Evaluation of Textile Materials
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Lecture No -18
Evaluation of Tensile Properties of Textile Materials

Hello every one, today we will start one new topic which is Tensile Testing. In last classes what we have seen, we have discussed that, the yarn characteristics we can test by it is linear density or there are various other characteristics. Fiber characteristics we have seen, which, we have seen that by length, we can express and measure the length and related characteristics, length variation. Then we have seen that the finess of the yarn we can test by various methods and maturity of cotton we have discussed and then linear density of yarn.

Now, in this topic, we will discuss the tensile testing. Here tensile testing, it is actually divided into three distinct categories. One is in the tensile testing of fibre, next is, tensile testing of yarn, and then tensile texting of fabric. So, three different measurement techniques, but, if you see the basic principles, basic theories of all this three types of testing are almost same. We get similar parameters; we will discuss all these aspects in this session. So, why tensile texting of tensile materials are important?

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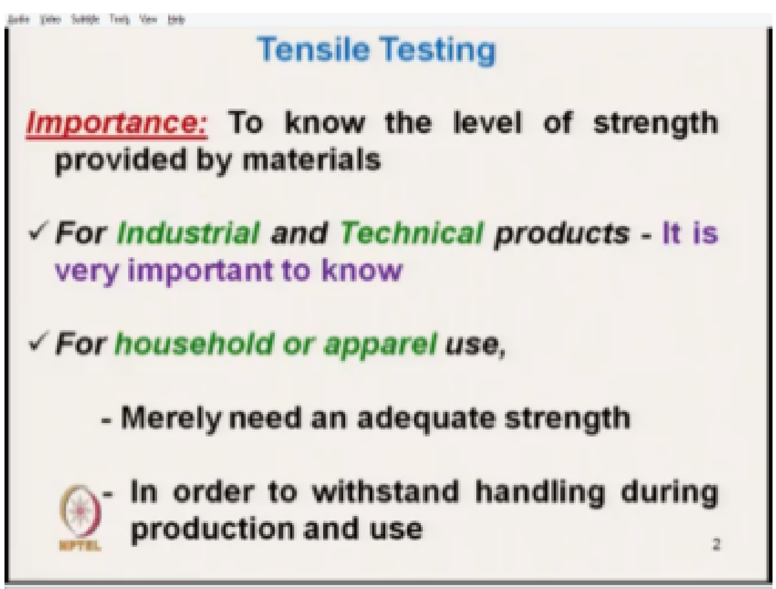

So, why do you know, why do you want to know the tensile characteristics? It is just to know the level of strength provided by the material, okay. What is the strength of the material, okay? That, we must know because at which load it will fail, that it must know. But that particular value, it is very important for industrial and technical products, okay? This is very important because in those appliances this strength, breakage of material, it is extremely you should know the; extremely important to know.

Because that, like, let us take example, rope. In rope, if we do not know the, it is breaking strength or stress stain characteristics, then, it may fail during it is actual use. So, any industrial application, like filter fabric or maybe Geo-textiles, we must know the strength characteristics, its breaking strength, its elongation. All these characteristics, we must know, but for apparel application, house hold applications, so this importance, although we must know the tensile characteristics but it is importance is not as that in-case of industrial textiles, okay?

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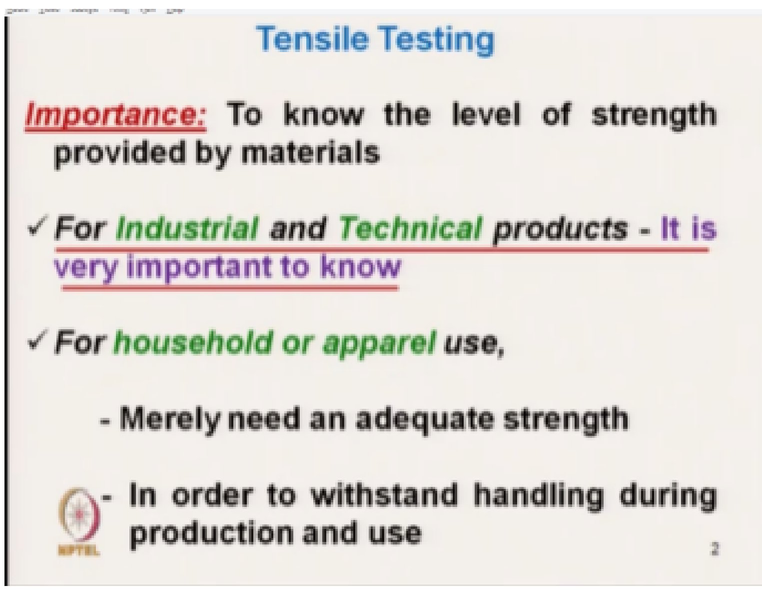

So, because, in household or apparel, never apply that level of force where it breaks. So, merely it is needed to for adequate strength is needed. So, during handling it should, actually the product should not fail, okay? In order to withstand handling during production and use, like, we need that much strength of yarn so that it should break during weaving.

So, that much; if we have excess strength, by imparting, by using, various very sophisticated, very high tenacity fibre, that means we will, unnecessarily add to it is cost. So, for fabrics for apparel application, we do not need that much strength but for technical application, definitely, for like composite making we must use yarn or fabric with very high strength. So, in those applications, it is extremely important to know the actual strength, even strength related characteristics.

Now Let us see what the factors are which affects the strength of textile materials. First is that, molecular structure of fibre. So, if the orientation, molecular orientation is high, and then it is stress strain characteristics will totally differ, will change. So, higher molecular orientation will result better strength characteristics, number and intensity of weak places. So, if the weak places are high, so basically, strength of any material is the strength of it is weak point.

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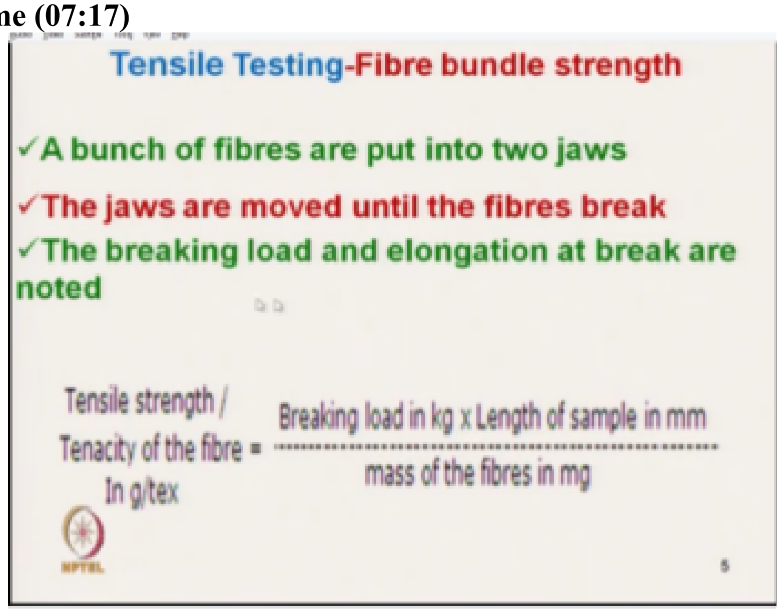

