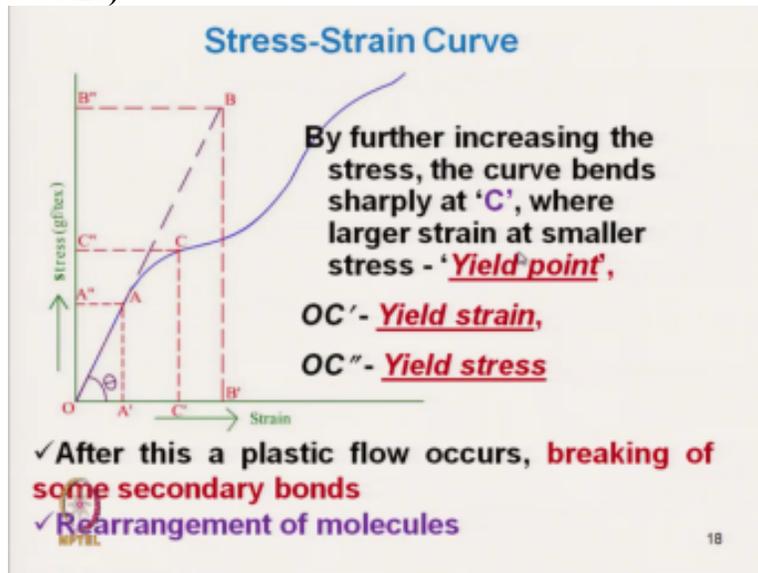


Evaluation of Tensile properties of Textile Materials  
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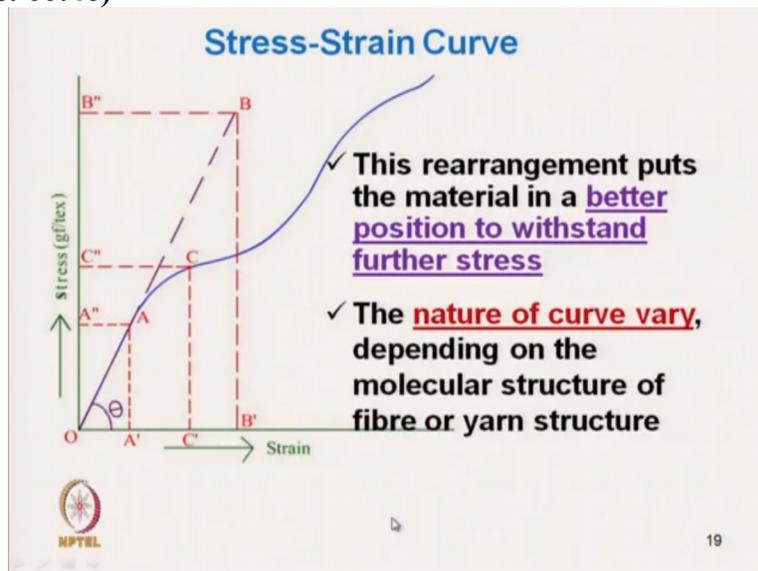
Lecture - 19  
Evaluation of Tensile Properties of Textile Materials (contd.,)

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Hello everyone, we are discussing the nature of stress-strain curve for different material. In this stress-strain curve we can get various, parameters like initial modulus, yield stress, yield strain these we have discussed.

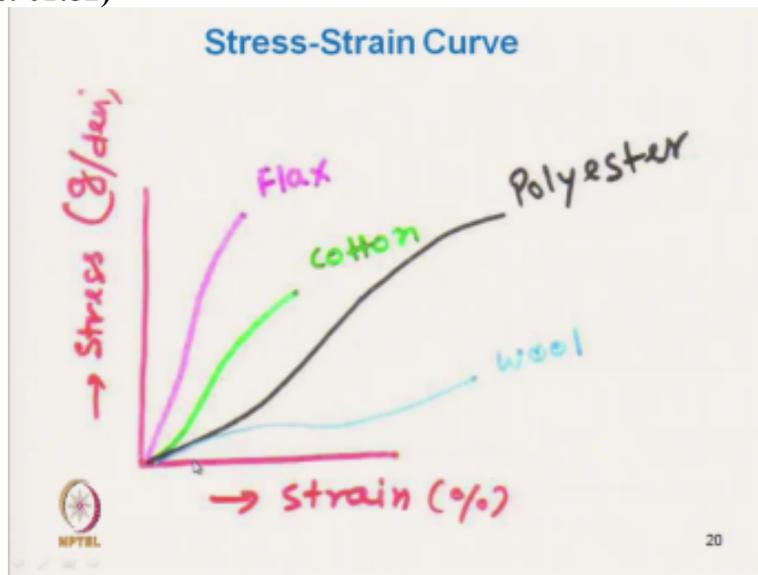
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And the total nature of curve this stress-strain curve we have discussed. So, this region beyond the yield point, after that, due to rearrangement of the molecules. So this curve again, it increases and the nature of curve depends on the molecular structure of fibre and the fibre structure of yarn. So, if the fibres in the yarn are aligned towards the axis, then stress-strain curve will be entirely different than the fibres which are twisted. So depending on the twist characteristics stress-strain characteristics will change.

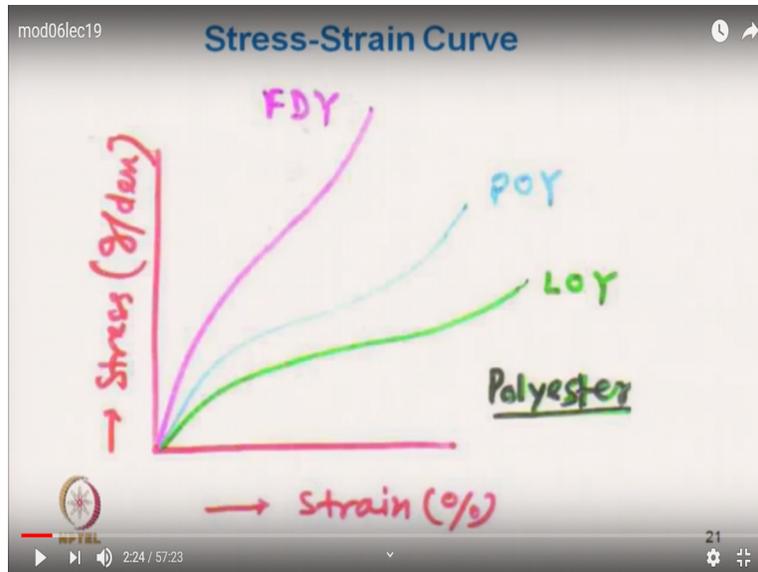
Now let us see, different fibres, different yarn. How do they change how they are stress-strain curve and characteristics change.

