Testing of Functional & Technical Textiles
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Lecture - 1
Testing of Low Stress Mechanical Properties of Textile Fabrics

Hello everyone. So, we will start today the first lecture on the course Testing of Functional and Technical Textiles. In the first segment as I have mentioned earlier, that we will discuss the functional textiles that is the clothing's used for functional aspects. First we will deal with the Low Stress Mechanical Characteristics. Basically by low stress mechanical characteristics, we mean that the fabric or clothing when we wear, how it interacts with our body as per as fabric handle is concerned.

A fabric, a clothing maybe very good as far as the transmission characteristics is concerned like moisture transmission, thermal transmission, or air transmission. But, if the fabric handle is not proper, then it will not be able to perform its function. So, that will be totally uncomfortable. So, the measurement or testing of low stress mechanical characteristics is extremely important.

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So, fabric handle it is for industrial fabrics, the performance characteristics are very important, like for filter fabric it is a filtration characteristic. For composite there are many other characteristics, their performance characteristics are important. A geo textile, its strength and other characteristics important, but for functional textiles handle is extremely important, whether the fabric is smooth or rough, stiff or limp or it is draping quality. So, or frictional characteristics, its surface roughness, its shear characteristics all these characteristics are extremely important.

So, in this segment we will discuss all these low stress mechanical characteristics.

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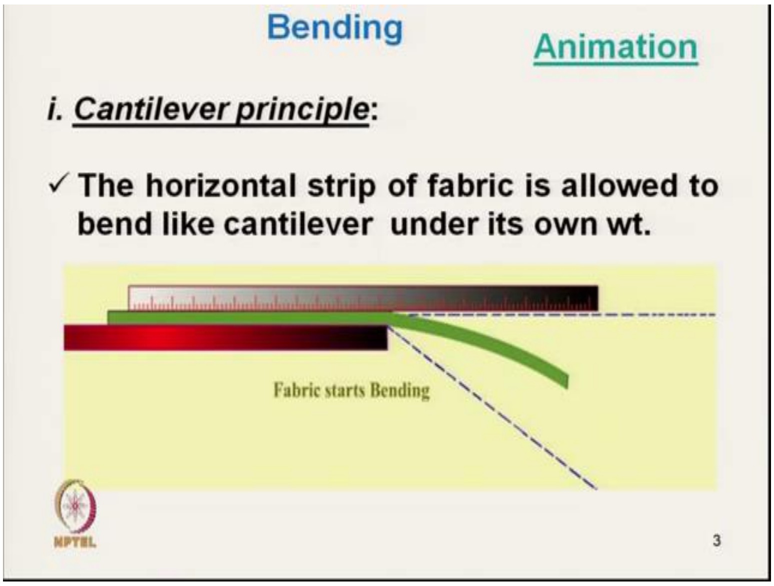

So, first let us see the standard method of measurement of one of the most important low stress mechanical characteristics is the bending. So, the method which we use to measure the bending characteristics is called cantilever principle. So, the common method is Shirley stiffness tester, where we test the horizontal strip of fabric is allowed to bend like a cantilever under its own weight. Like suppose this is a fabric sample and in a horizontal platform if we hang; under its own weight this fabric will bend.

So, from this bending angle or from the overhanging length we can calculate the flexural rigidity of the fabric. So, this is the principle, where the fabric this a green colour, it is a fabric sample and this is the platform. And when we push the fabric, it bends, its the tip point, it is making an angle with the horizontal, it is a certain specific angle and from there we can calculate the bending characteristics of fabric.

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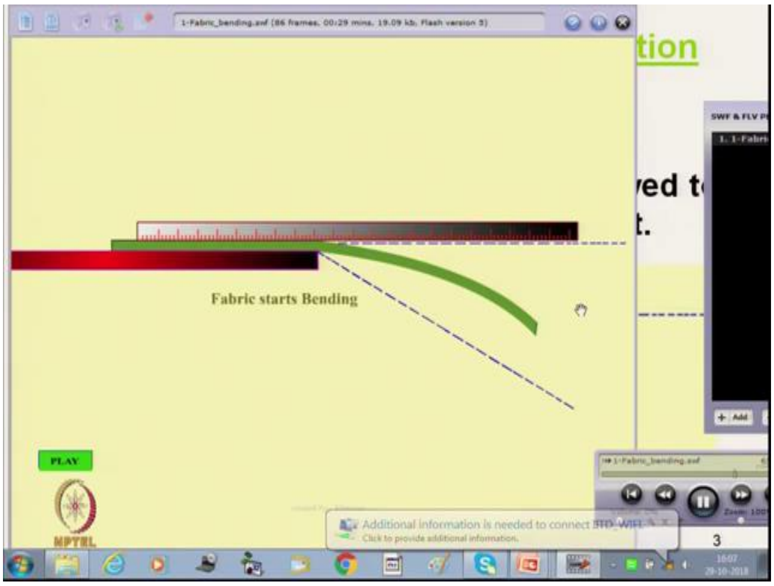

So, let us see the animation of this principle, now when the fabric is pushed and it is hanging like cantilever and gradually as the length is increasing overhanging length is increasing, its tip point it is making certain angle ok.