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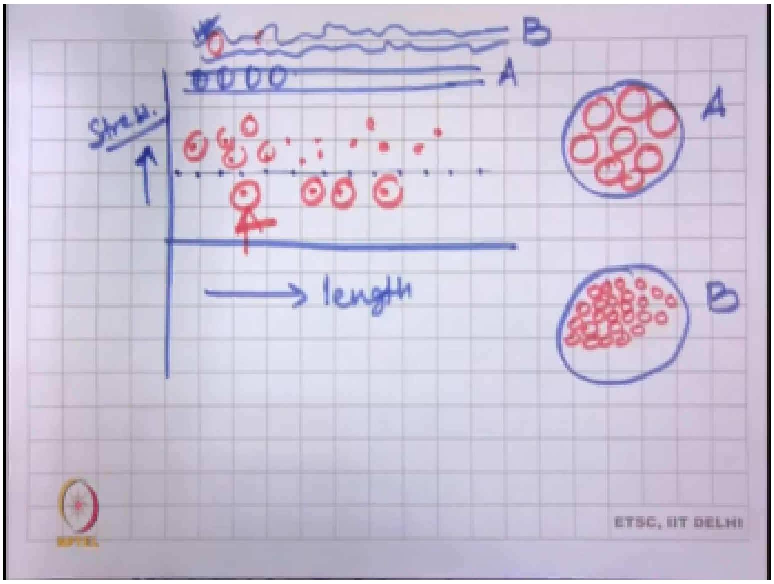

So, a yarn, with, say lower mean length let us see, this is the mean value, okay, one yarn, this is the length along the yarn ok from the yarn. Suppose this is one yarn, an even yarn, yarn A. Another yarn which is uneven, yarn B, now the yarn A has got, this is the strength, breaking stress. So, this yarn A, if we see theoretically, at A, each and every point, okay, that the strength it will be approximately be the same. Because this yarn is uniform and the number of fibres in the cross-section yarns are the same. So, this yarn has got almost uniform strength along the length at different point. If we test strength here at this point, at different point, the strength will be almost same.

But if we test the yarn B, suppose this yarn we have produced the very good fibre, it is a very strong fibre. So, at different point this yarn strength will be different. Suppose , mean strength is very high, okay, so strength is higher than the strength A of the yarn A , so, but, what we have observed that few points where due to unevenness there will be weak points are there, okay. So, few weak points are there and when we test it does not matter the other places, it is very strong. It will break only at weak point.

So, that is how the yarn will fail, okay. So the number and intensity of weak places will result weaker here. So that is why the yarn which is uniform yarn with relatively lower strength is preferable and is better than the yarn with higher mean strength but it is non uniform. Coarseness or fineness of fibre, so coarser fibre will result, let us see so cross section of two yarn A, B of same component. Yarn A is made of the coarser fibre and yarn B is made of fine fibre. Linear density of these two yarns is same as this yarn B is made of finer fibre and the number of fibre is more.

And also the specific surface area, surface contact of fibre in yarn B is much more than yarn A. So that due to the finer fibre so the yarn strength relation will be more in case of B. Third factor is relative humidity and temperature. So, as you know textile material, most of the textile material absorbs moisture. They are hygroscopic in nature. There are fibres like cotton with the increase with the absorption of humidity, the strength increases. But on the other hand fibres like viscous yarn after absorbing moisture the strength drops.

So, the relative humidity of the during testing if it varies the that for same yarn will get different result. And also temperature although not directly affect, but if it is too high, to high temperature, very high temperature, then fibre may get degraded and it affect the strength, also at too low temperature at zero temperature at that temperature, so some time few polymeric fibre they may be brittle and it affects the strength characteristics , so the relative humidity and it is temperature we must maintain, that is why it is suggested that to test the yarn at any textile material under standard atmospheric condition.

And then next is the elasticity. Elasticity also affects the strength characteristics of the material. We will discuss all these characteristics. When an external force is applied to any material and it is balanced but the external force developed in the molecular structure. That is how we get stress strain characteristics.

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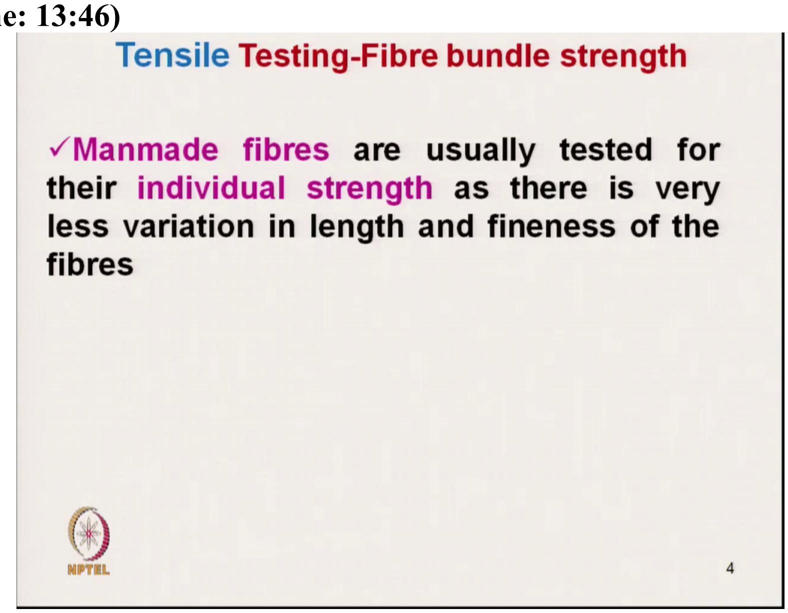

Manmade fibres are usually tested for their individual strength. So, the fibres we can test in two ways, in the single form and in the bundle form. So, most of the manmade fibres will get in the long continues length form that is why it is easy to test in the individual fibre strength. We can test as there is less variation in it is length and fineness of fibre. So, it is available in long fibre and in continues condition. And in manmade fibre another advantage is that it is a uniform in nature in terms of fineness.

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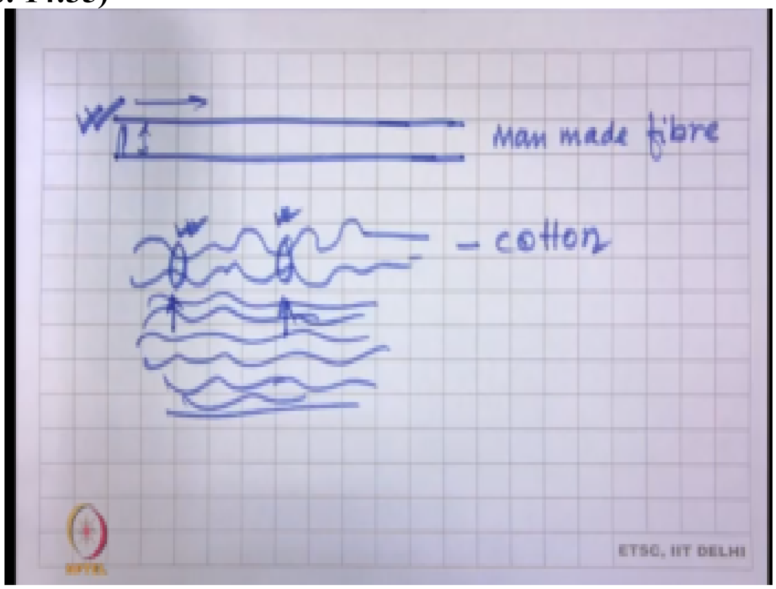

As we have seen earlier, this is a manmade fibre; another is nature fibre like cotton. Now it is easy to test the fibre in the single fibre form. The advantage of manmade fibre is it is diameter wise towards the lengthwise it is totally uniform. Across the total diameter the cross-sectional shape or diameter is same through the length, but in case of cotton it varies. If we test the cotton in single fibre form it will always break at the weakest point.