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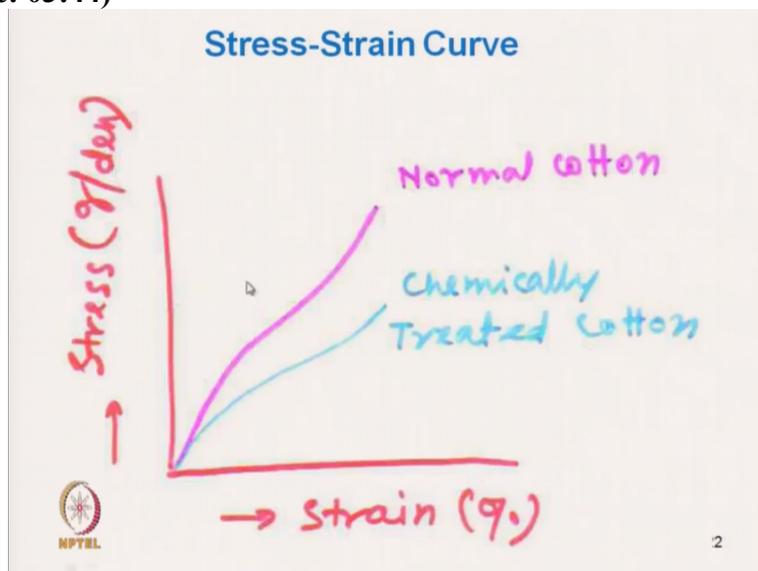
So, this is wool and wool has got this stress-strain characteristic where with the diff; small increase in stress it gets strain, very high strain. So it is got a really high extensibility. But on the other end, flax has got very less extensibility. So, this is mainly due to the difference in their molecular structure.

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Now for same fibre ok polyester, it is low oriented polyester, partially oriented polyester and fully drawn polyester. So, in case of same fibre, if we can orient the molecule the stress-strain curve will totally change. So, this is basically low oriented polyester as we have discussed earlier, this nature mainly due to rearrangement of the molecule. Molecules with straightened aligned towards the axis.

So, during that time the strain is very high. Okay. But in case of fully drawn, yarn FDY it has been aligned, oriented. So, that is why it takes higher stress with smaller strain. Okay. So, rigidity of that FDY is much harder than LOY, which is expressed by initial modulus. (Refer Slide Time: 03:44)

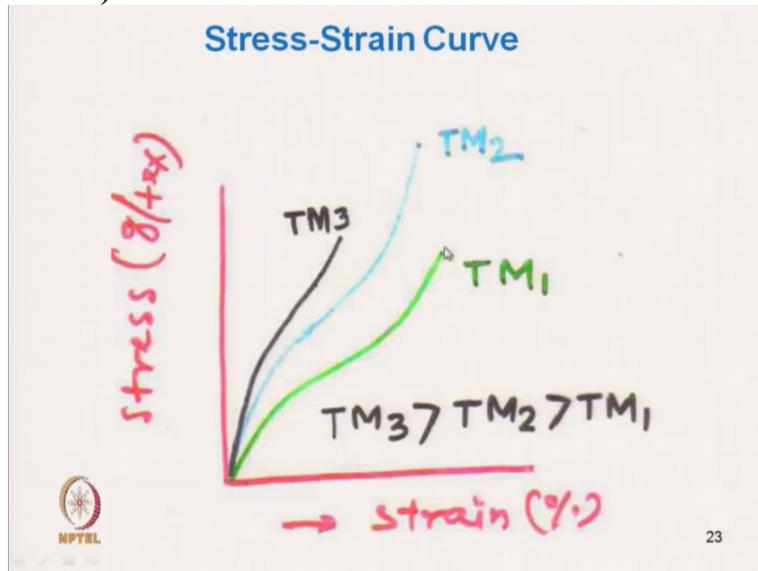


Now another example where normal cotton is treated chemical after chemical treatment, both stress and strain normally changes. So, here it shows the cotton becomes weaker and it has got it

is the lower breaking stress. So, the stress-strain curve also changes with the chemical treatment. Now, as I have mentioned with the increase in twist multiplier for staple yarn, it gets changed.

The stress – strain curve, stress and characteristics get changed.

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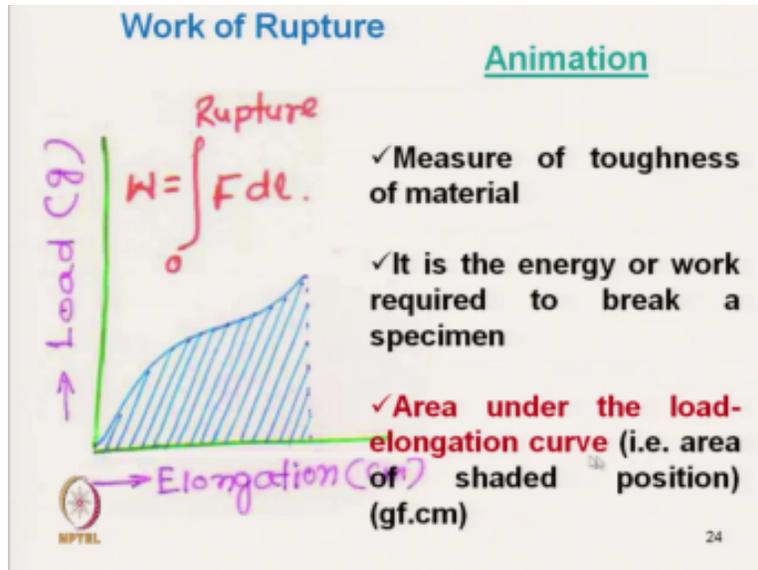


Now here we can see that in green curve it shows itself say normal yarn and with the increased, so here it; says this is the characteristics and when the twist increases so TM to TN, TM1 which is lower and increase to TM2 twist multiplier 2 then twists multiplier the highest TM. So, as the twist multiplier increases the fibre, the yarn become stiffer and stiffer that means initial modulus is increasing because the fibres are they come packed together packed in a better way.

For better packing due to this, better packing, that initial modulus increases. The yarn becomes stiffer, but that as the twist increases initially, this is the strength increases. This is due to the increase in the frictional contact, but beyond certain point when we move beyond TM2 to TM3 what happen due to the obliquity effect of the fibre, so actual final breaking stress drops, although the initial modulus is higher.