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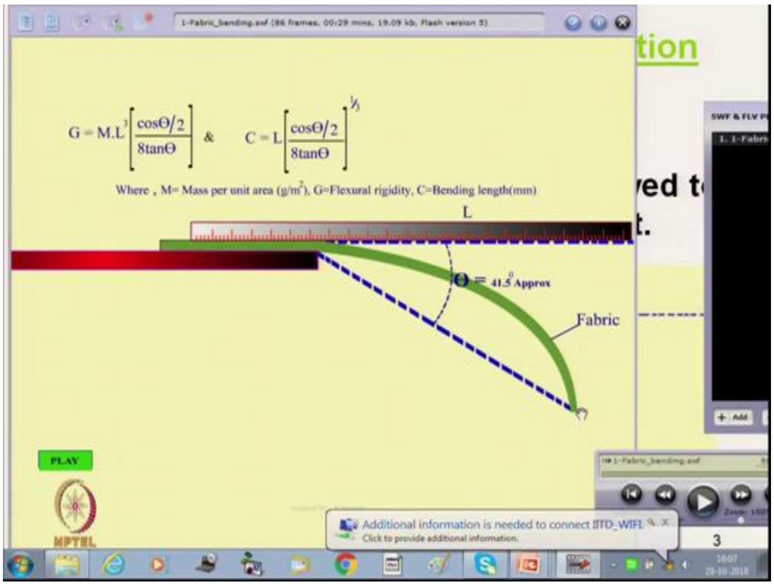

As soon as it is making a predetermined angle which is typically 41.5^0. So, that based on that angle, we can calculate different parameters, where G equal to G is the flexural rigidity of the fabric, M is the mass per unit area, L is the overhanging length of the fabric. And, with this equation

$$G = M.L^3\left[\frac{\cos\theta/2}{8\tan\theta}\right]$$

where θ is the angle the tip point of the fabric is making with the horizontal plane. And, C is the bending length

$$C = L\left(\frac{\cos\theta/2}{8\tan\theta}\right)^{1/3}$$

which is L is equal to the overhanging length. So, from there we can calculate the both the flexural rigidity and the bending length ok. So, if we know all these characteristics so, this will actually reflect the bending characteristics of fabric.

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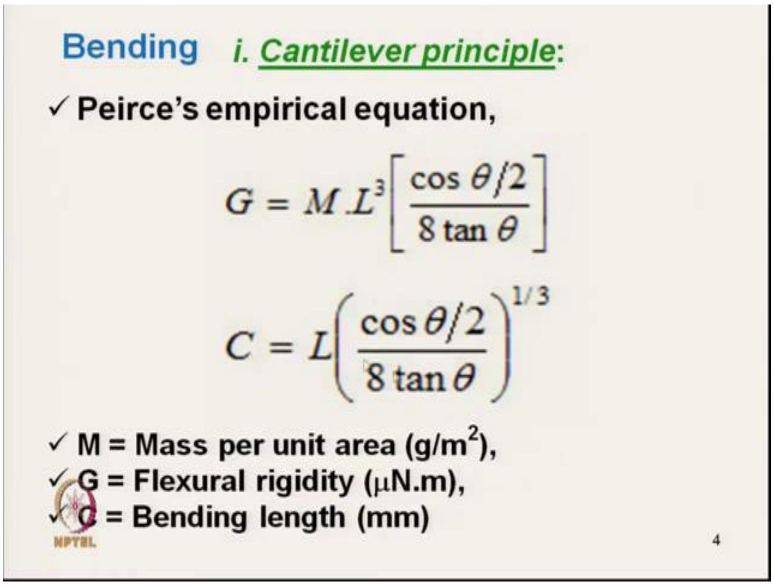

This formula these are the Peirce's empirical equation from the as I have already explained, where M is the mass per unit area, and G is the flexural rigidity in μN.m, and C is the bending length in mm ok. From there we can calculate this 2G and C these 2 parameter it, shows the fabric bending characteristics.

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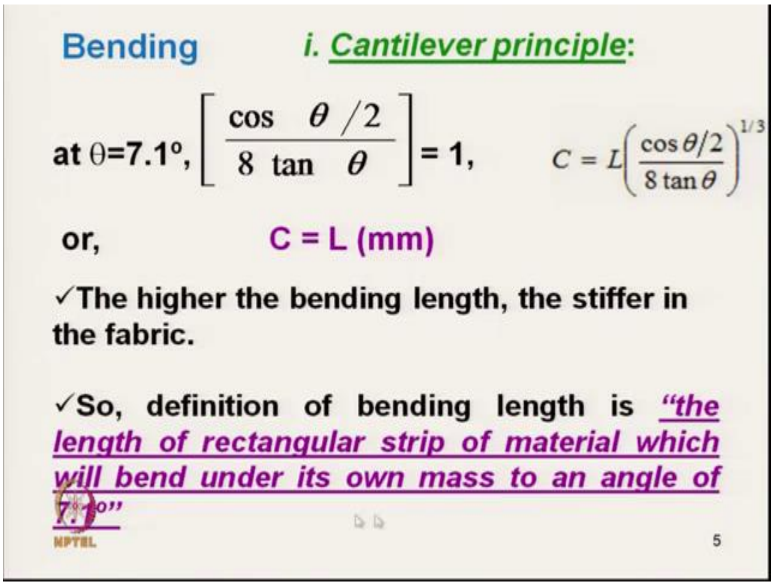

And, if we know this empirical formula from there we can calculate for ϴ equal to 7.1^0. This total parameter this, the right hand side parameter, it become 1 ok which means that the overhanging length is equal to the bending length for ϴ equal to 7.1^0 so; that means, the higher the bending length the stiffer will be the fabric. So, we can get the value directly from the overhanging length. The main problem is that we can have in our instrument the angle 7.1^0. In that case directly overhanging length will show the bending length, but the problem is that the fabric as the fabric is very very flexible.

So, measurement of 7.1^0 that it will come immediately after the hanging so, that is why we normally do not use the value 7.1^0. So, we can define the bending length C in this way that the length of rectangular strip of material which will bend under its own mass to an angle of 7.1^0. That means, the overhanging length L which will be which will make 7.1^0 with the horizontal, horizontal plane that will be equal to the bending length.