Because variation in diameter, variation in all these parameters finesse, so it will always break in it is weakest point so, we will land up with the value which is much lower than it is capability. Another reason is that in manmade fibre, as I mentioned there it is available in continues form. So, to minimize this variability, what we must take a number of fibres together. So bundle of fibre we take together and then we test.

Like in bundle form, suppose this is the cotton. We do not test the fibre in single form, because it is almost difficult to handle a single fibre of short length. Instead of that we take a bundle of fibre this is the bundle, and then try to break the bundle, and try to measure the bundle. After that the simple calculation we can convert into fibre tenacity, fibre strength characteristics. So, natural fibres are tested for their bundle strength due to high variation in terms of length and fineness.

So, that is the reason why the natural fibres are tested in bundle form. It may be cotton, may be jute or different natural fibres.

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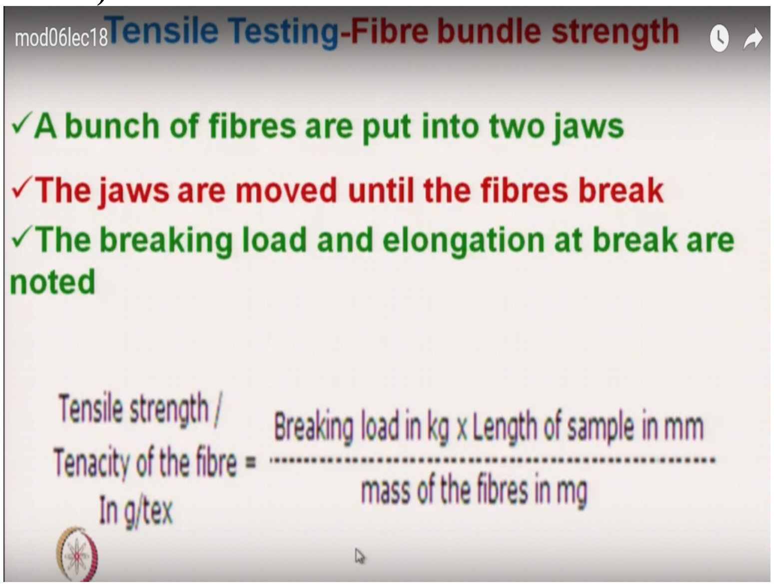

So, in bundle strength a bunch of fibres are put into a jaw. Two jaws are there, so by gripping the two jaws, so bundle of fibres are put then we try to break the fibre and measure the breaking strength. The jaws are moved out until the fibres are break. The breaking load and elongation at break are noted ok. And tenacity of bundle in terms of gram per tex is measured is equal to breaking load in kg multiplied by length of the sample, length of the bundle. We can measure the length of the bundle by different length measuring instrument, there bundle length is fixed. That if you know the length of the bundle and then what you have to do after breaking, we have to take the mass of the bundle. So, in bundle strength testing we have to take the mass of the bundle then we can convert the strength in term gram per tex.

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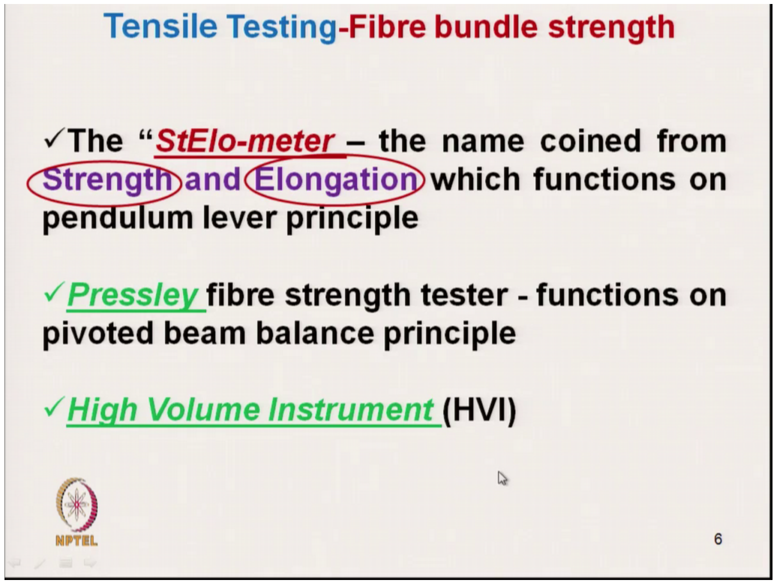

There are various instruments those for measuring the strength and elongation characteristics of bundle, one of them is stelometer, in stelometer the name came from strength and elongation. St from strength, elo from elongation, the stelometer which measure the strength and elongation of fibre bundle and which works on pendulum lever principle. So, we will discuss the details, in the principle of this instrument. Another instrument is there it is Pressley fibre strength tester. Pressley fibre strength tester also measures the fibre bundle strength tester, but here the working principle is beam balance principle ok. It is a pivoted beam balanced principle. These two instruments, stelometer and Pressley fibre strength tester, there calculation are exactly same.

Even there, fibre jaws are interchangeable ok that is why the bundle of fibres, the jaws can be interchangeable. We can use Pressley jaw also in stelometer sometime. And another instrument that we mentioned earlier also in high volume instrument HVI we test in bundle form, but not like, will not be like Pressley or stelometer, here bundle will like a comb. Directly the comb which has been used for the fibre length measurement that same comb is used for breaking.

It breaks the fibre in comb form ok, so that is in bundle form ok. These are the three instruments which measures the fibre, particularly cotton fibre in terms of; in the form of bundle.

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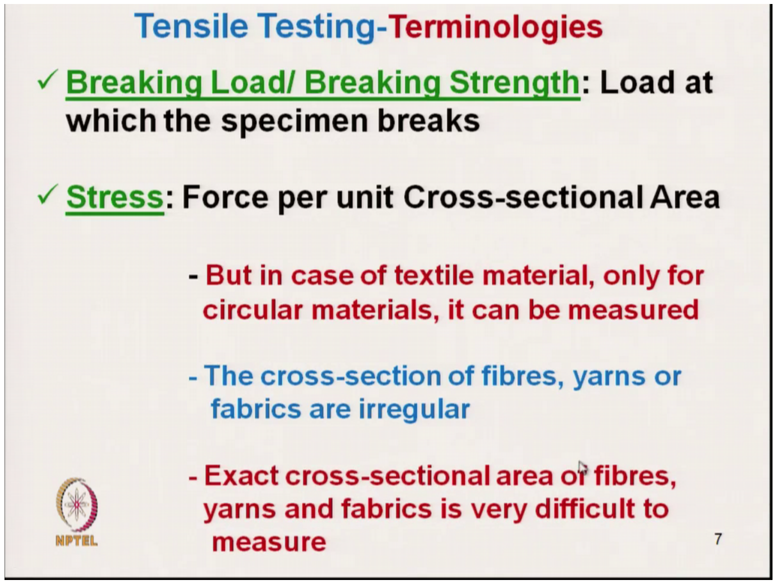

Now we will discuss the different terminologies which are used to express the tensile characteristics of textile materials. And these terminologies are; few terminologies are specially for textile materials. But many other terminologies those are for in general any engineering materials. First is breaking load or breaking strength. This is very general terminology; it is load at which the specimen breaks. That is the breaking load. Simple, that is it measure for fibre it is centiNewton or Newton. So, that type of load, any load measure the; at which the specimen breaks. Then stress, stress for any engineering material with specific cross-sectional area is measured by force per unit cross sectional area ok.