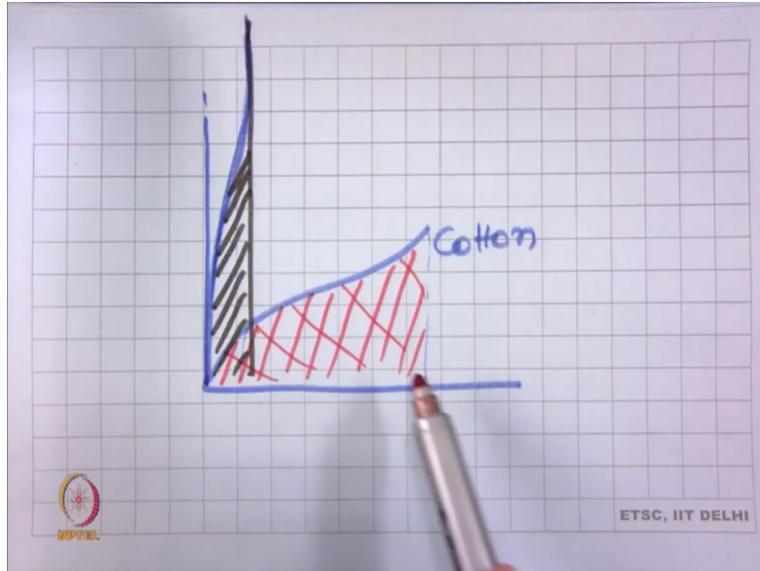
So, this total yarn characters total stress-strain characteristics. Looking at the stress-strain behaviour, one can predict what is happening there, so these are the different factors which affect the stress-strain behaviour of the textile material.

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Now we will discuss another terminology which is called work of rupture or it is called that the area under the curve. Work of rupture is nothing but the energy required for break. Okay, before it rupture. So it is measure of toughness of the material okay. This is work of rupture is very important for many applications. Like one example in mountaineering rope. So, it is not that the strain, that stiffness of the material which is important, which is the important is that how much shock, how much energy it can absorb before it fails.

So, that is important, there are many applications where the energy required to before breaking, like in weaving, it is not the strength of the work yarn which is important. It is the work of rupture of the yarn which is important because during the shedding and beating operation, the yarn has to actually with stand the energy. Energy required to break that is important and it is not important that, which is a stiffer one or stronger one, a strong yarn very strong yarn with very high stiffness that means very low elongation or low work of rupture like that is 2 yarn.  
**(Refer Slide Time: 08:10)**



This cotton yarn and another is suppose steel wire, strength is very high. But, stiffness is very, very stiff. And here it is say high carbon steel wear. Now here, if we see the area under the curve, what is the area under the curve? For cotton this is the area under the curve that means energy required to break the cotton yarn will be this one, but on the other hand, if we see the steel wire, the breaking energy required will be this much that means the cotton requires higher energy than steel, although steel is extremely very high. So, the question is which one will be suitable for weaving.

If we use the steel wire as work in weaving, it will immediately break. It will start breaking its performance very poor. And as compared to cotton, cotton will do much better performance. It will have much better performance, so not only in weaving; there are many other applications like a parachute, in parachute, even in the parachute fabric or the rope when the paratrooper jumps. So the work of rupture that his energy before it breaks, it has to be very high. Otherwise it will fall.

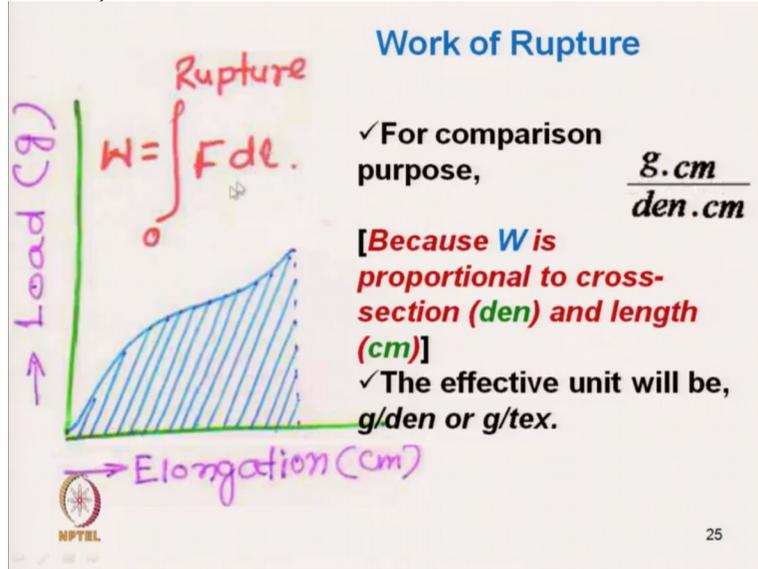
So, in that way the textile material has got its advantage. So, it is the energy or work required to break a specimen okay. That means the area under the load elongation curve, the area of the shaded zone. That is the, work of rupture. Now we can see the animation here.

**(Video Start: 10:51)**

This is the load elongation curve. We should; we must be very careful. This is the area under load elongation curve not stress-strain curve because it is an energy. Load and that is the force and multiplied by elongation this is work of rupture. So, area under the load elongation curves.

(Video Start: 11:34)

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Now, what will be the unit of workup rupture? So unit of work of rupture is gram force multiplied by a centimetre. That is force multiplied by distance. That is the work of rupture. But for practical purpose, for comparison purpose, what do we do? This is the work because  $W$  is proportional to the cross sectional cross section.  $W$  is proportional to denier and also it is a length. That means if the denier is higher, denier is coarser denier or coarser tex then it will be the work required force required to break will be high.

That is why  $W$  work is proportional to the denier and also as the initial length of specimen is high then the work requirement will be high because that extension will be high, so the work of rupture will be high. So, the work of rupture is actually it changes with the denier proportionally and with the initial length. That is why for comparison, if we divide these things with the denier and centimetre length in that case, like for we have seen earlier the stress is divided by the linear density.

The gram force is divided by the text just for comparison purpose that we have seen here, again, if we divide the work of rupture by denier and the length so that we can compare. Okay, we can compare the; if we rearrange this equation, then the centimetre will be cancelled out. Ultimately will remain it will remain gram per denier or gram per tex. So, if someone says that. Okay, what is the practical, the unit of work of rupture? It will be gram per denier, so effective unit will be gram per denier or gram per tex for comparison.