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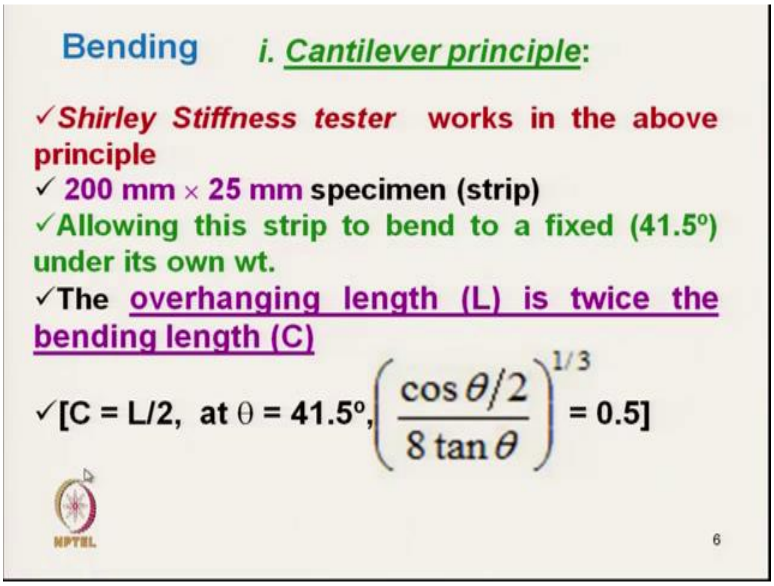

So, in Shirley stiffness tester it works in the same principle. So, where we use the specimen the width wise width of the specimen. So, this is suppose a specimen it is a 25 mm approximately 1 inch and it is a 200 mm it is approximately 8 inch ok. So, that is the specimen dimension. So, it allowing this strip to bend to a fixed angle 41.5^0 under its own weight. So, why is it 41.5^0 I will just come? So, the overhanging length L is twice the bending length C; that means, to make the equation simple it will make it will be twice than that of the bending length.

So, bending length will be exactly half to that of overhanging length to make the equation simple we keep it 41.5^0. So that means, if the ϴ becomes 41.5^0 then this total value, this function of ϴ will become 0.5. So, we can get directly C = L/2. So, to have this simple equation we have to keep this angle that is 41.5^0.

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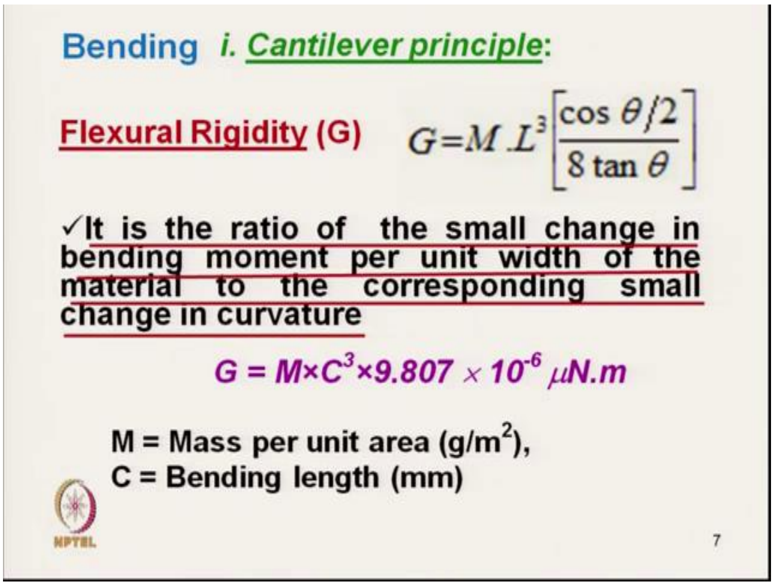

So, from there we can get the flexural rigidity which is

$$G = M.L^3\left[\frac{\cos\theta/2}{8\tan\theta}\right]$$

So, it is the ratio of small change in bending moment per unit width of the material to the corresponding small change in curvature that is the definition ok. And, we can calculate this G flexural rigidity in terms of μN.m with this formula

$$G = M\times C^3\times 9.807\times 10^{-6}\ \mu N.m$$

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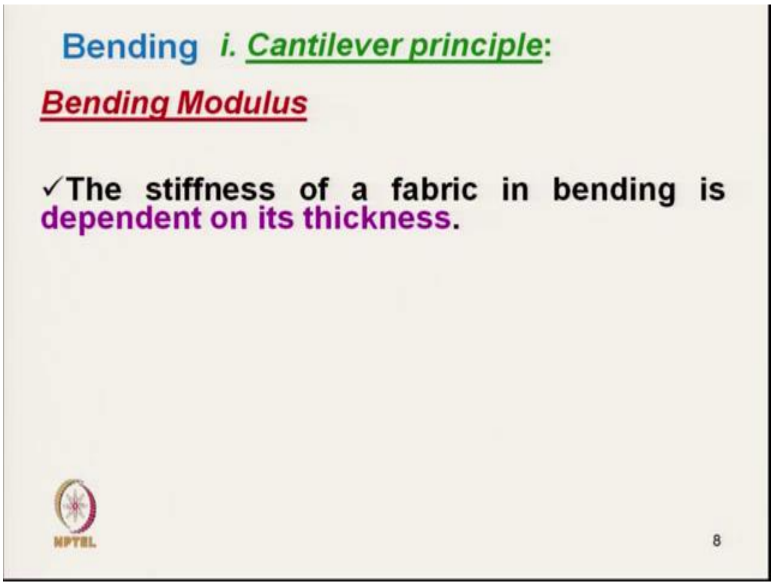

Where, M equal to mass per unit area in g/m^2, C is the bending length in mm and bending modulus it is a the stiffness of a fabric in bending is dependent on the on it is thickness; that means, for similar structure if we increase the thickness the stiffness will increase ok. So, if the flexural rigidity is same still we can have different bending stiffness, if we increase the thickness.