But in case of textile material as we have discussed already while discussing the fineness or linear density measurement, the fibres or any textile materials, they are not circular in nature or as matter of fact any normal specific size neither it is circular, nor rectangular or it is the cross sectional shape is totally random. So, in case of textile material we cannot use the stress in terms of cross-sectional area, load per cross sectional area. So, cross section of fibres yarns and fabrics are irregular. So, exact cross sectional area of fibres, yarns and fabric is very difficult to measure, we cannot measure exactly.

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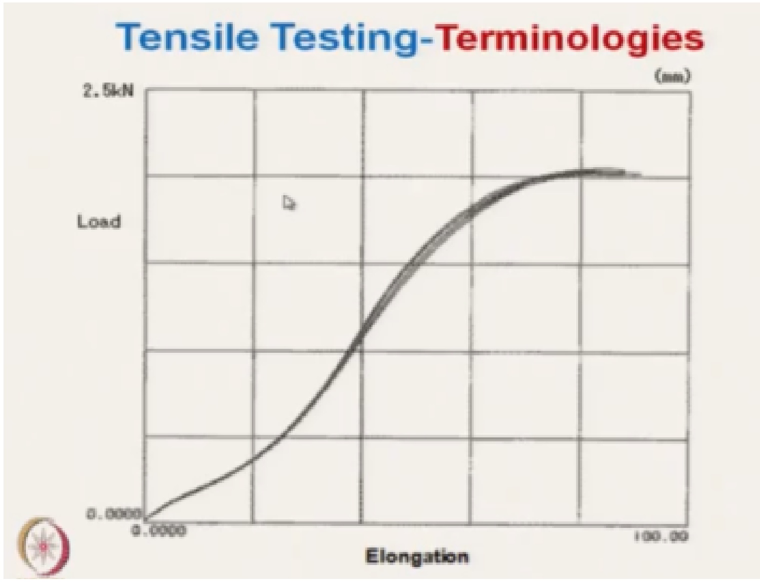

So, we cannot use the term, in-terms of stress, in terms of mass or force per unit cross sectional area. So, this is the typical stress load elongation curve for any fibre or textile material.

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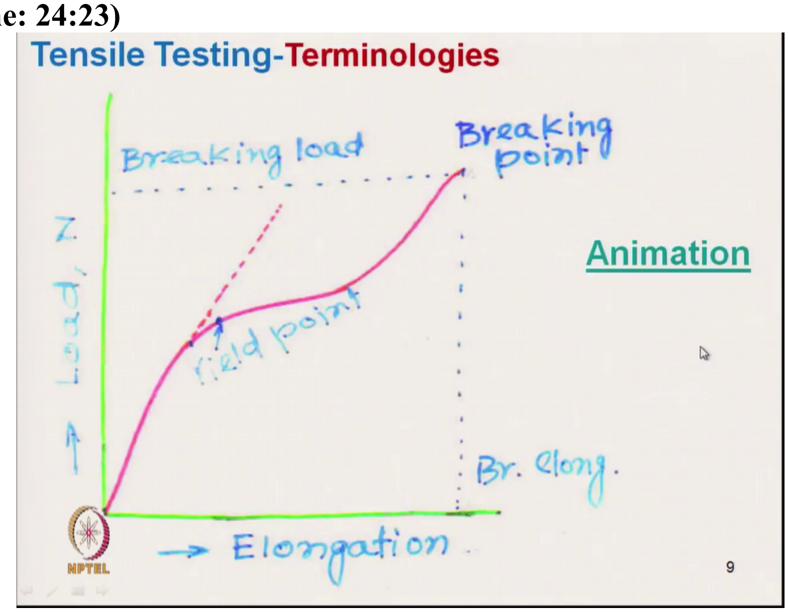

Now try to see here, this is the typical curve I have drawn, so this curve is taken from almost this type of fibre. So here this is straight point where the load increasing with the elongation in the linear increase so this is the hook's region ok after that yield point then again there is a increase in the stress load ok and this is the breaking point and at this point the material breaks. So, this point if you see this is the breaking elongation horizontal distance and the vertical distance is called breaking load. Let us see the animation here.

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This is the elongation and this one is the load ok, so, in the load elongation curve, at the point where there is a sharp bent it is called yield point. And this height, this is the breaking point and here from X as origin this is the breaking elongation and this is the breaking load y axis distance is the breaking load. Now if we see the stress-strain curve this is the load elongation curve. If you see the elongation curve the nature is almost same ok, this is the breaking point, at this breaking point this height is called tenacity, here is called breaking load, but here it is called tenacity that is breaking stress, other term is tenacity. And the horizontal distance is known as the breaking strain. So this is the stress-strain curve ok.

And we can easily convert the load elongation curve to stress-strain curve. Because if we know, if we want to convert the load elongation curve to stress-strain curve what are the parameters required. We must know the initial gauge length, initial length. So, we can calculate the stress from elongation ok. And for calculating the stress we must know the linear density. Which linear density? Initial linear density, always wants to remember.

Here we have to divide the load with the initial fineness, initial linear density in tex. Because as we increase the yarn as we extend the yarn or textile material, that tex value changes. But we do not care of that part; we only divide by the initial linear density ok. Now that is the process measurement.

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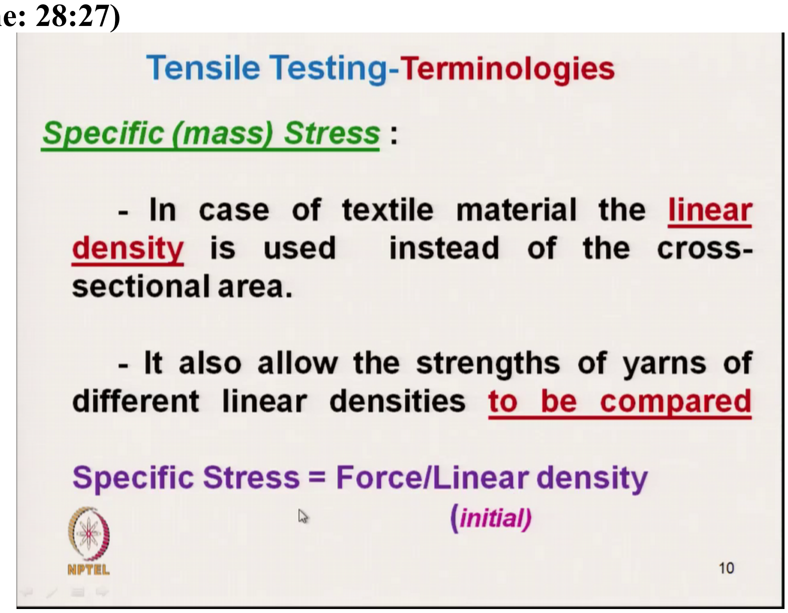

Now next is that specific stress that is called mass stress. So, as we have seen in textile material, we cannot measure the stress in terms of load per unit cross section. Here specific stress is measured by the, it is not the stress, we call it as specific stress or mass stress. In this case we do not divide it by the cross-sectional area; we divide it by the linear density.