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**Work Factor**      Animation

**If the curve follow Hook's law up to breaking point, then;**

$$\frac{\text{Area under the curve}}{\text{Br. stress} \times \text{Br. strain}} = \frac{1}{2}$$

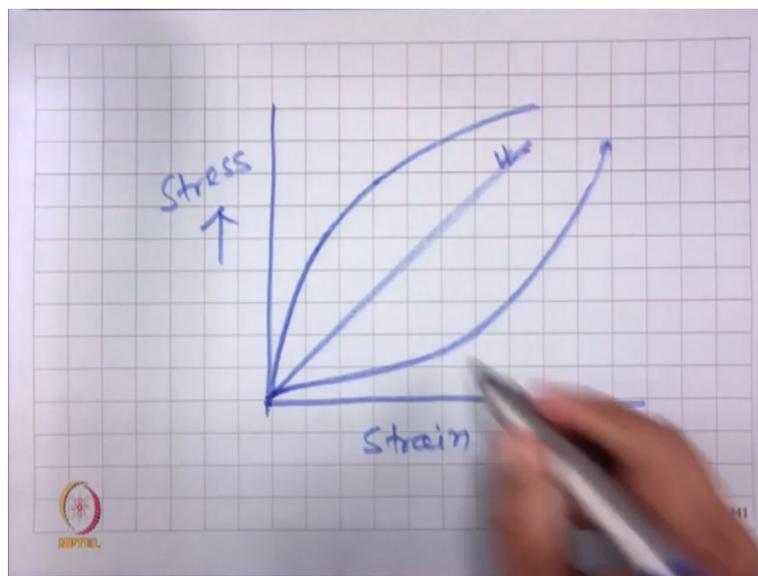
**This is Work Factor**

**It describes the nature of curve numerically**

NPTEL

Next is that work factor, now the work factor the concept of work factor is just to understand the nature of curve.

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Curve can be any textile material. The curve can be like this or can be like this. Okay, so for a very stiff material the curve will be initially it will have higher stress strain curve initially it will take higher stress then gradually due to the bond breakage and all this, it will have; another, like wool the initial extension, then it will increase and there is ideal curve which will increase with the; there will be a straight line that is ideal material, that is the elastic material which will straight to increase.

Although the textile material will not follow this one either, this will follow this type of curve or this type of curve. Now work factor gives an idea by; if we know the factor value it gives an idea about the nature of the curve whether the curve is following this type of pattern or this type of pattern. So, always we do not have the curve in front of us, but if we have the curve factor value, then we can tell it is the nature. We can actually guess the nature of curve. Now let us see the animation here.

**(Video Start: 16:33)**

This is the ideal curve ok where the work factor is nothing but the area under the curve, this area under the curve divided by breaking stress and breaking strain. This is the breaking point. So, what is the area under the curve? Area under the curve is half of breaking stress and breaking strain, so this is the area under curve half of this base and altitude ok, altitude height is stress and the base is the strain and divided by the breaking stress and breaking strain. So, in that case, if it cancels out, so it remains half.

So, work factor will be half in case the ideal elastic material? Okay, now another material where this is the; there is an increase in this, here work factor will be; what will be the work factor? Area under the curve will more than this straight line, actual area under the curve will be more ok and divided by the bricking stress and breaking strain so that means work factor will be more than half ok. On the other hand if we see the other type of curve, it shows the blue line. So this is the curve where the work factor here is less than half so then by knowing the value of work factor we can guess, we can actually predict the; what type of nature of the curve.

**(Video End: 18:31)**

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**Work Factor**      Animation

**If the curve follow Hook's law up to breaking point, then;**

$$\frac{\text{Area under the curve}}{\text{Br. stress} \times \text{Br. strain}} = \frac{1}{2}$$

**This is Work Factor**

**It describes the nature of curve numerically**

So, if the curve follows Hook's law the material follows Hook's law up to the breaking point. There is no bent then the work factor will be half. So it is area under the curve divided by breaking stress and breaking strain. And it describes the nature of the curve numerically. It is not; if we do not have the curve in front of us, but numerically if it is the value, then we can guess we can tell them, okay, this is the work.

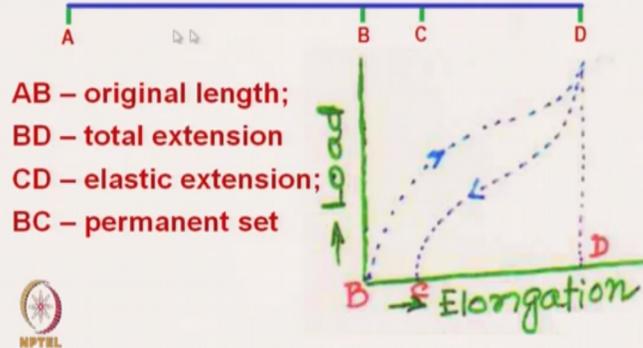
So, work factor of 0.4? It is asked draw stress-strain curve of material with work factor of 0.4, so in that case, you have to draw a curve like this 0.4. Okay. Work factor of 0.4 straight line, work factor of 0.5, work factor of this 0.6. So this type of actually problem it is given in the exam. So, it is given that the nature of curve different nature of curve and tell the work factor, whether it is at this 0.4 or some values will be given. We have to tell the work, predict the work factor logically.

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## Elastic Recovery

[Animation](#)

✓ It is the property of a material by which it tends to recover to its original size and shape after deformation



Now the term elastic recovery, what is that? It is the property of a material by which it tends to recover to its original size. So, any material after extension it is normally, it tries to recover to its original size and shape okay, but it may not be 100%. So, by the term elastic recovery it is actually one can see one can actually calculate the, how much but deformation it will try to gain to its original size and shape.

Now, this is the yarn. Suppose yarn. Initially the yarn AB is the initial length. Okay. Now its load elongation curve now we are extending from B to D we have extended. The Load has increased. Okay. Up to this point, we are not breaking them material and after that we released the material after releasing its load is gradually reducing. And then it is reaching up to the point C it is not coming to the original point.

So, this is the deformation. It is called plastic deformation and this is the deformation it is called elastic deformation. Okay. Where it is recovered? Now we can see the animation here.

**(Video Start: 22:03)**

Now it is increasing, see this is the initial length of the materials; suppose it is yarn AB, now it is extending and it is increasing and it is reducing ok. If this is the distance we can calculate the AB is the original length CD, okay is the elastic extension where it is come back and BD is the total extension from B to D is the total extension and BC is that permanent set. That is plastic deformation and from there one can calculate.

So, elastic recovery is the CD. What is the recovery divided by total deformation. So, CD by BD for perfectly elastic material that will be total recovery that means BC will be zero. So BD will



### Calculation of Percentage elastic recovery of yarn

**Problem:** A yarn specimen of 200 mm extends by 10% when loaded with 500 cN force. The length of the specimen after removal of load was found to be 202 mm. Percentage elastic recovery of yarn is \_\_\_\_\_

#### **Solution:**

Given Data,

Original length of specimen= 200mm; Extension% =10%

Loaded force = 500 cN; Final length = 202 mm

Percentage elastic recovery of yarn =?