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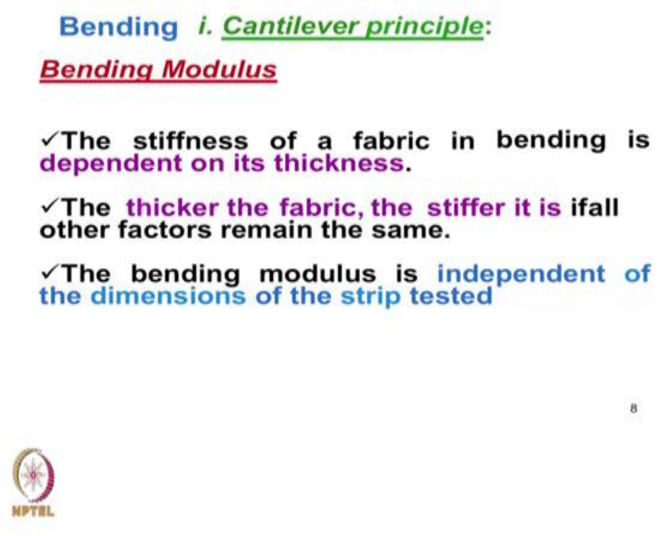

That is why the thicker the fabric the stiffer it is. So, if all other factors remain constant so; that means, we have to have certain equation certain parameter, which will be independent of thickness that is the bending modulus is independent of the dimension of the strip tested.

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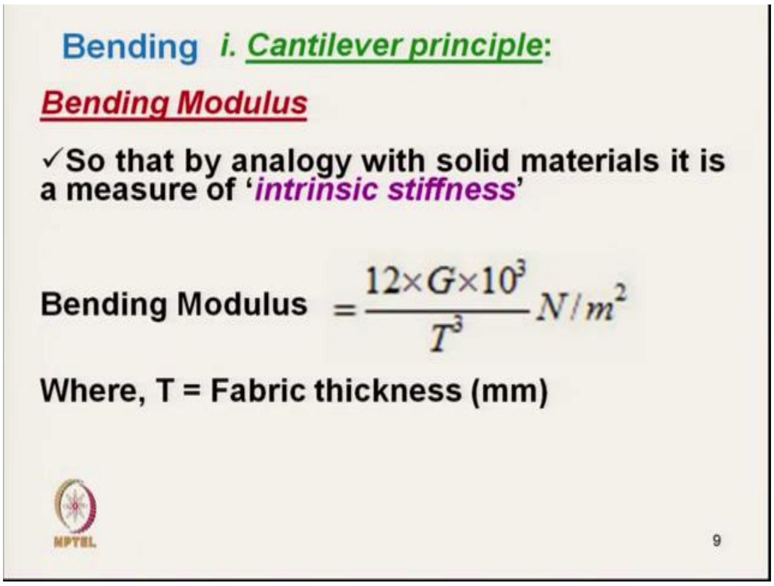

So; that means, it should be independent. So, that by analogy of the solid material it is the measure of 'intrinsic stiffness' ok. And, this intrinsic stiffness or bending modulus can be expressed in terms of

$$\text{Bending Modulus} = \frac{12 \times G \times 10^3}{T^3} N/m^2$$

where T is the fabric thickness. So, we can actually divide by T cube to get the bending modulus.

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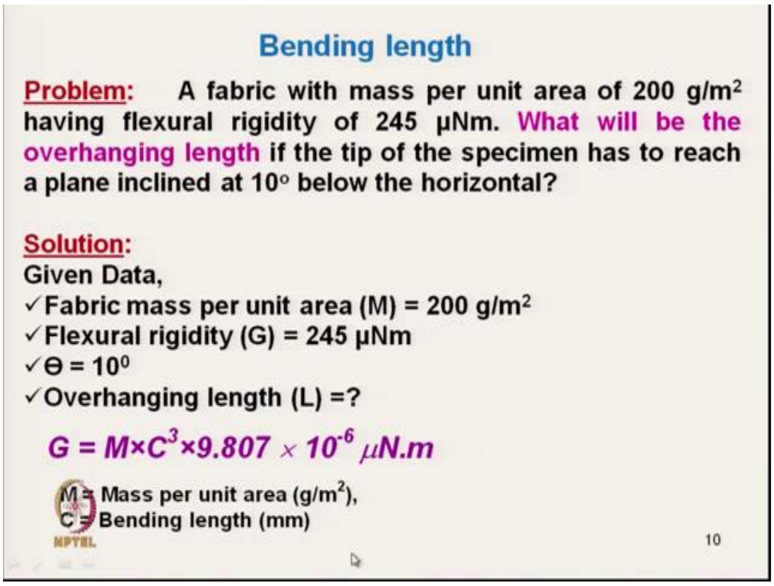

Now, let us try a couple of numerical to understand the how to achieve the overhanging length from different parameters known parameters.

So, here the problem is a fabric with certain mass per unit area that is 200 g/m^2, mass per unit area having flexural rigidity of 245 µNm, that is the flexural rigidity. What will be the overhanging length? If the tip of the specimen has to reach a plane inclined at 10^0 below the horizontal. So; that means, the fabric suppose this is the fabric of mass 200 g/m^2 and it has got flexural rigidity of 245 µNm Now, the question is that what will be the overhanging length you have to calculate when this tip will reach a point which is 10^0 below the horizontal point.