As we have seen the linear density is proportional to the cross section, so the value will be actually it is proportional, we get the indicative value but the actual numerical value may be different, but it is comparative value. So, in case of textile material, the linear density is used instead of cross-sectional area. So, here we can absorb in fineness we have absorbed that instead of cross-sectional area we have converted to linear density here, also we converting the stress to specific stress.

So, it allows, it also allows the strength of yarn of different linear densities to be compared. So, suppose let us take one example.

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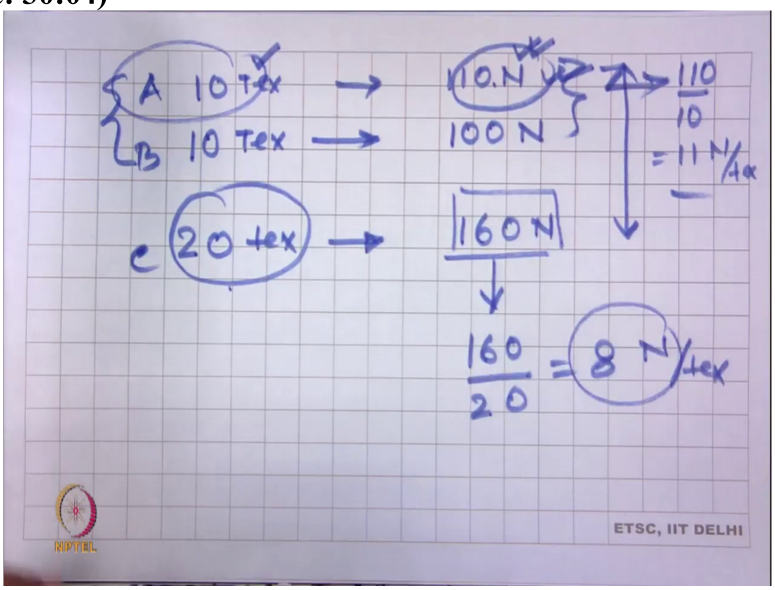

One textile material, say of 10tex has strength 100N, now another material of coarser material has 20 tex it has got the strength of 160N ok. Now how can we compare if another if yarn of 10 tex has strength of say 110 N then we can say among these two yarn we A, B, C between A and B, so this A is stronger that we see but if we want to compare A and C which one is stronger here the complexity is that it is of different linear densities.

So, to compare this, we convert this strength to stress mass stress 110/10 this is 11N/Tex whereas this yarn C will have 160/20=8 N/tex. So, that means yarn A is stronger than C in terms of specific strain. Although, the yarn actual breaking load is high in case of yarn C but which one is stronger strength wise, the yarn A is stronger because it has got higher specific stress. So, Specific Stress = Force/ Linear Density which is initial linear density one should always remember that it is initial density. Otherwise linear density always changes.

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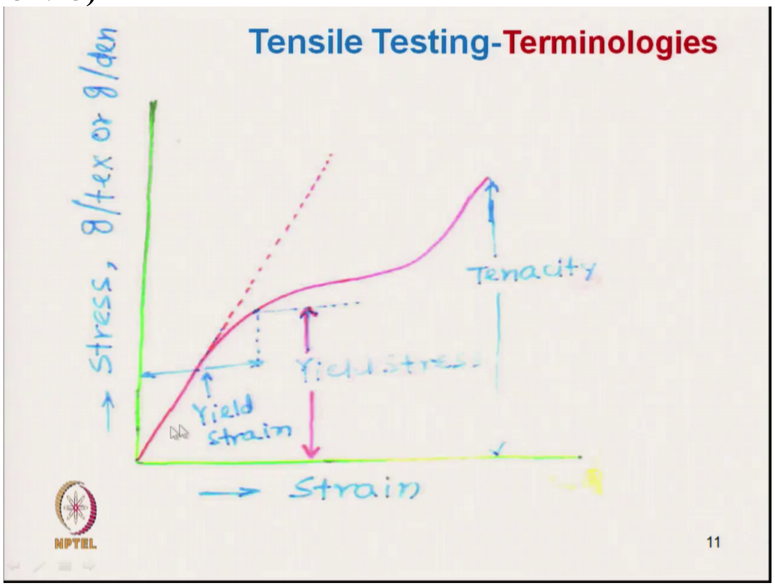

Now these are the different terminologies yield stress, yield strain, tenacity this I will just discuss.

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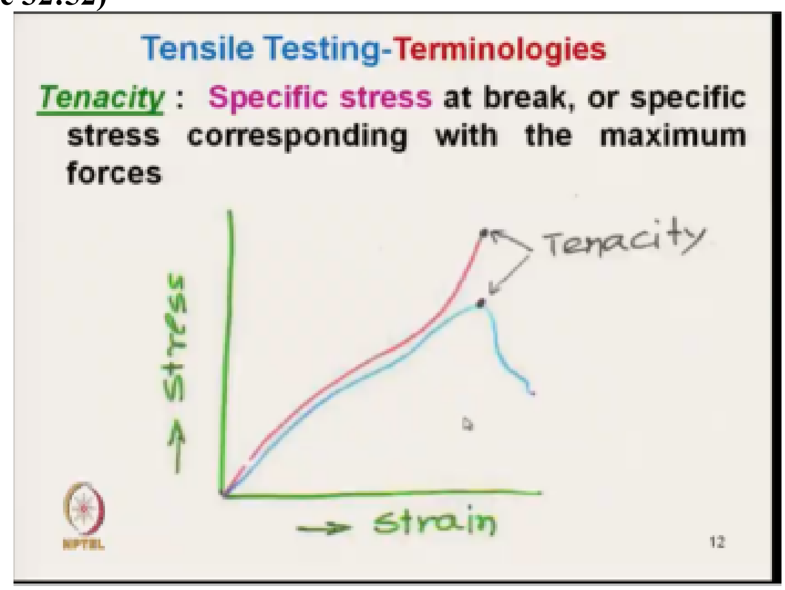

Tenacity, what is that, specific stress at break that is the tenacity or specific stress corresponding to the maximum force, this we should remember. So, we normally get confused that student get confused that which one is actual stress giving a curve one has to actually identify one has to calculate that specific stress or tenacity. Tenacity specific either specific stress at break all specific stress corresponding to maximum force which one is higher that is the stress.

Now we can see from these two curves, this pink curve we can see that is the breaking point is the highest point that is why this stress we can called it as tenacity. But the curve with the blue curve after reaching the maximum point, this always we observe this type of behaviour particularly in staple yarn. After reaching; this you absorbs as filament yarn because after breakage starts, it does not break catastrophically, due to sliding the slippage of fibre it also carries some load.

So after, reaching to it is maximum point, where fibres start breaking so here it carries some load for some time. So where should we can take the tenacity at this point or this maximum point. For this case we must take the tenacity for this case as the maximum point.