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Next is that so we can calculate the yarn specimen of 200mm extended by 10% when loaded with 500 cN force. That between 500 cN forces is applied. Okay. The 200mm yarn is extended by 10 %. The length of the specimen after removal of load was found to be 202. So after removal there a deformation, it is the length was 202, it was initially 200. Now it becomes 202. Calculate the percentage elastic recovery of yarn. So, 200 was the initial length and extension 10% loaded 500 cN and final length is 202 ok. Here the load value it is not required because extensive value is known okay.

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### Calculation of Percentage elastic recovery of yarn

$$\begin{aligned}\text{Extended Length} &= \text{Original Length} * [(1 + (10 / 100) ] \\ &= 200 * 110 / 100 = 220\text{mm}\end{aligned}$$

$$\text{Total extension} = 220-200 = 20\text{mm}$$

$$\begin{aligned}\text{Elastic extension} &= \text{Extended length} - \text{Final length} \\ &= 220 - 202 = 18 \text{ mm}\end{aligned}$$

$$\begin{aligned}\text{So, Percentage elastic recovery of yarn} \\ &= (\text{Elastic extension} / \text{Total extension}) * 100 \\ &= (18 / 20) * 100 = 90 \%\end{aligned}$$

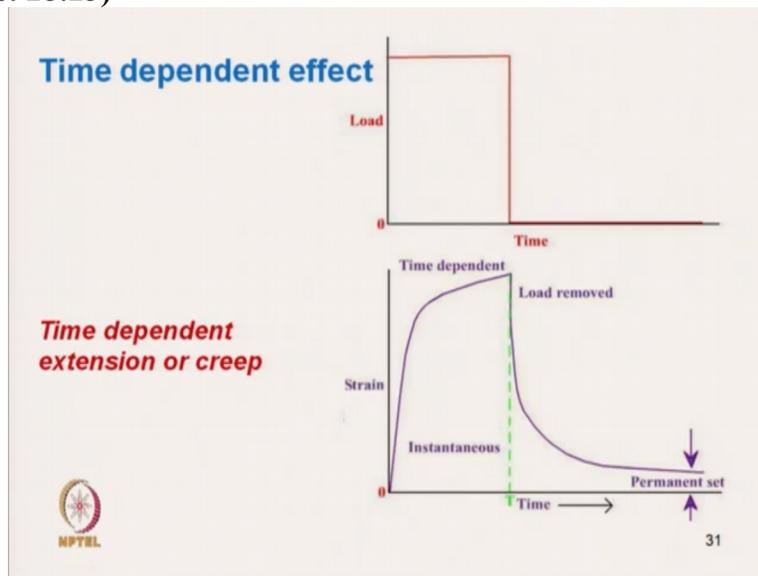


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So, extended length will be its 10% of initial length original length 10% of original length it has increased. So, it has become 220mm and the final length has become. It is a; that is the total

extension is 20mm and elastic extension is that extended length by final length, final length was given. So elastic extension was 18 millimetre, so 20 millimetres is that total extension at elastic extension is 18 millimetre. That means the ratio of this two will give us the value in percent multiplied by 100. So, it has become 90%, so 90% elastic recovery is there. So, one should practice this type of new numerical, this is the answer.

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Next is that time dependent effect ok, so time dependent effect is that; so here it is load is not increased continuously. In our earlier stress-strain we have seen stress is load is increasing and strain is taking place, but here the material is loaded once ok and it is kept at that loading condition for a long time. So, this type of situation is they are in most many technical applications like in geo textile for any applicants where the material is under constant load for long time.

So, for that we must know the stress-strain behaviour ok the strain time and strain behaviour, what is that? The load is fixed is fixed that this is for geo textiles under the ground it is continuously loaded, so we must know the strain characteristics so that we can predict whether it will fail or not ok. So, that characteristics is the time dependent extension, it is known as the creep ok.

Now, once it is loaded, there will be two types of extensive. Suddenly we are hanging a constant load. It is not the load is increasing continuously increasing at a certain rate. Suddenly we are hanging certain load ok. Here as per this, it is loaded. So, during that time there will be one

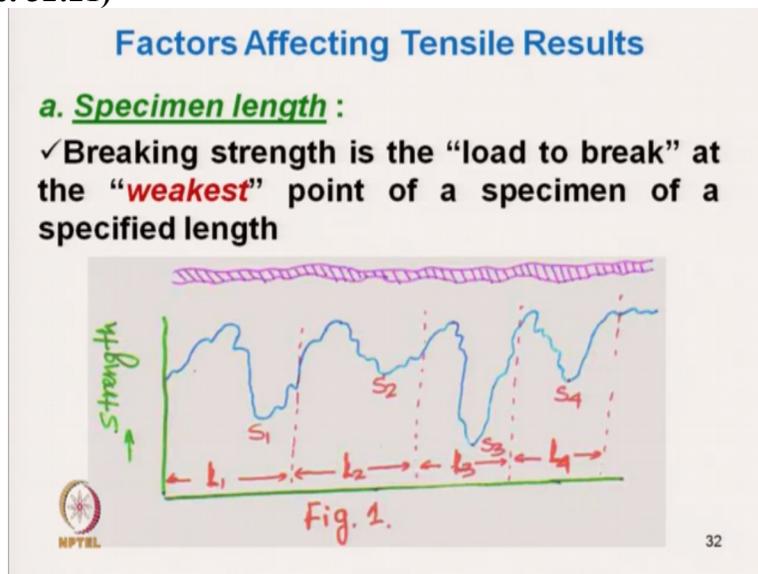
instantaneous extension. This is the zone where, the material will get extended instantaneously. Then after that it will not stop here. It will keep on extending ok.

So, if we see in normal load elongation curve that particular load value the extension could be like this could be up to this point. This is the extension up to this point ok. But if we live, let, the load remain for a long time on the material that has been observed, that there will be again, continuous increase in elongation. It will keep on elongating. This illustration is known as the time dependent elongation is known as the creep behaviour.

This is due to the molecular rearrangement of them, and after that, after a certain time, if we release the load ok again it has become 0 and it is not that immediately it will comeback, so it will try; it will come back slowly. Initially there will be immediate response, immediately there will be sudden drop in strain. Suddenly there will be contraction, but gradually it will come back, try to come back, but after certain time there will be no reduction in shape or size.