So, that is the question; now the solution we see the data which are given here. So, fabric mass per unit area is given 200 g/m^2, flexural rigidity is given G is equal to 245 µNm, theta is given 10^0 and we have to calculate the overhanging length. So, we know this formula $G = M \times C^3 \times 9.807 \times 10^{-6}\ \mu N.m$

that is the flexible flexural rigidity is known here. So, M is mass per unit area in g/m^2 and C is the bending length.

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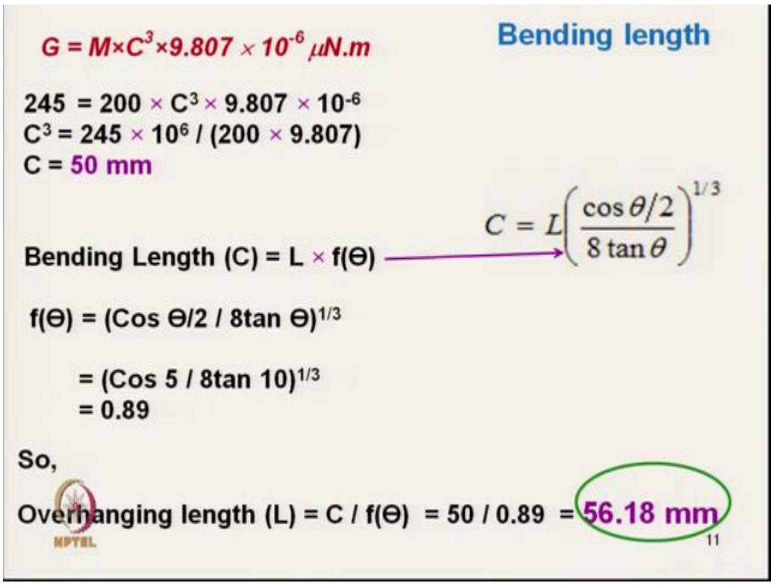

So, first we have to calculate the, we know the bending length. So, this is the bending length is C here. So, we can calculate the bending length from all the given data and here bending length comes out to be 50 mm from this data. So, bending length we have calculated and from there this is the formula by given by Peirce's formula as we have discussed earlier and using the data. Here C is known ϴ is known ϴ is here is 10^0 ok. So, from there, so, bending length C equal to L and function of ϴ this is the function of ϴ. So, from there we can calculate that f(ϴ)

$$G = M.L^3\left[\frac{\cos\theta/2}{8\tan\theta}\right]$$

So, theta is 10^0. $f(\Theta) = (\cos \Theta/2 / 8\tan \Theta)^{1/3} = (\cos 5 / 8\tan 10)^{1/3} = 0.89$

So, C form there we can calculate the overhanging length, if we know the value of C 50 mm, 50/0.89. So, it is coming out to be 56.18 mm so, which means that we have to have 56.18 mm overhanging length to have 10^0 when the tip of the fabric will reach 10^0 below the horizontal plane.

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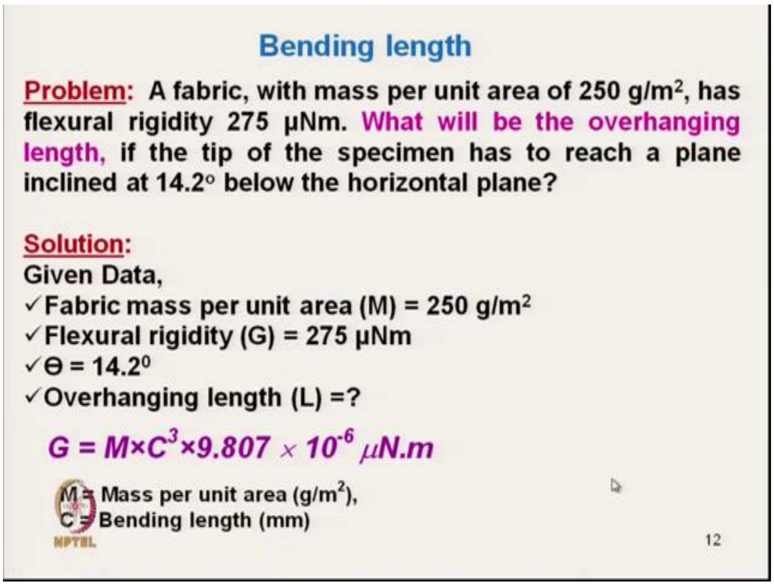

Similar problem another problem which is exactly similar to that, a fabric with mass per unit area of 250 g/m^2, has flexural rigidity of 275 μNm. What will be the overhanging length exactly same if the tip of the specimen has to reach a plane inclined at 14.2^0 below the horizontal plane?

So, the treatment will be exactly same as earlier. So, here we have to get the Ө value is known. So, we have to get the overhanging length. So, G is this is the formula which is given.

