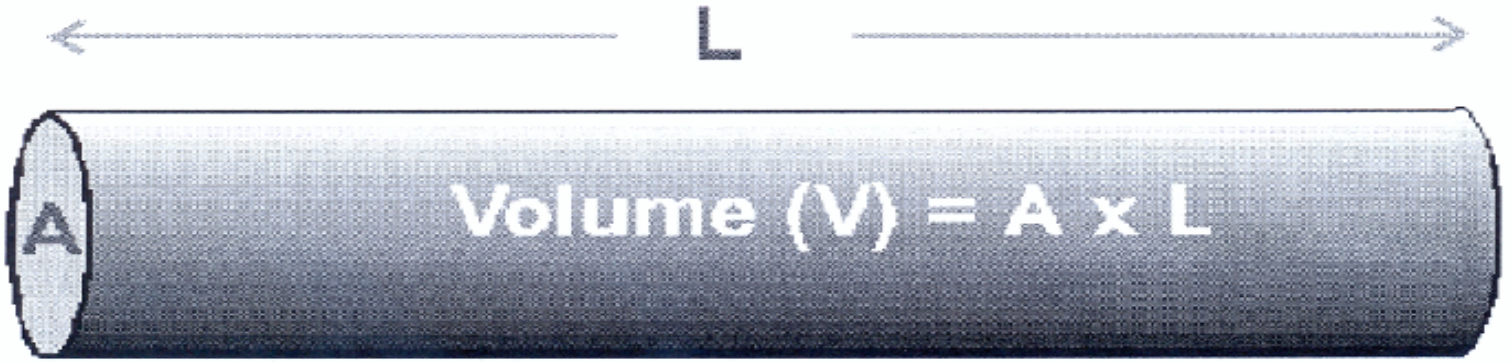
Cont…

- The textile industry has developed different yarn production system in different localities and each of these has chosen a different way of expressing the count or linear density to suit its own local conditions
- The linear density is expressed directly mass per unit length ;the count is expressed indirectly as length per unit mass
- Each system is referred to as being either direct or indirect
- For example the cotton count system is ***indirect*** (the lower the number the courser the material)while the tex

Direct System

Tex system

The linear density of a fiber gives an indication of its cross-sectional area. This stems from the fact that the mass of a cylinder (or prism) of a given length is proportional to its volume and hence its cross-section.



Mass = V x density (d) = ALd

Fig…. volume, mass & cross area relation

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- Linear density or linear mass is a measure of mass per unit of length & it is a characteristics of strings or other one dimensional objects.
- Hence, linear density =mass/length

$$= ALd/L$$

$$= Ad$$

- Therefore, linear density is proportional to the fibers/yarns cross-sectional area for given d.
- The linear density ,expressed in appropriate unit is called the fineness.
- The linear density is actually the weight (more properly the

Cont…

- It may be expressed in a unit such as g/cm, or more likely (using the so called “tex” system.
- In tex systems one of the submultiples decitex (dtex) milltex (mtex)
  - The tex of a yarn is the weight in g of a 1km length
  - The decitex of yarn a yarn is the weight in g of 10km length
  - The milltex of a yarn is the weight in g of 1000km
  - Or the weight in kg of a 1km length w/c is the same thing

denier (den)

- denier (den) – weight in grams of 9000 meters

den = g/9000 meters

Indirect System

- Depend on the fiber type for natural fibers at any rate as each tradition has its own specific count system

Cotton (Ne)

- This is perhaps the most commonly applied indirect system.
- The “standard length” unit length (or “hank”) in this case is a length equal to 840 yards ,and the reference weight is one pound.
- Thus ,in cotton system ,the count is:

“The number of 840 yard hanks required to weigh one pound”

…continued…

- For yarn ,it is conventional to measure out a lea(a length of 120 yards)weigh this in grains(7000 grains=1lb)
- Again approximately 20 yards of roving and 10 yards of sliver are considered to be sufficient & this then being converted to cotton count using formula:

$$\text{Cotton Count} = \frac{\text{length in yard}}{\text{weight in grains}} \times \frac{7000}{840}$$

The worsted count System

- This another indirect system ,very similar to the cotton count system, but the unit of length used is different
- The worsted count is defined as the number of hanks of 560 yards in length that weigh one lb in weight

The woolen count System(Yorkshire)

- Again ,an indirect system that uses a different unit of length
- Woolen count is defined as the number of hanks of 250 yards in length that weigh one pound .

The Metric System

- This is an indirect system with a major difference from other indirect systems.
- It uses metric rather than empirical units and has been used for export. Most spinners who export their yarn to Europe are required to quote metric count in their package labels
- The metric count is defined as the number of kilometer lengths that weigh one kilogram

Conversion Factors

- There are a number of conversion factors used to convert b/n the systems:

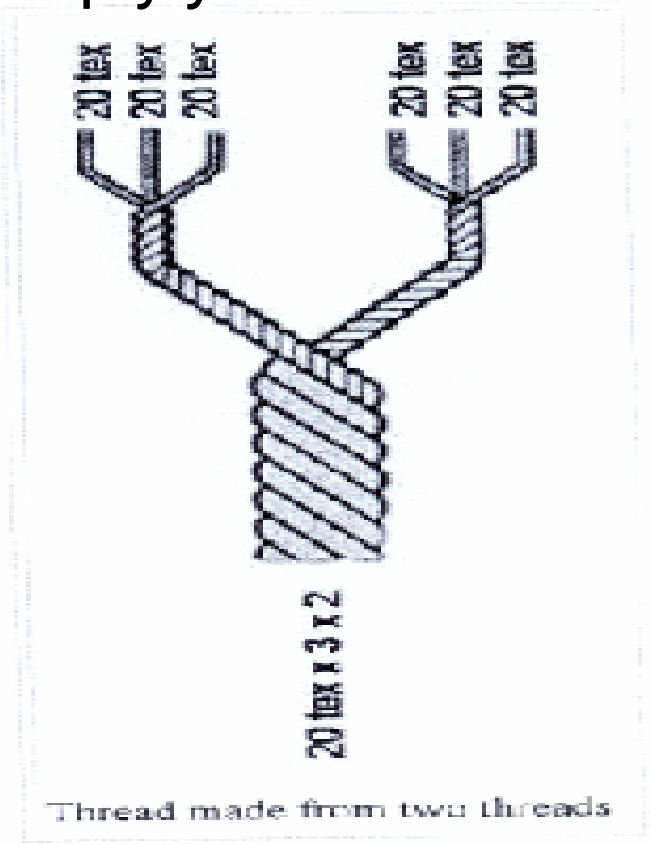
1. Cotton Count (Nec) = 590.5 /tex
2. Metric Count (Nm) = 1000/tex
3. Worsted Count (New)= 885.8/tex
4. Woolen Count (Ny) =1938.0/tex
5. Denier =tex/0.1111