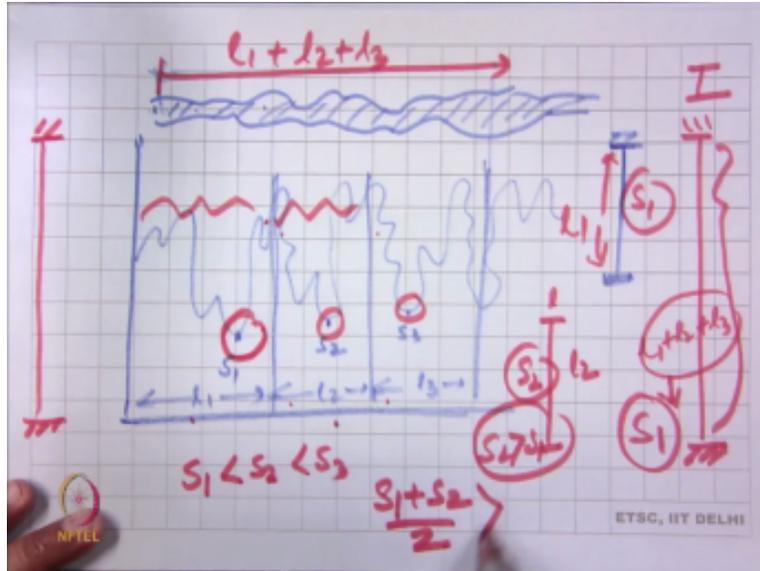
So this difference is known as the permanent set. Okay, that means there will be permanent deformation in the molecular structure.

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Now we discuss one important factor, some important factors which affect the tensile result. Okay, that tensile result means that for same yarn if we change the textile material, if we changes these parameters.

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The load value will get changed. Suppose there is a yarn, this the yarn okay. Now the yarn across section is unevenness will definitely be there. Now yarn will break in its weakest point. Now if we can plot the yarn, the strength, theoretically, if we can get the yarn strength at different point okay. The strength of the yarn will be like this at different point. The actual strength will be like this ok. So this is say  $S_1$ ,  $S_2$ , and  $S_3$ , these are the weakest point.

Now this is the specimen length, we can test that tensile test by this is the yarn sample. This is top jaw. This is the bottom jaw. And here suppose it is a length  $L_1$ , length  $L_2$  and length  $L_3$  like that ok. If we take this, the strength, if we measure the strength of yarn by taking this total length total by taking the total length, which is  $L_1 + L_2 + L_3$ . Now if we take suppose this is the top jaw, the bottom jaw, this length it is called  $L_1 + L_2 + L_3$ .

If, we take this length, so here as per this picture  $S_1$  less than  $S_2$  ok, less than  $S_3$ .  $S_1$  is the lowest value followed by  $S_2$  and  $S_3$  is little bit high. Now if we take the gauge length as  $L_1$  and  $L_2$  and  $L_3$  total length if we take, in that case, what will be the strength of the yarn? The strength of the yarn will be  $S_1$ . If we take that means, in this case, if we take the strength of the yarn is  $S_1$ . Now if we take the yarn another test, if we do, if we perform, in that case. so here another test, it is test 1, another test if we take that, we are now trying to break we are now trying to reduce the size, reduce the specimen size. So this is  $L_1$ ,  $L_2$ ,  $L_3$  ok. Now if we test the  $L_1$ , this  $L_1$  what will be the strength? Again should be  $S_1$ , lowest. Now if we test the  $L_2$  then the strength will be  $S_2$  which is more than  $S_1$ . Again, if we take  $S_3$  it will be  $S_3$ , so in this way if we can reduce the size ok. Now here, if we see with the smaller

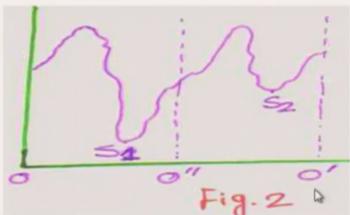
length, if we test the mean strength will be; so if we take L1 and L2 the mean strength will be  $S_1 + S_2$  by 2 because in this portion the strength will be  $S_1$  the next portion the strength will be  $S_2$ . So, the mean strength if we take, means strength  $S_1 + S_2 / 2$  which is numerically more than  $S_1$ .

So, that means if we reduce the size of the specimen for the same yarn the actual, the strength, which is actually a reported strength will be more, but the yarn is same. So breaking strength is the load at the break, at the weakest point of a specimen of a specified length ok. Now for the length L1, the breaking strength is  $S_1$  and so on,  $S_1, S_2, S_3, S_4$  like this okay.  
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**Factors Affecting Tensile Results**

**a. Specimen length :**

✓ When we test two halves, i.e. OO", O"O', we get  $S_1$  and  $S_2$ , the average



$$\frac{S_1 + S_2}{2} > S_1$$


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Now, gauge length of OO dash. The breaking strength would be is  $S_1$  because it will break at  $S_1$  point. When the test; we test two halves so we can actually divided into two halves. One is OO double dash another is O double dash and O dash. So OO dash we are dividing into two parts in that case we are getting  $S_1 + S_2$  by 2 because we are taking to values and then taking the mean. So, that is how we are getting  $S_1 + S_2$  by 2, which is numerically, it is more than  $S_1$ .

So, that means it is in any standard test method as we have discussed when we are discussing the standardization of testing. So the length of the specimen is specified. Otherwise to show the higher strength one would like to test the material, add with that lower gauge length and to show and to prove that yarn is poor quality, he will start testing with the longer gauge length. So, that is why gauge length and effect of gauge length specimen length is very important to be fixed okay.

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## Factors Affecting Tensile Results

### a. Specimen length and irregularity :

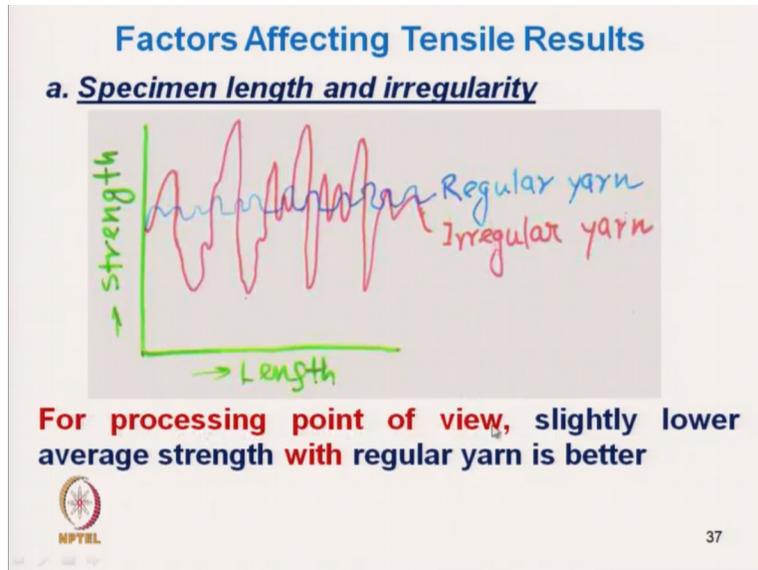
- ✓ Hence, by testing yarn with **shorter gauge length** the apparent yarn strength has increased. This effect is known as '**weak link effect**'.
- ✓ For **more irregular yarn**, the "effect" is more
- ✓ **Hence by adjusting gauge length, the test result may be changed**



So, this specimen length and irregularity, so hence here if the irregularity is more so the yarn is having higher irregularity in that case S1 and S2 difference of S1 and S2 will be more. So, if irregularity is less in that case S1 and S2 will be very close that means effect of fibre, the specimen length will be less okay. So, hence by testing yarn with shorter length, the apparent yarn strength has increased. This effect is known as weak link effect.