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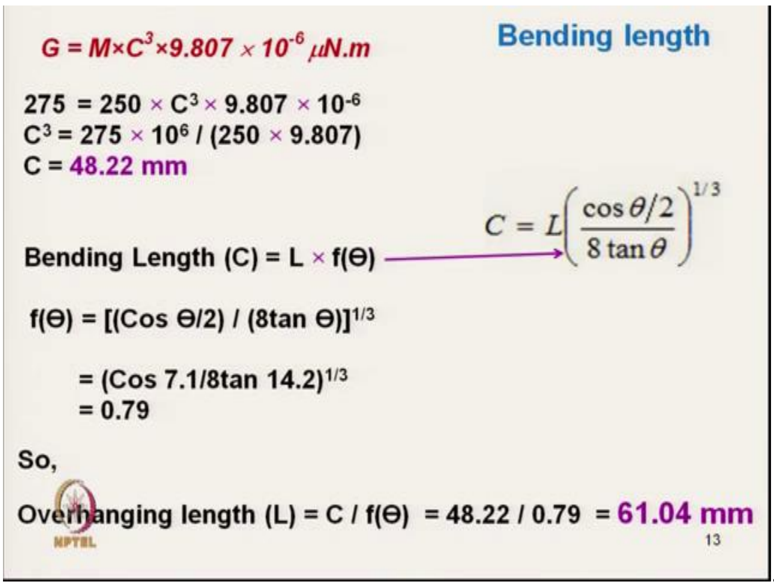
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So, from here from the given data we can calculate the bending length which is 48.22 mm and C = L, function of ϴ. So, we can calculate the function of ϴ if we know the angle. So, here angle is 14.2^0. So, 14.2^0 using theta equal to 14.2^0 we have got function of ϴ is 0.79. So, using this value we have got the value of overhanging length 61.04 mm; so, this 61.04 mm.

So, we can calculate any data anything, if we know the basic equations. So, after the basic bending so, this is the isolated instrument; so, there are different instruments which we can measure the low stress mechanical characteristics. Even we can use the some simple tensile tester to measure the low stress mechanical characteristics. But, one few complete instruments are available. So, one of them is a Kawabata evaluation system ok.

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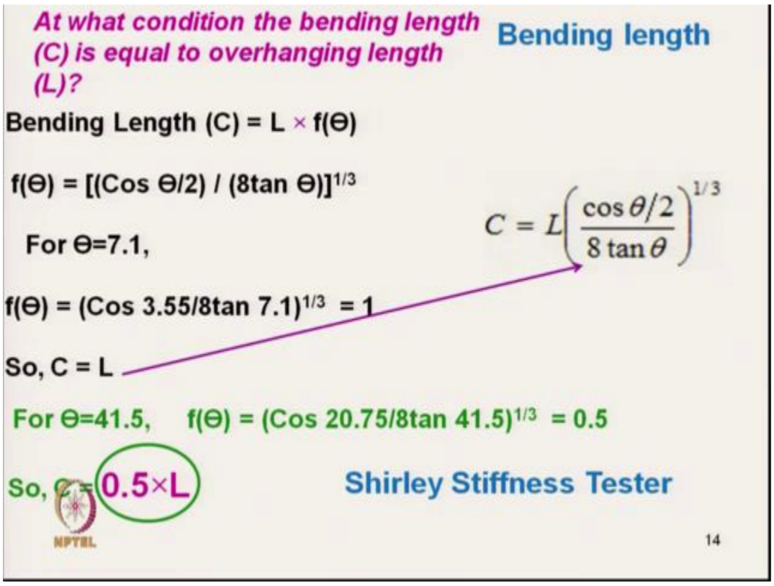

Now, the question is at what condition the bending length C is equal to the overhanging length, the condition is simple Bending Length (C) = L × f(Θ)

$f(\Theta) = [(\cos \Theta/2) / (8\tan \Theta)]^{1/3}$

For Θ=7.1,

$f(\Theta) = (\cos 3.55/8\tan 7.1)^{1/3} = 1$

So, C = L

So, for theta equal to 7.1^0 we will get this value. So, so, C equal to L we can achieve at the value of ϴ equal to 7.1.

This is the end for ϴ equal to 41.5^0 we get function of ϴ equal 0.5. So, ideally that function of ϴ should have been 1, then we can directly use the value overhanging length equal to C. As, I have mentioned as the fabric, most of the fabric samples are stiffer in nature. So, we cannot get the it is a and 7.1^0 is very small angle. So, it is very difficult to measure the value exactly correctly. So, we use the next value easy value simple value and where function of ϴ is used 0.5. So, that we normally use and in most of the instruments like your Shirley tester or first bending tester we use the value 41.5^0.

So, this is the simple formula if we get the overhanging length then half of that is the value which is the bending length, that is why if we see carefully the scale in Shirley tester it is 1 cm, which is showing it is typically it is a actually it is a 2 cm it is gauzed in such a fashion. So, that directly we get the value the overhanging length it is not the exact overhanging length we are getting it is the bending length, that is why the scale there is just doubled, it is used in Shirley stiffness tester now.

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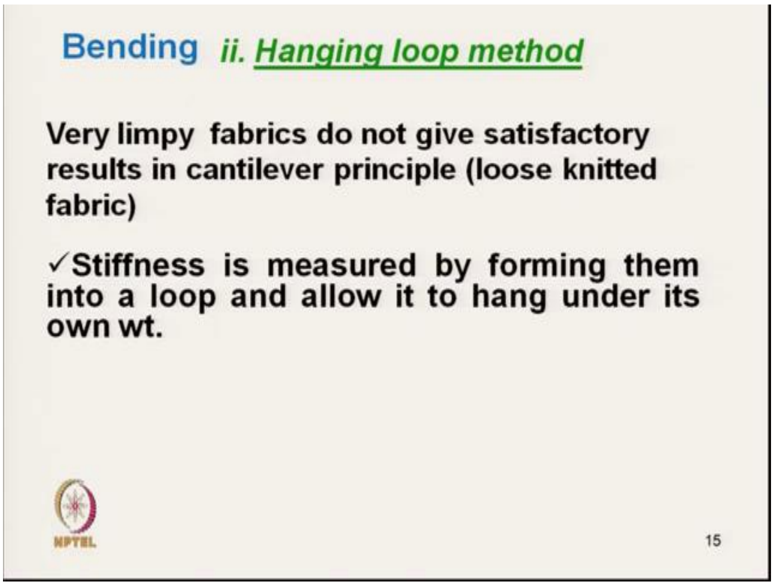