Double Yarn (Folding Number)

- The number of individual threads (‘singles’) that have been plied together to form the final yarn is called the folding number.
- If there is only one, the yarn itself is often referred to as “single yarn”
- However, depending on the counts system being applied the folding number will appear differently
- Using any of the cotton ,woolen or worsted systems a two fold forties cotton would be written as “2/40” with the first digit signifying the folding number, and the second number the count of each single ply

Examples:

- 1/30s-30 count single yarn
- 2/30s-30 count two ply yarn
- 2/2/30s-two ply yarn of 30 count two ply
- 1/150- 150d single yarn
- 2/150-150 d two ply yarn
- 20te 3x2 – 2 ply yarn of 20 tex of three ply



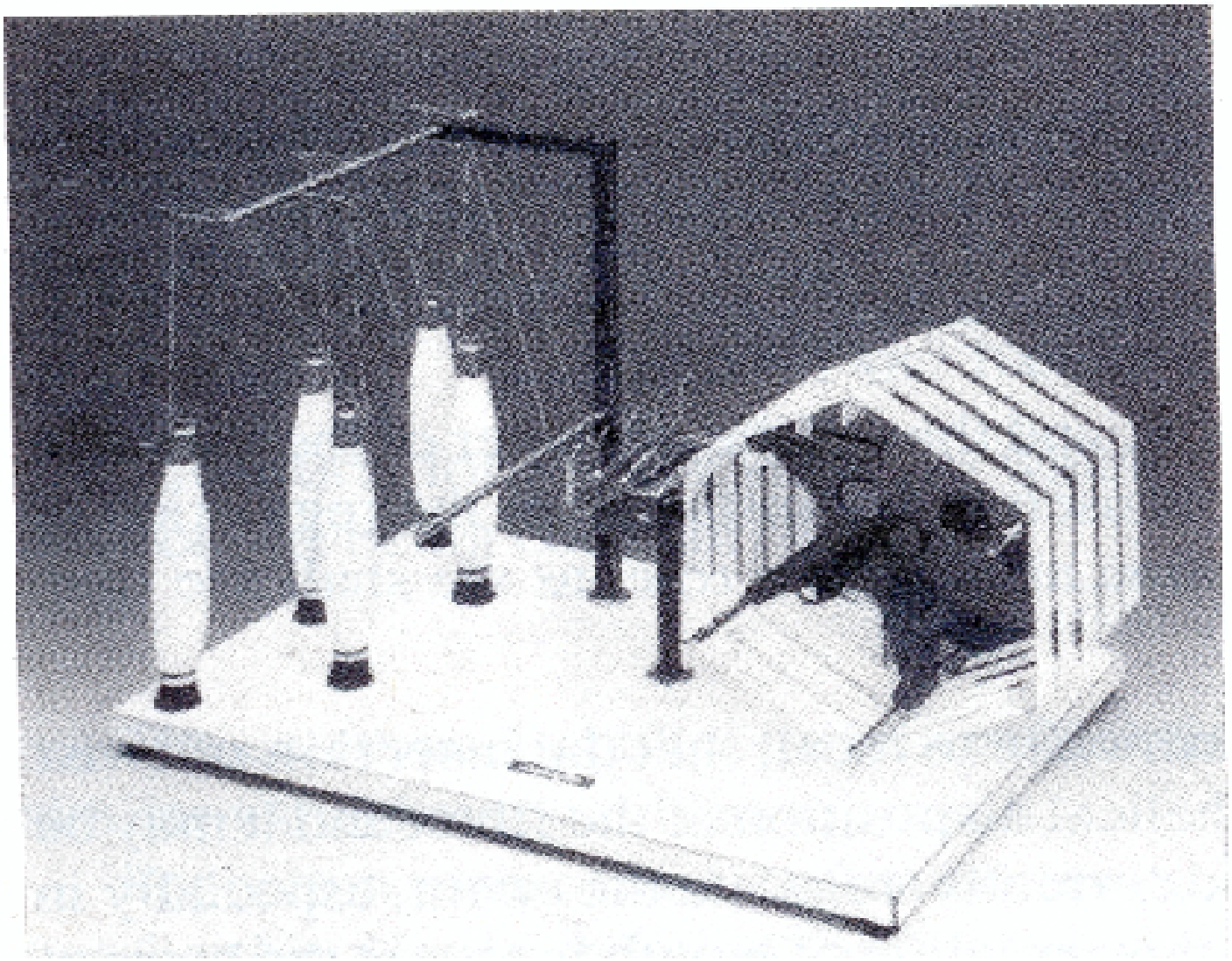
Thread made from two threads

Length & Mass Measurement

- The determination of a count or of a number regardless of the unit to express it ,always involves the measurement of a ***length*** and a ***mass*** operations which are apparently very simple, but w/c require certain precautions when applied to yarn .