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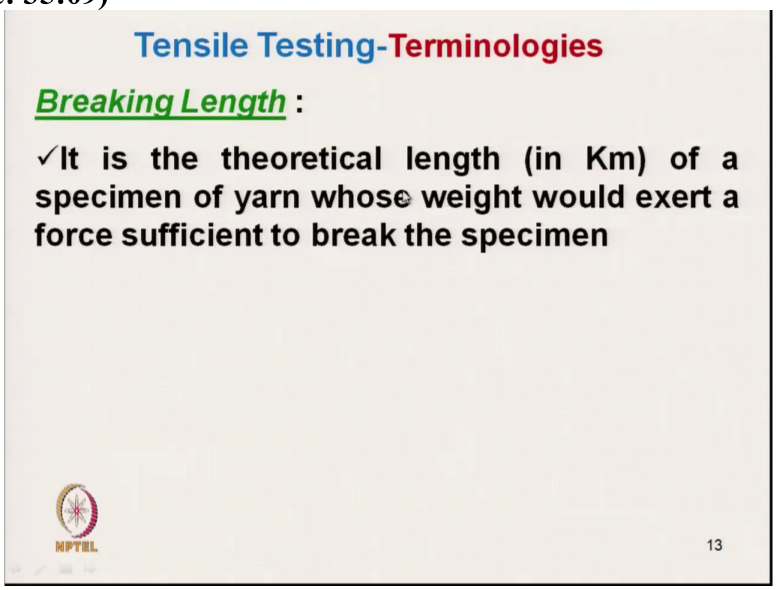

Next term is that breaking length what is that, it is basically the length of a yarn by it is own weight it will break? It is theoretical value; it is theoretical length in kilometre of specimen of yarn whose weight would exert a force sufficient to break the specimen. So, theoretically if we see, if we keep on unrolling from the space without any air disturbance vacuum if we imagine so if we keep on unrolling and till the yarn on its own weight when it break yarn that length is known as, breaking length and it is expressed in terms of kilometre. So, that is why breaking length actually termed as RKm from the breaking length.

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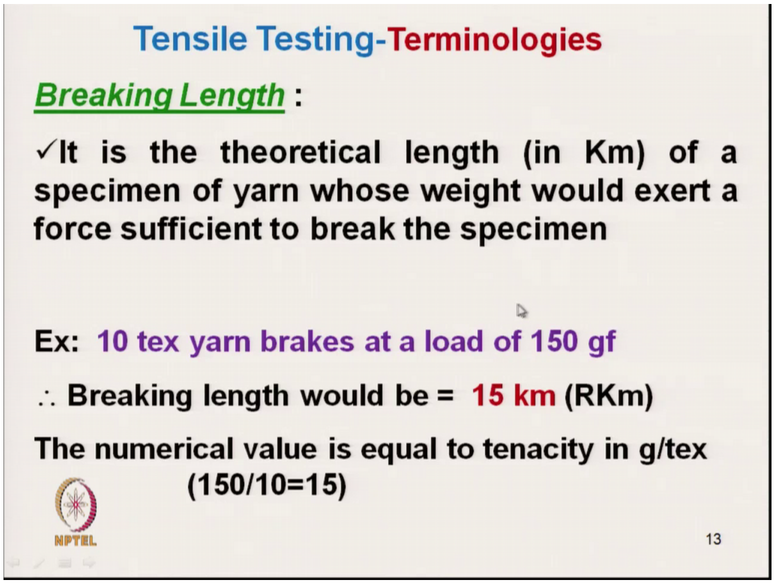

So, now let us see 10 tex yarn breaks at load of 150 gf. That is the condition here one tex yarn breaking at 150 gf what will be the breaking length in kilometre? Breaking length, so, let us see breaking length would be 15km because we can see here10 tex means 10g ok 10 gram of yarn length will be 1km. 1km yarn length 10gm ok that means 15gm, 150gm is the gramforce will have 15km length. 15 km yarn will weigh 150 gf.

It exert force of 150gf ok that is why it is called RKm, R came from breaking and Km for kilometer, RKm is the term Which we use normally and it is basically and numerically the value is exactly same as the gram/tex. So, this is the gramforce per tex of course 150 divide it by tex so 150/10 is 50. So, this two terms are exactly same. And we can see in yarn trading these days it is called the breaking RKm value.

RKm value means we do not actually measure the breaking length we measure the gram/tex and it is called gram/tex.

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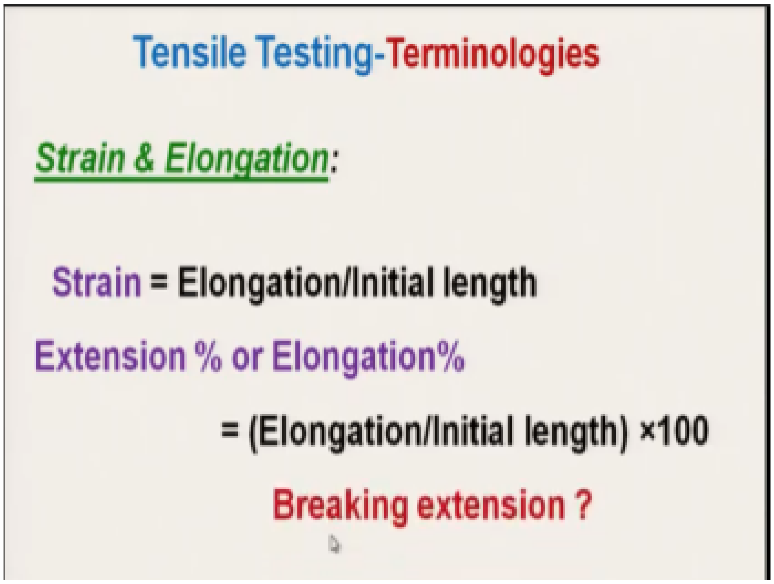

Now we must clearly understand the difference between strain and elongation. What is strain? Strain is the elongation/initial length but the ratio of elongation and initial length that is the strain which is unit less. But elongation has got the unit of length and extension percent or elongation percent what is that elongation and ration of elongation and initial length multiplied by 100 this is the extension. This term Strain and Elongation is used in any engineering material, any material we can use. It is not specific for textile material. And what is breaking extension? That is the extension at which material breaks.

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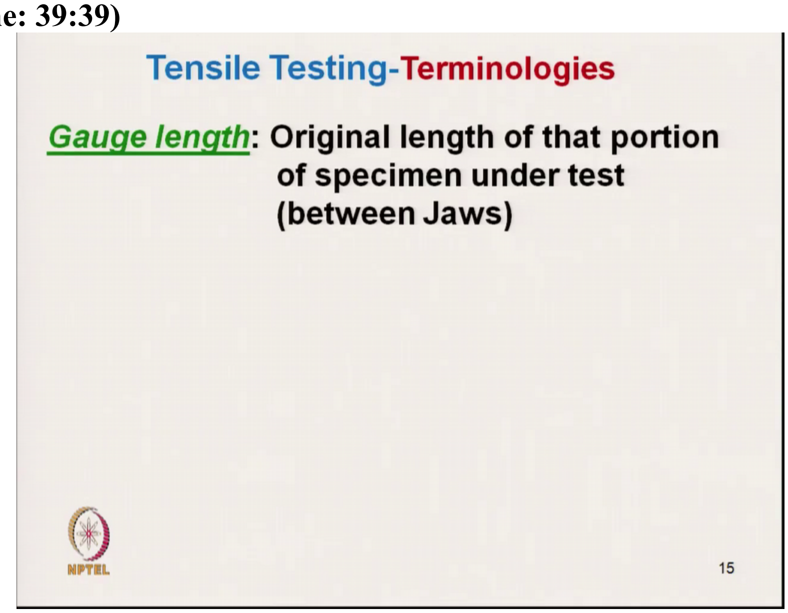

What is gauge length? Gauge length is another term it is the length between jaws ok original length of that portion of specimen under test.