So, yarn breaks at weakest point and as we go on reducing the gauge length apparent strength of the material will increase ok. For more irregular yarn as I have explained this weak link effect will be more because the S1 and S2 difference will be more ok. Hence by adjusting the gauge length the test result maybe changed that is why for any standard test that gauge length has been fixed, any testing any tensile testing gauge length is most very important okay. It has got a direct impact on their test result. So standardizing of gauge length is important.

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Now, specimen length and irregularity, so this is the regular yarn blue one is a regular yarn and this red one is the yarn, which is irregular. But if we see that this yarn with higher mean length mean strength still regular yarn with little bit lower mean strength is better. For processing point of view slightly lower average length with regular yarn is better. So, that is why for, particularly in weaving for warp yarn irregularity very important. So we normally do not; it is difficult to measure the length regularity, strength regularity because strength value is there, strength CV is there so which one is important?

Strength CV or strength value, first for weaving particularly in warp yarn it is the strength CV which is important. So, two parameters are given 2 yarn one yarn is weaker yarn, little bit weaker yarn, but better strength CV one should also one should actually go for the better yarn better irregularity with little bit lower strength ok  
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## Factors Affecting Tensile Results

### a. Specimen length and irregularity:

Peirce's empirical equation:

$$S_l - S_{rl} = 4.2 (1 - r^{-1/5}) \sigma_l$$

$$1 - \frac{S_{rl}}{S_l} = 4.2 (1 - r^{-1/5}) \frac{V}{100}$$

$$V = \frac{6l}{S_l} \times 100$$

$$rl = r \times l$$

$\sigma_l$  = Standard deviation of strength result at gauge length 'l'.

$S_l$  = Mean strength measured at length 'l' (higher  $S_l$  is at lower length)

$S_{rl}$  = Mean strength measured at length 'rl'

$V$  = CV% of strength



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Here this Peirce's has given actually empirical equation, is derived empirical equation which shows the effect of specimen length on strength. Now let us see carefully here,  $S_l$  is the length of yarn. Okay mean strength sorry  $S_l$  is the mean strength measured at the gauge length  $l$  ok. Higher  $S_l$  is that lower length,  $S_l$  is actually mean strength of yarn measured at the length  $l$  and  $S_{rl}$  is that means strength of yarn measured at length  $rl$ . What is  $rl$ ?  $r$  times of  $l$  suppose if  $l$  is say  $l$  is 10 its value, so 10 centimetre, so  $rl$  if it is  $rl$  is 20, so  $r$  will be 2, so 2 times of 10.

So,  $S_l$  is  $S_{10}$  supposed 10 at 10 centimetre gauge length the strength is  $S_l$  at 20 centimetre gauge length the strength will be is  $S_{rl}$  where  $r$  value is 2. That means the  $S_{rl}$  will definitely will lower than  $S_l$  always because the gauge length, higher gauge length will result lower value. So,  $S_{rl}$  is the value which is lower than  $S_l$  ok that means this value will be less than one  $S_{rl}/S_l$ . So,  $S_l - S_{rl} = 4.1 * 1 - r$  to the power  $-1/5$ th multiplied by this the standard deviation ok.

Standard deviation of breaking strength, standard deviation of strength  $\sigma_l$ , this formula is been developed by; this is the empirical formula is been derived by Pierce based on large number of experiments. Just by rearranging here what we can get is  $S_l$  is the length,  $S_l$  is the mean length, mean strength sorry,  $S_l$  is the mean strength of yarn at length  $l$  ok. Now we divide both the term both the sides by  $S_l$ , so  $1 - S_{rl}/S_l$  and here this right hand side tab would be that  $\sigma_l$ , that is your; it is standard division by the mean strength standard division of strength by mean strength multiplied by 100, it will be the CV%.

So, that means it will; that standard deviation by strain it will be CV% by 100. So, this term; this has been rearranged in this fashion. So this is the equation. So here from there we can predict the strength at different gauge length.

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**Factors Affecting Tensile Results**

**a. Specimen length and irregularity:**

$$\frac{S_{rl}}{S_l} = 1 - \left[ 4.2 (1 - r^{-1/5}) \frac{V}{100} \right]$$

$$r \uparrow \frac{S_{rl}}{S_l} \downarrow \text{ and } V \uparrow \frac{S_{rl}}{S_l} \downarrow$$


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So, this is the term here. Now here, what we can see is,  $r_l$  as we have discussed,  $S_{rl}$  will be less than  $S_l$  the ratio; from this equation, if we just rearrange this equation once again, we will get this equation that means  $S_{rl} / S_l = 1 -$  this within bracket and 4.2 and this value ok. Now here, if we see what will happen, if  $r$  is 1, suppose  $r$  is in this equation  $r$  is 1 means, is that at the same gauge length we are testing, we are not changing gauge length.

If  $r$  is 1 means we are not changing the gauge length  $r$  is 1 here ok. Okay? Now, what will be happen  $r$  is 1 means this value will be 1 ok and this total value will become 0  $1 - 1$  the total value will become 0, that means  $S_l = S_{rl}$  that means for same gauge length it is predicted that gauge length if we keep gauge length the mean length will be same ok. We are not taking care of other factors. Here we are talking only specimen name.

Now, let us see what happened, If we increase the  $r_l$  the  $r$  value, if we increase the  $r$  value this  $r$  value, so there will be some positive value here, so, this value will be reduced will be lower value ok. This if we increase it from 1 to some other value, so this will be earlier it was 0. Now what will be the value? It will have some value; some parameter this value will be less than 1, so earlier it was 1, so it is less than 1 so that it will have some positive value. So, that means 1 minus some positive value.