Measurement of Length

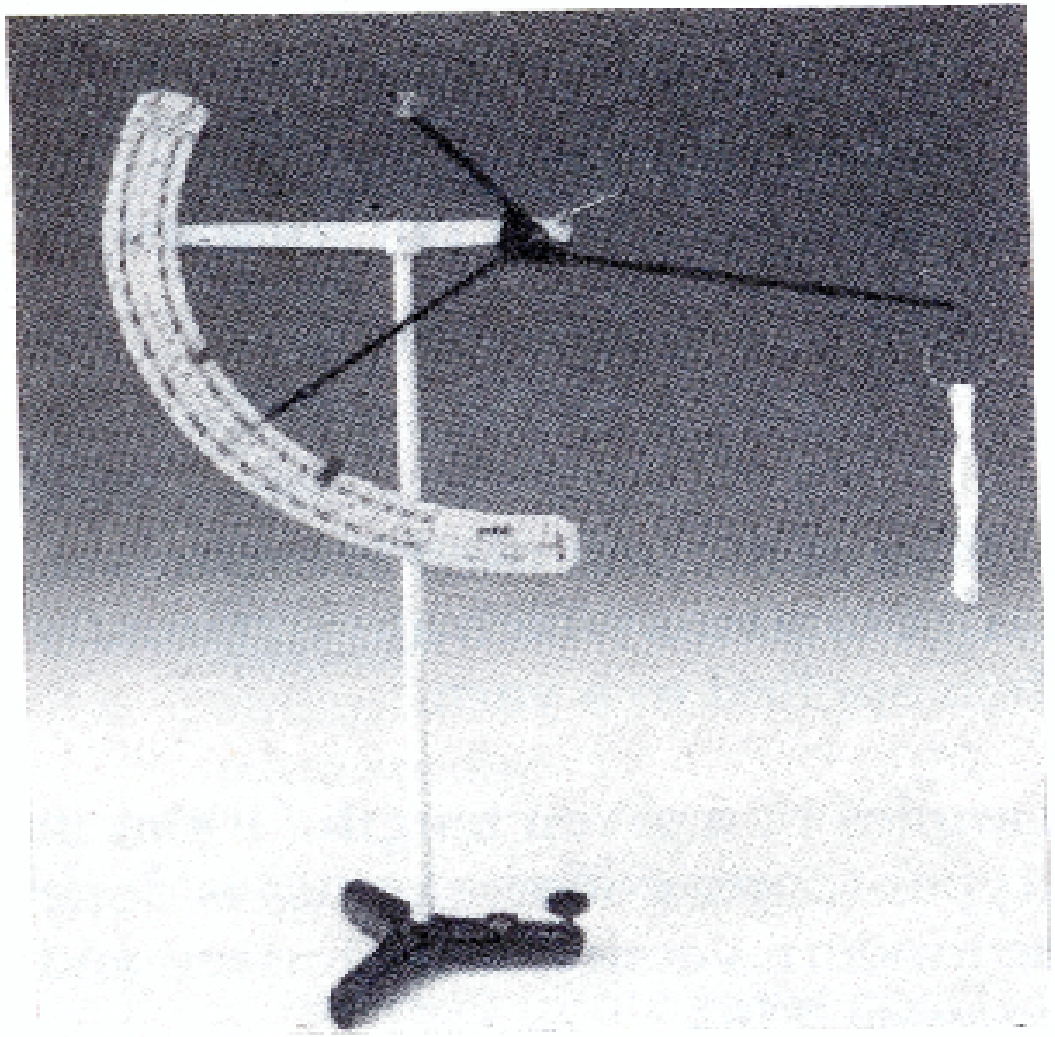
- The extraction of a sample of a given length (100 m in the tex system) starting out from packages of various types(cops, cones ,skeins) is done by using an instrument known as “ a warp reel” w/c in modern version is



Fig… wrap reel (Zweigle)

Measurement of Mass

- To determine the mass of a specimen of yarn one can use various types of balance of w/c the most commonly used is the so- called ***yarn quadrant balance*** whose quadrant scale has different scales according to the system of measurement of the count (clearly the total length of the specimen is assumed to be known and constant ,for instance 500m)
- Among the more modern instruments there are some with digital reading systems ,whose signals is sent to computer to perform the statistical processing of the data (mean and CV); in the case obviously ,one does not perform a global weighing , but the single specimens are weighed separately, to obtain



Fig… Yarn quadrant balance (Zweigle)

5.6 Yarn Count and Diameter

- Yarn diameter is used to predict fabric structural parameters such as width ,cover factor ,porosity , fabric comfort and so on.
- Since thousands of ends or picks are presented side by side in the woven or the knit fabrics ,a slight change in yarn diameter can result in a substantial change in overall fabric cover factor
- Measuring yarn diameter and compressibility and their effect on fabric quality is important to both the fabric designer and the textile technologist
- In fact ,the dimensional and mechanical characteristics of fabrics are dependent on yarn diameter, thread spacing of warp and weft in woven fabrics, courses and Wales per unit length and stitch length in knitted goods

…continued…

- Many researchers studied the yarn diameter and they estimated it using empirical formula.
- One of the most commonly used expressions for estimating yarn diameter is that developed by Peirce in 1937.In this expression, yarn density was assumed to be $1.1 g/cm^3$.
- In recent study ,Elmoghazyet al in 1993 developed empirical expression for estimating the diameter of ring –spun yarn, rotor-spun yarn and MJS air-jet spun yarns
- These expressions (Table 5. 1) were developed by an extensive microscopic testing of actual yarn thickness for a wide range of yarn count and twist levels

…continued…

- In 2003 A Basu et al (SITRA) measured the rotor spun cotton yarn diameter using the image analysis method .The used yarns count range from 6Ne to 20 Ne and they found that the actual yarn diameter can be predicated by using the formula shown in Table 5. 1 .
- The formula shown in Table 5.1 indicate that yarns made by different spinning systems and of equal nominal count will exhibit different values of yarn diameter. This is a result of the difference in fiber arrangement and fiber compactness of different yarn types

…continued…

Table 5.1 Empirical formula of yarn diameter

Yarn Type	Expression	Units	Source
Ring Spun	$d = 1/28\sqrt{Ne}$	inch	Peirce(1937)
Ring Spun	$d = -0.10284 + 1.592/\sqrt{Ne}$	mm	El Mogahzy(1993)
Rotor Spun	$d = -0.16155 + 1.951/\sqrt{Ne}$	mm	El Mogahzy(1993)
MIJ air jet yarn	$d = -0.09298 + 1.5872/\sqrt{Ne}$	mm	El Mogahzy(1993)
Rotor Spun	$d = 1.08/\sqrt{Ne}$	mm	SITRA(2003)

…continued…

- Why the formula for ring spun yarn developed by El Mogahzy(1993) tends to produce a value of yarn diameter that is slightly higher than that estimated by Peirce equation?
- The majority of the studies were interested in determination of the apparent yarn .Thus the real diameter is defined as the measurement of the yarn dimension with out air.

Yarn twist

Twist is defined as turns per unit length & twist level is usually denoted as the amount of twist per unit length.

Twist is inserted in yarns to give them **coherence.**

In staple fiber yarns twist is very important since frictional forces, which alone individual fibers hold in the yarn are solely due to the transverse, pressures which develop when a fiber wrapped in a helical path round other fibers in the yarn is put under tension.

In staple fiber yarns, increasing twists binds the fibers together more and tightly. This action simultaneously increases the strength of yarn by preventing fiber slippage under tension, and decreases the volume or

Beyond the point at which most fibers are locked into place by twist additional twisting of a staple yarn actually makes it weakens.

The only practical reason for inserting very hard (high) twist is to make crepe fabrics by crepe yarn (a twisted & highly twist-lively yarn)

For continuous filament yarn, a small amount of twist (for example: half a turn per inch) is inserted to hold filament together.