So, the bending by cantilever method we can use for fabrics which are little bit stiffer in nature. But for fabrics which are very limpy, like knitted fabric with knitted fabric these are very very flexible. In those fabrics we cannot use the cantilever principle. For those fabric we have to use another method which is hanging loop method. So, hanging loop method for very limpy fabrics do not give satisfactory result in cantilever principle, like loose knitted fabric I have as I have mentioned, stiffness is measured by forming them into a loop and allow it to hang under it is own weight; like this is a fabric suppose it is a very limpy fabric.

So, what we have to do we have to form a loop? So, this is a loop formation. Now, without any deformation suppose it is a circular loop. Now, when it is allowed to deform under it is own weight this will form little bit it will be deformed. So, we have to measure the degree of deformation from there we can calculate using different equations we can calculate the bending characteristics of fabrics.

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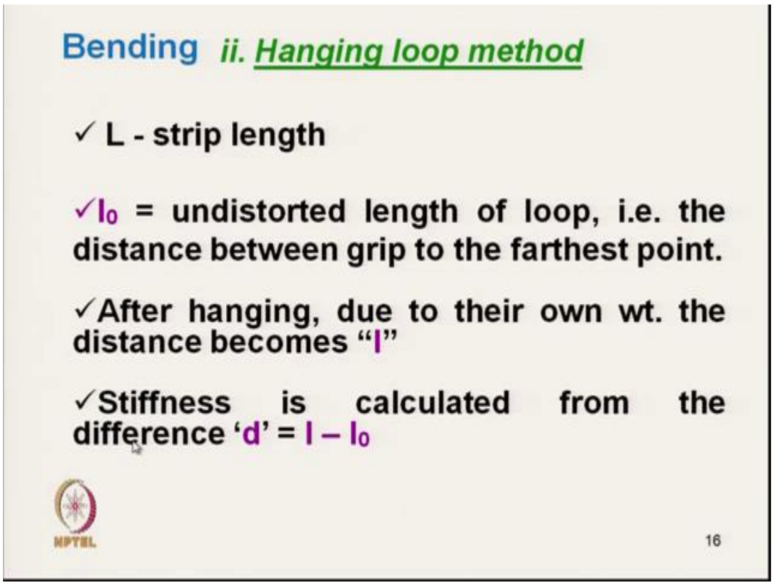

So, L is the length of the strip ok. l_0 is undistorted length of loop that is the distance between the grip to the farthest point. After hanging, due to their own weight the distance becomes "l" and the deformation. That is the difference between the l and l_0, which is used to calculate the stiffness. Now, let us see basically there are 3 types of loops available, this is fabric which is very limpy.

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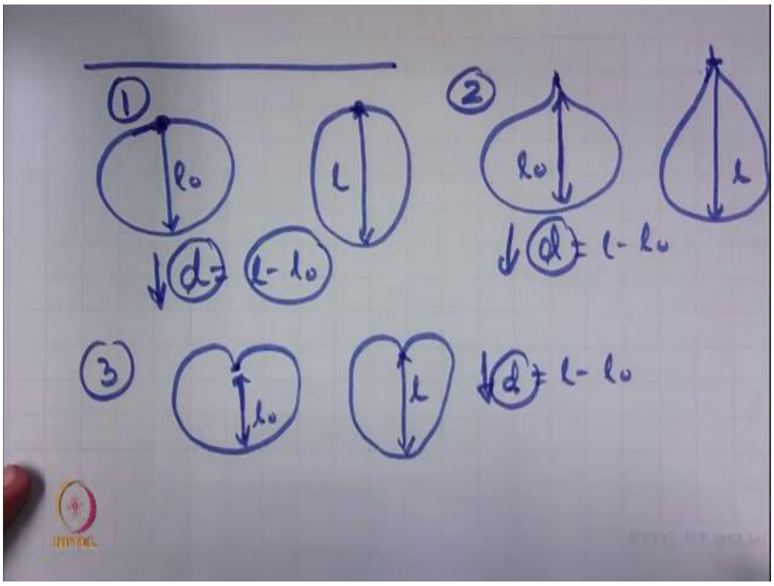

Now, we have 3 different types of loops, one is suppose we are making a loop form, this fabric has formed under form of loop this is ring loop ok. Where undistorted length this length is l_0 and when and at this is the joining point, and when it is hanging on it is own weight this will be deformed little bit. So, this length from the point of grip to the farthest point this is l. So, their distance the difference between l and l_0 it is a deformation.

So, using this value d we can calculate the stiffness of the fabric. This is the formation it is called ring loop, another formation which is we can form. Suppose this is the fabric and if we have this type of formation, it is called ring loop which is 1. Second formation this is a fabric which is formed in this fashion just like pear it is a called pear loop. So, without deformation this is pear loop l_0 and on it is own mass if it gets deformed l so, d equal to $l - l_0$.

Similarly, third type of loop which is called heart loop it forms like heart it is heart shape this is heart loop. Now, here the strip we are forming just like heart and here gripping here from here the length is l_0 and when it is deformed on it is own mass l so, d equal to l minus l_0. So, which means the stiffer the fabric the deformation will be less. So, d will be lower for stiffer fabric d will be the d value will be lower. So, depending on the d value we can we can calculate the stiffness of the fabric.