So, this value will reduce, okay as  $r$  value is increasing gradually. So this will also increase with increase in  $r$  this value will also increase. So, this right hand side value will reduce will be lower, so  $Sl$  value will be  $Srl$  value, as  $l$  is constant is  $rl$  value will reduce gradually. So, that means with the increasing in  $r$ ,  $Srl/Sl$  will reduce. So, this we can get. So if we know  $V$  and  $Sl$  one should be able to predict  $Srl$ .

If the variability; we have seen the variability in possess that the yarn strength is reducing ok. Now with this equation here, suppose the  $CV\%$  is increased, if  $CV\%$  increases so this total will increase okay, that means this value will decrease, so  $Srl/sl$  will also decrease. So, this ratio will decrease  $Srl / Sl$  this ratio decreases with the increase in  $r$  value means; which means it is the specimen length and the  $V$  value.

$V$  value is nothing but the specimen irregularity. So, with the increasing irregularity and the specimen length, this  $Srl/Sl$  actually reduces. Okay, so that means we get the lower strength, lower actual lower strength with the increase in the gauge length and with the increase in variability.

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**Factors Affecting Tensile Results**

**b. Rate of loading and time to break:**

- Most textile materials show an increase in breaking strength with increasing rate of extension together with a decrease in extension
- Due to visco-elastic nature of textile material, they require certain time to respond to the applied stress
- Different types of textiles (fibres/yarns/fabrics) respond differently depending on the structure

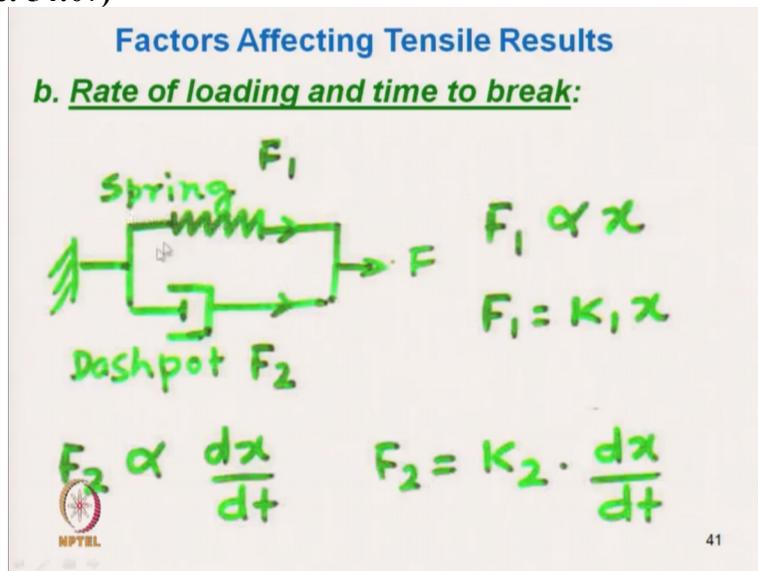
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Now another important parameter, we will discuss. It is a rate of loading and time to break. The tensile characteristics, the strength of the material, it changes with a rate of loading. That means at the rate at which rate we increase extension rate of loading. So that changes the tensile characteristics. Earlier we have seen the with the changing the gauge length, the tensile strength changes, so apparent tensile strength changes.

Here also, if we increase the rate of loading and time to break, so then the tensile characteristics will change, so most textile materials, so increase in breaking strength, with the increasing rate of extension. So, with the increasing rate of extension, the breaking strength, will is it changes together with decrease in extension that is the nature of any viscous-elastic material. The textile material is one of the most important viscose-elastic material.

So, due to viscose elastic nature of textile material that require certain time to respond to the applied stress. So, due to this, the rate of loading, it affects the rate of loading ok different type of material like fibre, yarn or fabrics respond differently depending on the structure. But in general the structure is like this.

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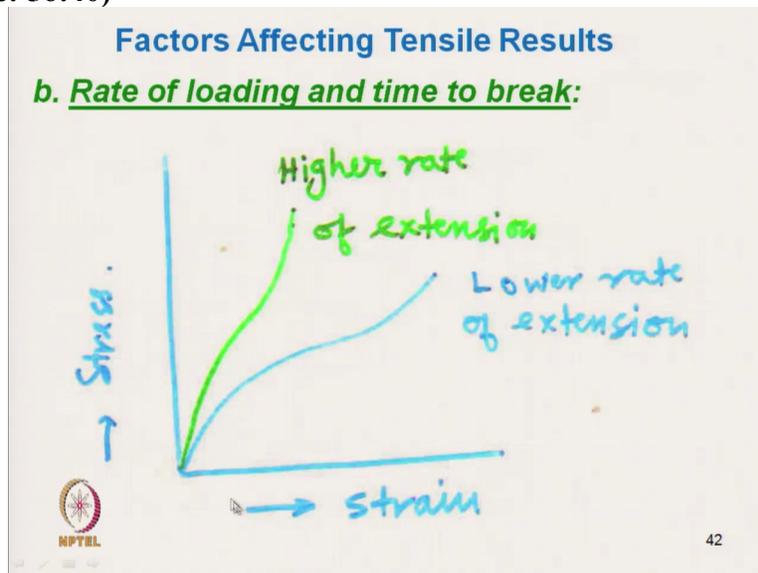
It is called spring dashpot model. So in the spring, dashpot, if we see carefully here, it has got two components this is the simplest model where these are in parallel spring and dashpot are in parallel. The spring equation is that spring when we apply force, F on the textile material; suppose it is a model for yarn or any textile material. So here it is any textile fibre also. So, here if we apply force, it has got two components.

F1 component which is actually represented by spring F2 component which is by dashpot for spring, the equation is that a force increases with the extension. Suppose we are extending by X, so the force increases with extension and force is proportional to the extension. So, here  $F = K_1 X$ ,  $K_1$  is called spring constant. So, as we increase the extension so the force will increase, it is proportionality.

But in case of dashpot, what happens, the equation is that the force increases but with the rate of increase in; at the rate of extension increases. But in case of dashpot, if the rate is very slow very low then dashpot will actually exert very low pressure. Okay. So, if it is very low then force will be very less. But as the rate increases, the dashpot will actually exert very high force. That due to this the dashpot this  $K_2$  is dashpot constant its proportional to the  $dx/dt$ , that is the rate of extension..

So, as the rate of extension increasing so, due to the  $F_2$  components the textile material actually exerts more force that is why due to the increasing rate of loading or rate of extension tensile characteristic increases.

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So this picture shows that the lower rate of extension, at lower rate of extension this is the curve and the same material with the high rate of extension. It has become stiffer and it shows higher strength. Now we will stop here. We will continue with this discussion in the next class. Thank you.