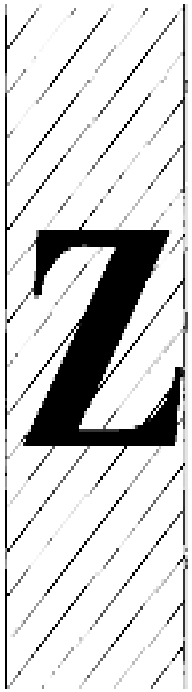
For special purposes higher twist may be used.

The role of twist in continuous – filament yarn is thus to produce a coherent structure that can not readily be disintegrated by lateral stresses.

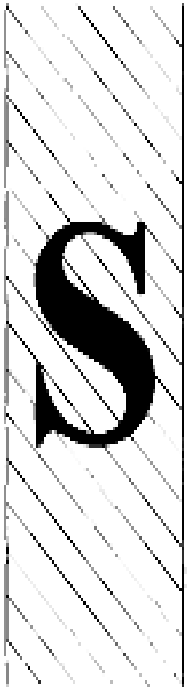
Twist Direction

✓ Twist can be inserted in either of ***two directions***, designated as ***S*** and ***Z***; according to which of these has its center inclined in the same direction as the surface elements of a given twisted yarn, when the yarn is viewed vertically.

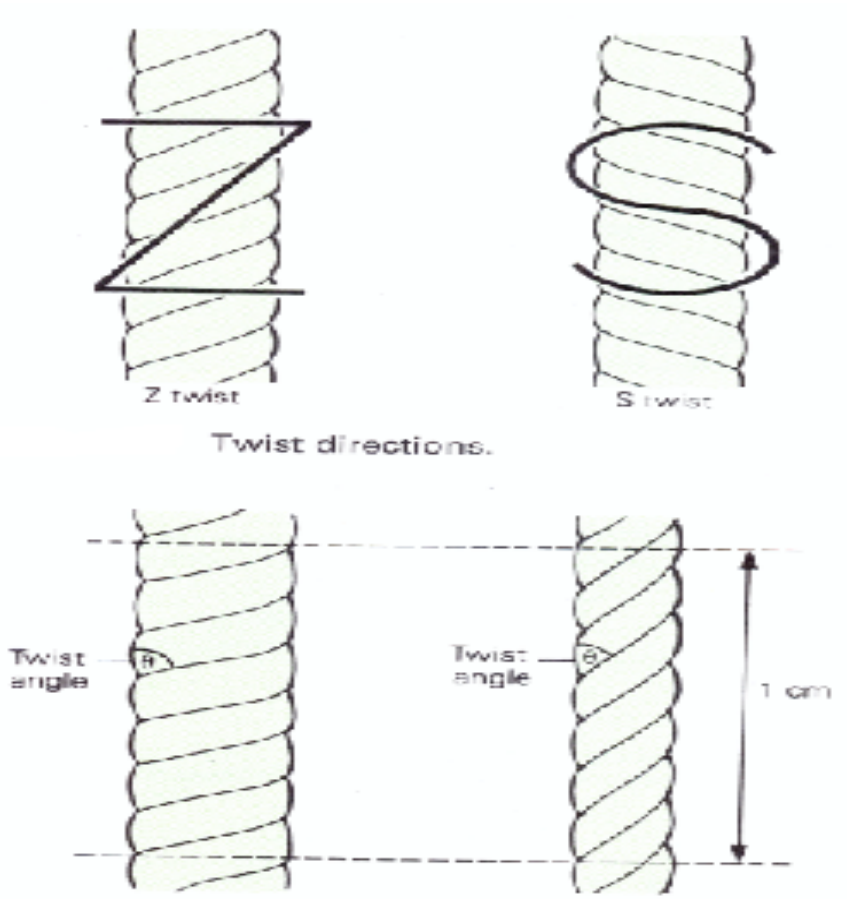
✓ The direction of twist is very important in yarn doubling, as the direction & amount of doubling twist in relation to the single yarn twist affect many of the resultant yarn properties



Z Twist



S Twist



Fig…:Twist direction and Twist angle

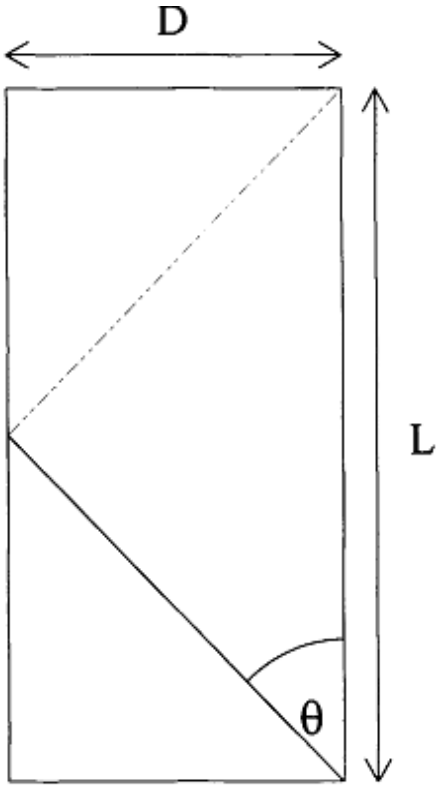
Level of twist

✓ Twist is usually expressed as the number of turns per unit length such as ***turns per meter or turns per inch***. However, the ideal amount of twist varies with the yarn thickness:

✓ the thinner the yarn, the greater is the amount of twist that has to be inserted to give the same effect.

✓ The factor that determines the effectiveness of the twist is the angle that the fibres make with the yarn axis.

Fig… shows diagrammatically a fibre taking one full turn of twist in a length of yarn L. The fibre makes an angle **θ** with the yarn axis. For a given length of yarn the angle is governed by the yarn diameter D:



✓ The greater the diameter of the yarn, the larger is the angle produced by one turn of twist. As 1/L is equivalent to turns per unit length then:

$$\tan\theta = D \times \text{turns/unit length}$$

In the indirect system for measuring linear density the diameter is $1/\sqrt{\text{count}}$tional to . Therefore

$$\tan\theta = \frac{\text{turns/unit length}}{\sqrt{\text{count}}}$$

A twist factor is defined using this relationship:

$$K = \frac{\text{turns/unit length}}{\sqrt{\text{count}}}$$

where K is the twist factor.

✓ The numerical value of the twist factor differs with each count system.