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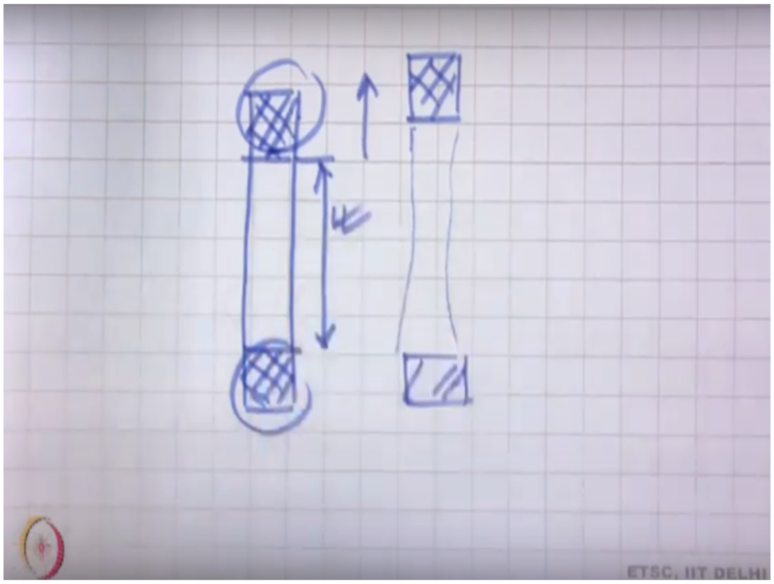

Now let us see, suppose this is our fabric specimen now what we do, we use top jaws we have gripped here at the top and at the bottom. What will gauge length? Gauge length will be actually the actual length of the specimens under the test. So, we do not consider the total fabric length this is the specimen length and gauge length is less than that is the gauge length that is the original length of the material and between the jaws.

Now when it is extended suppose it is extended up to this point even before breakage point, this has been extended so still this will be the gauge length, gauge length is the initial length between the jaws. Now let us try to understand clearly the details of stress-strain curve.

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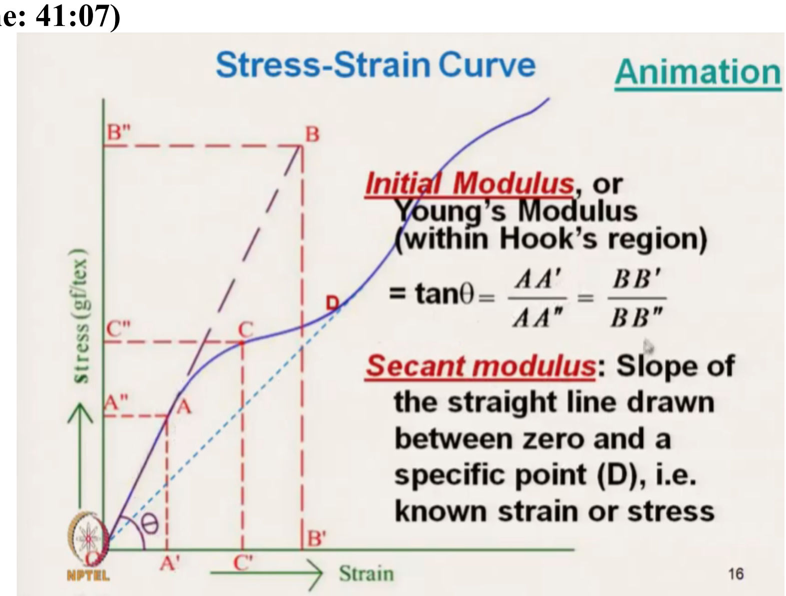

What are the different parameters? We will try to understand with the help of animation. So here, the terms of the initial modulus very commonly used in textile material or Young's modulus this is the modulus within Hook's region, where stress is proportional to the strain, straight line, so, up to the point A, this is where the proportionality that region if we measure the modulus that will be the initial modulus.

So, it is expressed in terms of tan theta that means AA dash vertical distance by AA double dash. This is the ratio where we express the initial modulus. If we extrapolate this line for easy calculation, that means, BB dash /BB double dash. So this is the stress/strain. So that is the, this is tan theta ok. Initial modulus strain/stress this one is the AA dash, so strain/stress. So, AA dash is the stress and AA double dash is the strain strain/stress we can get. This curve is stress-strain curve. So, initially it is a straight line curve that is why it is called initial modulus. Another term is called the secant modulus.

So initial modulus is another parameter which is actually useful to get the stress-strain characteristics at a very initial level just to the modulus ok to know what is the toughness; modulus of the material. But during it is stress strain path one may like to know the stress strain modulus at any point. That means the slope of stress strain line drawn between zero point initial origin and the any specific point D of known stress or strain.

That is called the Secant modulus at that point. So it is expressed at secant modulus at certain strain, secant modulus of the material at say, X strain or say X stress so again at this point stress/strain. So that will draw the vertical line stress and the horizontal line stress/strain that will give us the secant modulus.

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Now let us see here. This is the typical stress-strain curve along with the initial line is been drawn AA dash stress AA double dash is strain. So, here we can see the initial modulus tan theta AA dash/AA double dash BB dash / BB double dash. Now this is the point where sudden bend is there. So that point is known as the yield point. This is the yield point and the distance so OC dash is the yield stress and this distance is the yield stress and OC double dash is yield ok sorry OC dash is the yield strain and OC double dash is yield stress. So this is the yield point. So we can calculate the yield stress and yield strain.

This is the called yield point. Now a particular point is drawn the secant modulus, slope of the straight line so this is exactly not showing the slope of the straight line drawn between zero and a particular specific point D and that is how we can get all the this animation is not showing the tangent but it is a; tangent we can take this is the slope at any point this is the slope ok. And here it is a breaking point. And this distance OE, OE dash is the breaking strain and OE double dash is the breaking stress. So these are the terminology we can derive from stress-strain curve.

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Now OA elongation is due to, this is OA, during this OA that is Hook's region here the elongation is due to the stretching of primary or secondary bonds. That means it is not breaking the bond it is here only primary and secondary bonds has been stressed. As there is no breakage of bonds so this will come back, this will return this will totally recoverable. And this is the Hook's jaw which is called elastic jaw.