For the tex system:.

$$Twist\ (turns\ per\ metre) = \frac{Twist\ Factor\ (K_t)}{\sqrt{tex}}$$

For the metric count (Nm) system (the twist factor for the metric count system is also known as **alpha metric** - α_m):

$$Twist\ (turns\ per\ metre) = Twist\ \ Alpha\ (\alpha_m)\sqrt{Nm}$$

For English cotton (Nec) count system:

$$Twist\ (turns\ per\ inch) = Twist\ \ Factor\ (K_e)\sqrt{Nec}$$

For worsted count (Nw) system:

$$Twist\ (turns\ per\ inch) = Twist\ \ Factor\ (K_w)\sqrt{Nw}$$

✓ ***Twist angle***:-the included angle between the path of a yarn element & yarn axis.

✓Twist angle is the factor that determines how the yarn will behave.

✓ Yarns with a ***low twist level*** will have a lower twist angle, & will be relatively, soft & bulky yarns.

✓Yarns with ***higher twist angles*** will be strong, lean and hard yarns,

✓while ***over twisted*** yarns will have very ***high twist angles*** and they will be very hard, weaker and twist lively, that is they will ***snarl*** easily when not under tension

✓ The twist in a yarn is not usually distributed uniformly along its length.

There is a relationship between the twist and the thickness of a yarn which takes the form:

Twist X mass per unit length = constant

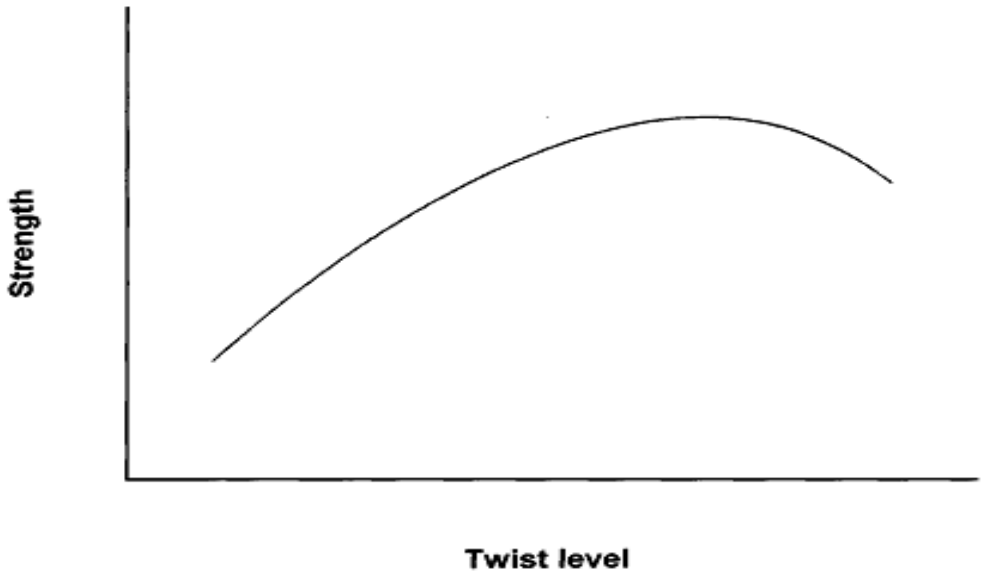
✓ that is, the twist tends to run into the thin places in a yarn.

➡ This means that the twist level will vary along the yarn inversely with the linear density.

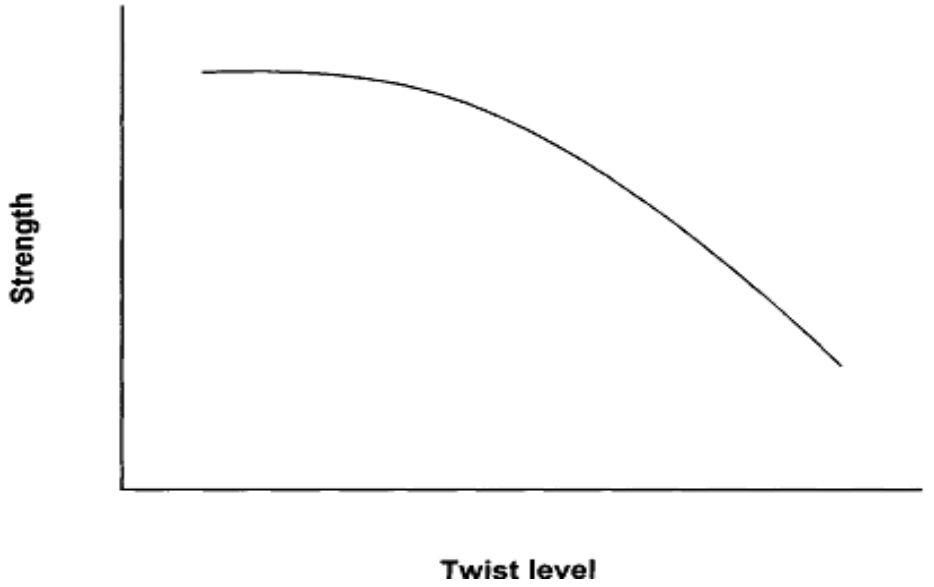
➡ An uneven yarn will therefore have a twist variability of the same magnitude.

✓ A small amount of twist is used in continuous filament yarns to keep the filaments together, but the effect of increasing twist is to reduce the strength of the yarn below its maximum possible value.

✓ The theoretical maximum strength of a continuous filament yarn would be expected to be realized when the filaments



The effect of twist level on strength, staple fibre yarn.



The effect of twist level on strength, continuous filament yarn.

Twist Contraction

✓ When a bundle of parallel fibres is twisted, the distance between the two ends of a fibre will decrease, particularly for fibres near the surface of the twisted bundle. As a result, the overall length of the twisted bundle is shorter than its length before twist insertion.

✓ The magnitude of contraction has been defined in two ways

a) $contraction\ factor = C_y = \frac{Length\ of\ zero\ twist\ yarn}{Length\ of\ twisted\ yarn}$

b) $Retraction = R_y = \frac{Length\ of\ zero\ twist\ yarn - length\ of\ twisted\ yarn}{Length\ of\ zero\ twist\ yarn}$

$$\therefore \quad C_y = \frac{1}{(1 - R_y)}$$

✓The reduction in length due to twist insertion is known as ***twist contraction***

The following formula is used to calculate the amount of twist contraction:

$$\%\ contraction = \frac{L_o - L_f}{L_o} \times 100\ \%$$

Lo = original length before twisting

Lf = final length after twisting

It should be noted that because of twist contraction and the associated change in length, the count of a yarn will change slightly when twist in the yarn is changed.

✓ Twist contraction increases yarn count (tex), because the weight of the yarn is distributed over a shorter length.

$$N_f = \frac{N_o}{1 - C}$$

No = count (tex) before twisting

Nf = count (tex) after twisting

C = %contraction

Measurement of Twist:

✓ The two common methods used in twist measurement are straightened fibre method and untwist/retwist method..

1. Straightened Fibre Method:

This method involves counting of the number of turns required to untwist the yarns until the surface fibers appear to be straight and parallel to yarn axis.

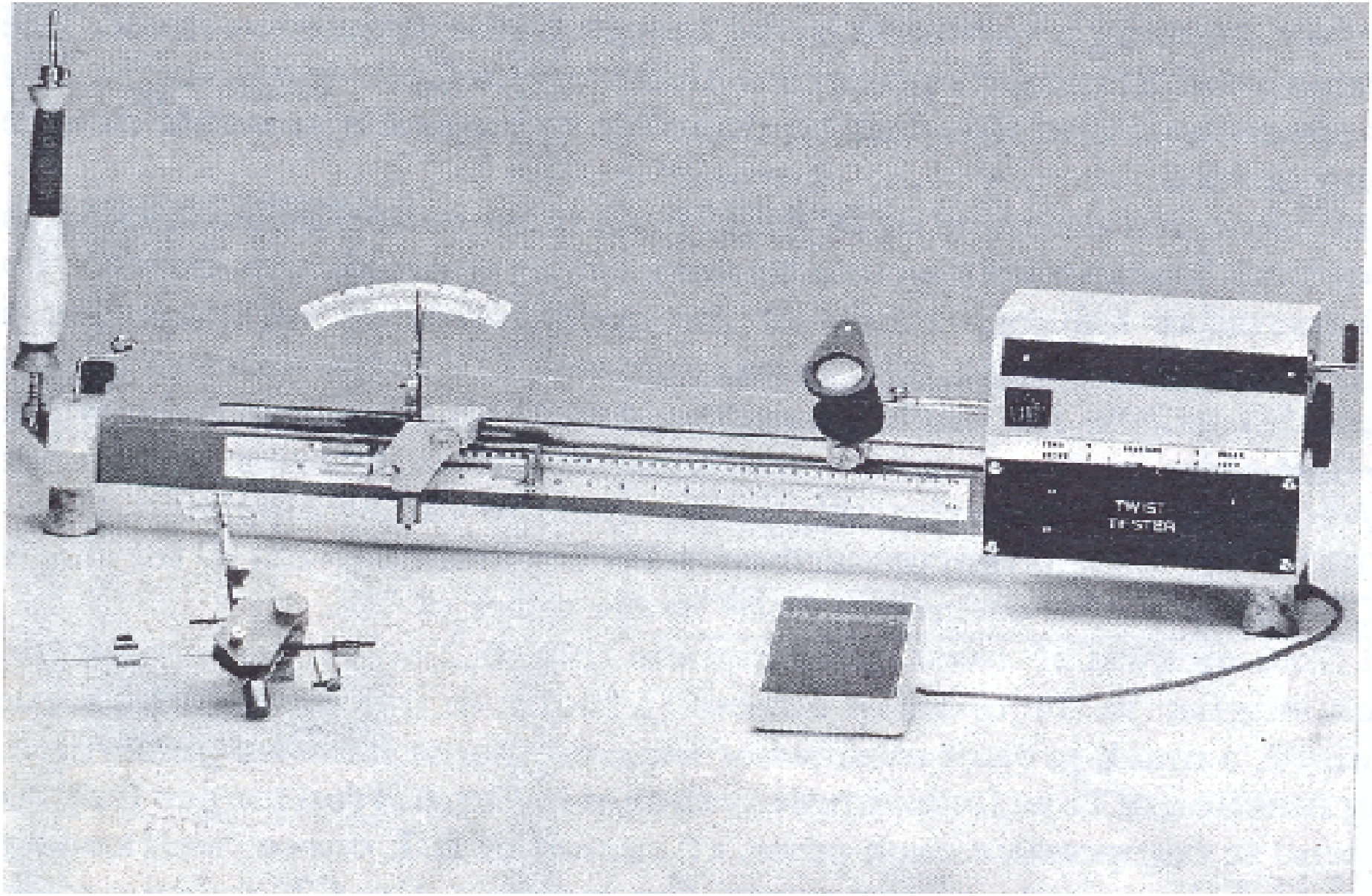
✓ This method is mainly used for ply and continuous filament yarns.

2. Untwist / Re-twist Method:

This is the common method used for staple fibre yarns. It is based on twist contraction (hence also known as twist

• The pre-tension is imported by means of weight applied to the specimen (already applied in the rotating clamp), before tightening the fixed clamp.
• For this method, it is assumed that the contraction in length, due to insertion of twist, is the same for both direction of twist (S and Z).

• Suppose we want to measure the twist level in a yarn with Z twist, the yarn is first untwisted (by a twist tester), and a counter on the twist tester will record the number of turns.
• During untwisting, the yarn would increase in length from its original length L to a new length L’.


TWIST
TESTER

✓ If the operation is continued, the yarn would have its twist completely removed first and then twisted up again in S direction. As the yarn gets twisted, its length will decrease (twist contraction) from L’ towards its original length L.

When its original length is reached, the total number of turns received by the yarn, as recorded by the counter on the twist tester, would be equal to twice the twist in the original yarn (with a length of L).

Effects of level of twist:

✓ The level of twist has other effects on yarn and fabric properties which may override the need for increased strength, including the following.

Handle: As the twist level in a yarn increased it becomes more compact because :-

✓ the fibres in it are held more tightly together, so giving a harder feel to yarn.

✓ Furthermore the covering power of yarn is reduced because of decrease the diameter of the yarn.

✓A fabric made from a high twist yarn will therefore feel harder and will also be thinner. Conversely a fabric produced from a low twist yarn will have a soft handle which is often a desirable property.

Moisture absorption: a high level of twist in a yarn holds the fibers together and hence restricts the access of water to the yarn interior. Therefore such a yarn would be used where a high degree of water repellency is required, for example in a gabardine fabric.

✓ A low twist yarn will also absorb water more readily than a high twist one so would be used in those applications where absorbency is required.

Wearing properties: The levels of twist have effects on aspects of wear: ***abrasion and pilling***. A high level of twist helps to resist abrasion as the fibres cannot easily be pulled out of the yarn. The same effect also helps to prevent pilling which occurs when fibres are pulled out of the fabric construction and tolled into the little balls on the surface.