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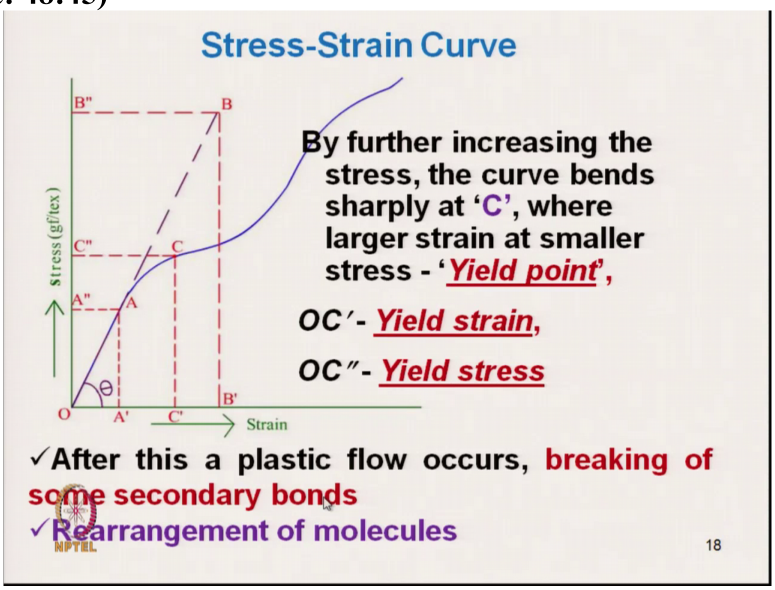

Because within this hook OA zone breakage of bond. Now once it crosses what will happen? By further increasing the stress the curve bends sharply at C suddenly it bends where large strain occurring with small increase in stress. So, that it gains towards the x axis. So, the large strain is occurring with small increase in stress. This particular point is known as yield point and OC dash is yield strain and OC double dash is yield stress.

After this the yield point plastic flow occurs breaking some secondary bonds. So here, there will be plastic flow that means if it increases stress is increasing than whatever the deformation will be the plastic deformation. So it will not come back. Because there are there are breaking of secondary bond and during this due to breakage of secondary bond the molecular rearrangement takes place.

So, what happens molecular starts sliding there will be excess strain due to small increase in stress but molecular rearrangement takes place during that time? Once the molecular rearrangement takes place that means molecules becoming straightened and rearrange once again then it will again try to impart some stress. So in that case straining will be difficult with a small strain again this stress will increase little bit.

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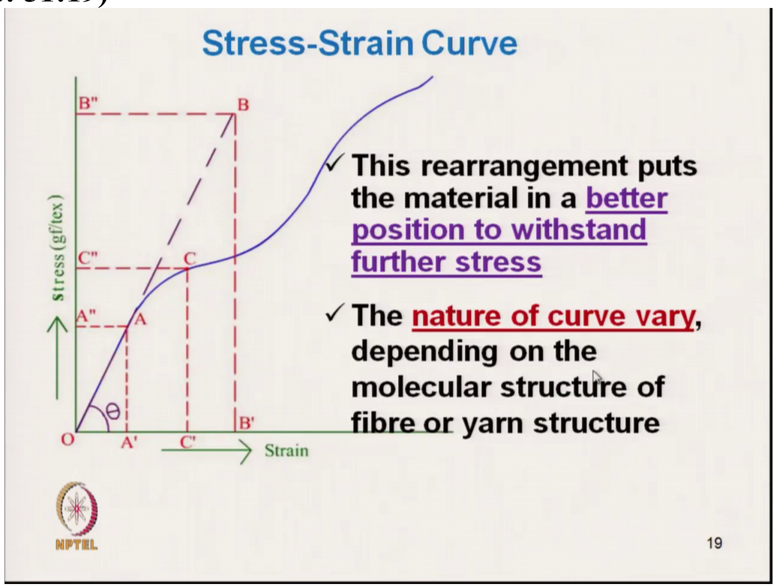

So this rearrangement puts the material in a better position to withstand further stress, that means from this point onwards, so here the breakage is taking place from C to say D point any other point if it is asked what is happening from C to D so here what happens the secondary bond breakage starts takes place and molecular rearrangement is occurring. So, this rearrangement put the material in better position to with stand further stress. Here the material in better position than again it is increasing.

Otherwise what happen if in this point so all the molecule starts breaking and the bonds start breaking then it would have dropped here, it would have failed here. Here molecules are rearranged that means again it has got capacity it gats capacity to actually take more load. So, that is why again it is increasing. The nature of curve it varies, it varies depending on the molecular structure of the fibre or yarn.

So, depending on the molecular structure this nature of curve changes, so there are various factors on which nature of curve depends ok. As the molecular orientation it more, then that means curve will be totally little bit steep. Like molecular if we see if we see the jute and cotton.

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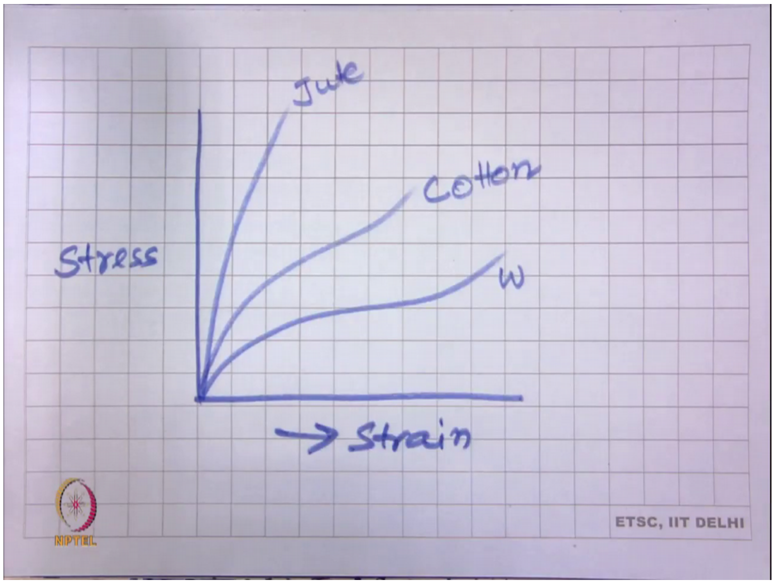

Now let us see, so, this is; these are the three fibres natural fibres this is for wool, this is for cotton, this is for jute. So this difference in nature it is basically due to the molecular structure so, depending on molecular structure nature of curve changes.

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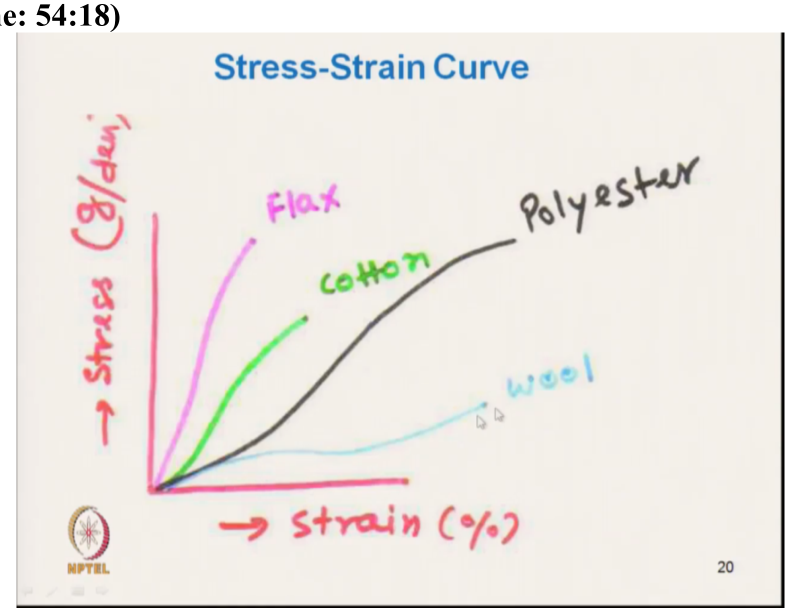

See, wool, polyester, cotton, flax so it changes depending on the molecular structure. Flax has got very high modulus ok due to structural orientation of molecule. So, we will stop here and continue in the next class.