Aesthetic effects: The level of twist in a yarn alters its appearance both by changing the thickness and also by altering the light reflecting properties owing to the change in angle of the fibers. This means that subtle pattern can be produced in a fabric by using similar yarns with different twist

Faults: Because the level of twist in a yarn can change its diameter and other properties such as absorption, variation in twist levels in what is nominally the same yarn can change the appearance of a fabric so giving rise to complaints.

Tensile testing:

✓ The level of strength required from a yarn or fabric depends on its end use. For some end uses it is the case that the higher the strength of the materials, the better it is for its end use. This is particularly true for yarns and fabrics intended for industrial products.

✓ However, fabrics intended for household or apparel use merely need an adequate strength in order to withstand handling during production and use.

✓ It is generally the case that a higher strength product can only be obtained by either making a heavier, stiffer fabric or by using synthetic fibers in place of natural ones.

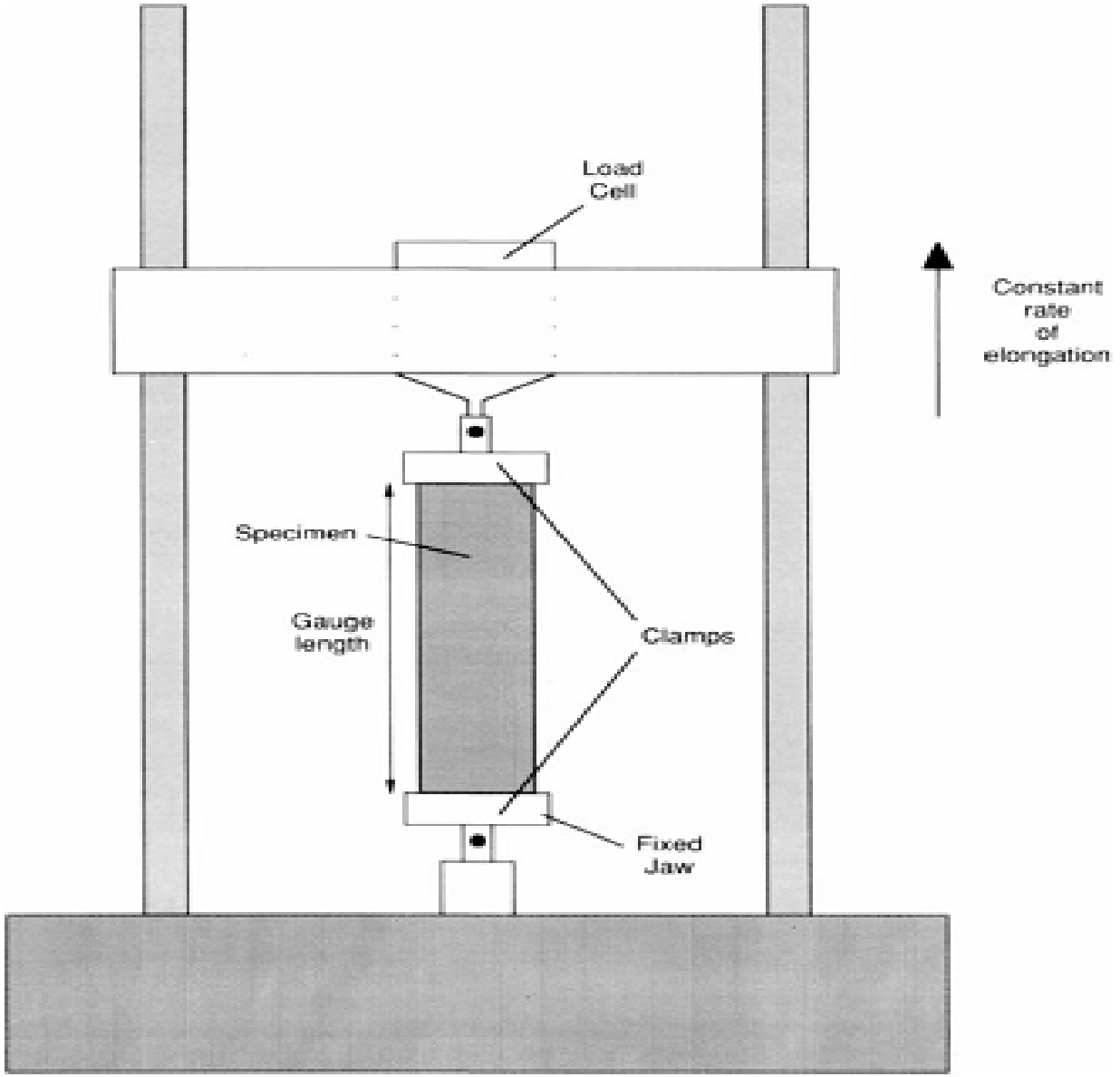
Tensile testing machine

Most tensile testing machines can operate in three modes:

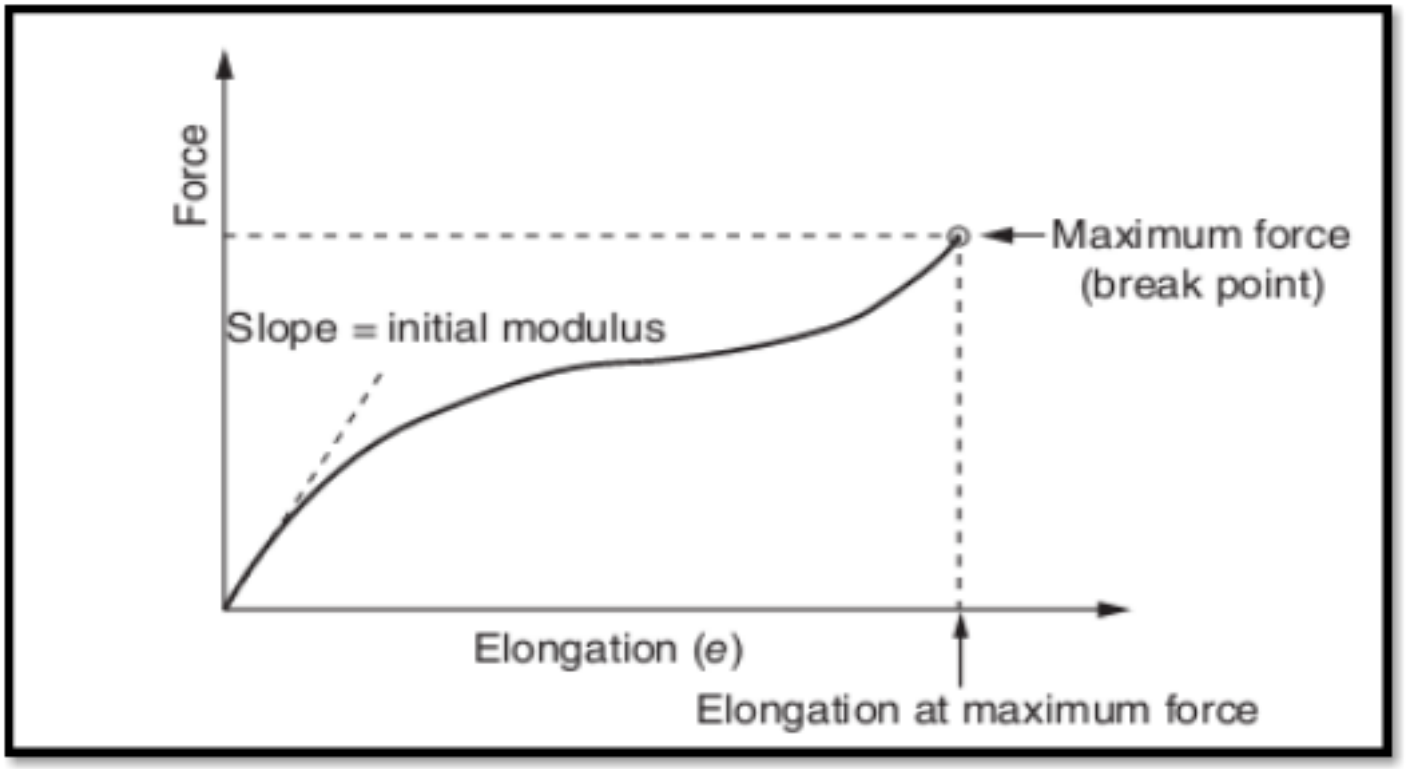
- Constant-rate-of extension (CRE)
- Constant-rate-of traverse (CRT)
- Constant-rate-of-load (CRL).

The most commonly used mode is the CRE mode and is often required by the test standards. The main factors that need to be considered are ;

- ❖the size and accuracy of the load cell
- ❖ the distance of cross-head travel
- ❖and the rate of cross-head travel



Constant-rate-of extension (CRE)



✓ Extension is defined as the change in length of a material due to stretching. When a fabric of original length ***lo*** is stressed along its axis, it extends an amount ***dl***.

✓ The strain in the sample is ***d l/l0*** (the ratio of the extension of a material to the length of the material prior to stretching). The symbol e is normally used to represent strain, and can be referred to as elongation.

Factors affecting tensile testing

1). *Specimen length*

The length of sample under test is known as the gauge length and in most textile tests it is equal to the distance between the inner edges of the clamps. This length has an important effect on the measured strength of the material because of the influence of weak spots on the point of failure.

A material when put under stress will always break at its weakest point. Therefore the longer the length of material that is stressed, the greater will be the probability of finding a weak spot within the test length.

2) *humidity and temperature*

✓ Humidity of the testing atmosphere greatly affects the strength and extension of textile materials.

✓ The effect varies with the regain of the fibre; hydrophobic materials are hardly affected whereas those with high regains change the most.

✓ Wool, silk and viscose lose strength and cotton, linen and bast fibers increase in strength.

3) *Previous history of the specimen*

✓ a specimen may have been strained beyond its yield point
✓ orientation of the material
✓chemical treatment such as bleaching or exposed to light
✓may be used in fault finding

4) *Clamping problems*

✓ During a tensile test textile materials are normally clamped between the faces of two jaws by lateral pressure. This clamping arrangement can give rise to two sorts of problem:

❖ **slippage** of the sample at the jaws or **damage** of the sample by the jaws, depending on whether the clamping pressure used is too low or too high.

5) *Rate of loading*

✓ The measured breaking load and extension of textile materials is influenced by the rate of extension that is used in the test.

✓ yarns of different elastic module require different test

Yarn strength testing

✓ The strength and extension results from samples of yarn taken from different parts of a package can be very variable.

✓ Yarn made from staple fibers is worse in this respect than yarn made from continuous filaments owing to the fact that the number of fibers in the cross-section of a staple fibre yarn is variable.

✓ This means that in order to get a reasonable estimation of the mean strength of a yarn a large number of tests have to be carried out on it.

Two types of yarn test are carried out:

1 Tests on single lengths of yarn,(sometimes referred to as single thread tests).

2 Tests on hanks or skeins of yarn containing up to 120 metres of yarn at a time which is broken as one item.

single strand method

Most yarn test standards are very similar. The British Standard lays down that the number of tests should be:

1 Single yarns

(a) continuous-filament yarns: 20 tests,

(b) spun yarns: 50 tests.

2 Plied and cabled yarns: 20 tests

✓The yarns should be conditioned before testing in the standard atmosphere.

✓The testing machine is set to give a test length of 500mm and the speed is adjusted so that yarn break is reached in 20 ± 3s.

✓The mean breaking force, mean extension at break as a percentage of the initial length, CV of breaking force and CV of breaking extension are recorded.

The US standard specifies a gauge length of 10 ± 0.1 in (250 ± 3mm) or alternatively by agreement 20 ± 0.2 in (500 ± 5mm) and uses a time to break of 20 ± 3s.

Yarn strength: skein method

✓ In this method a long length of yarn is wound into a hank or skein using a wrap reel as would be used for linear density measurement, the two loose ends being tied together.

✓ The whole hank is then mounted in a strength testing machine between two smooth capstans, which may be free to rotate.

✓ The hank is subjected to increasing extension while the force is monitored. When one part of the yarn breaks, the hank begins to unravel.

✓ Because of the friction present in the system the force continues to increase until sufficient strands have broken for the hank to unravel, the force passing through a maximum value at some point.

✓ This maximum force is known as the hank strength.

✓ Measuring the strength of a hank or skein of yarn is a method that was used in the early days of textile testing but that is now being replaced by the single strand method, especially since the development of automatic strength testing machines.

✓ **The main advantage of the hank method is that it tests a long length of yarn in one test. The yarn is expected to break at the weak spots so giving a more realistic strength value and also the same hank can be used for measuring the yarn count.**

✓ **The disadvantage of the test is that it is dependent on the friction between the yarn.**

The British Standard specifies a hank of 100 wraps of 1m diameter.

This is tested at such a speed that it breaks within 20 ± 3 s, or alternatively a constant speed of 300mm/min is allowed.

- ✓ If the yarn is spun on the cotton or worsted systems 10 skeins should be tested ,
- ✓ and 20 skeins if the yarn is spun on the woollen system.

The method is not used for continuous filament yarns.