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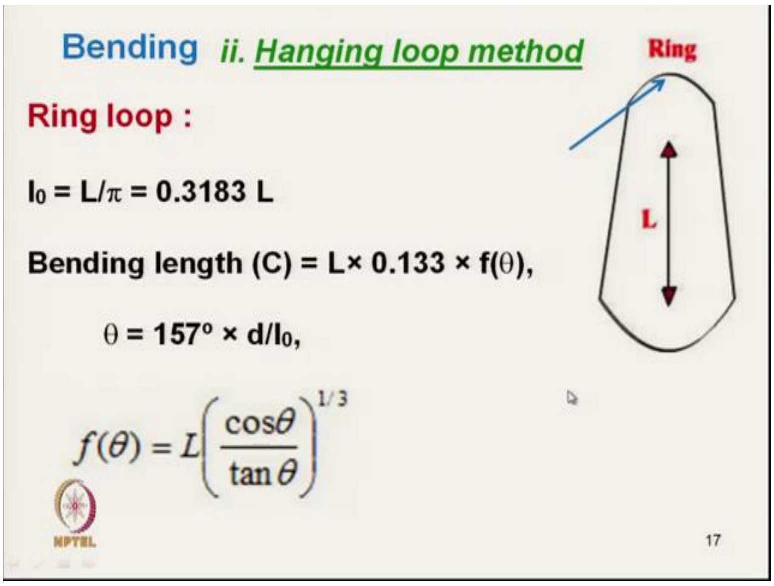

So, d is the difference between l and l_0. So, the ring loop method this is the gripping point and after deformation the length is L. So, l_0 as it is a ring it is a circular one. So, L is the total length which is circumference. So, that divided by π it is a very simple from there we can calculate the $l_0 = L/\pi = 0.3183$ L. So, if we know l_0 and then we have to calculate the L value. So, L value if we calculate and from there the bending length is given by this formula Bending length (C) = L× 0.133 × f(θ), So, function of θ is given by this formula.

And, this function of θ is same for all the other different types of loop method hanging loop method and θ = 157º × d/l_0, So, d means here the their difference. If we can calculate this difference; so, we will get defined value of θ, and from there we can calculate the function of θ, and using this function of θ value we can get the bending length ok. A and knowing the length of the strip ok. This is that and for other loop method only thing only difference will be this 2 formula this formula ok.

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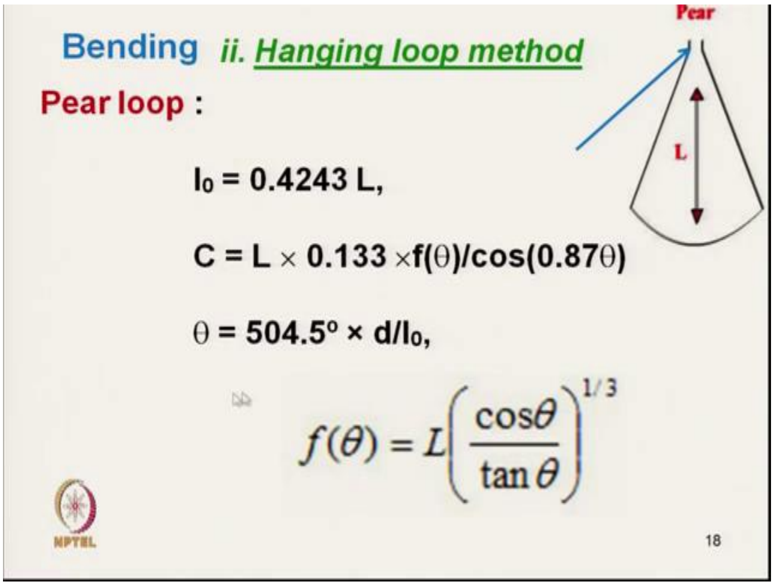

Now, for pear loop method $l_0 = 0.4243\ L$, and $C = L \times 0.133 \times f(\theta)/\cos(0.87\theta)$. This is the difference in equation and $\theta = 504.5^{\circ} \times d/l_0$, where function of θ remains same.

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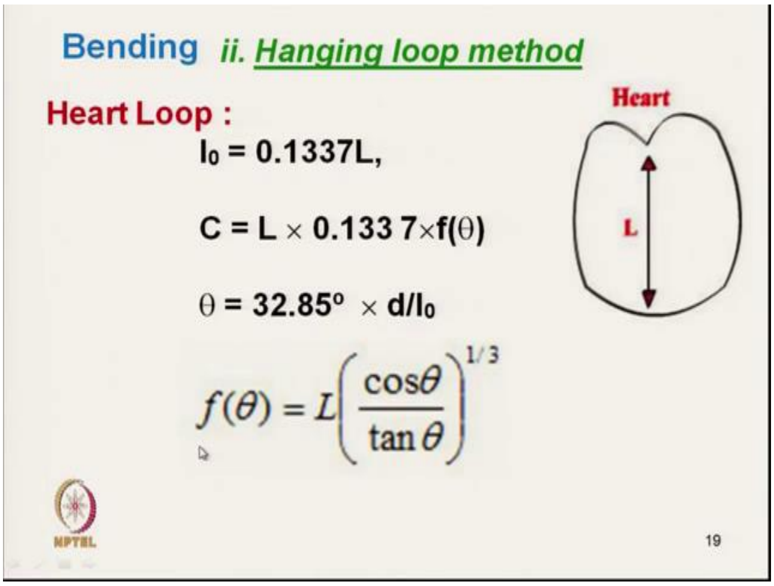

Similarly, in heart loop method as I have already shown. So, this is the L length after deflection this is a small l it is not the actually it is a smaller small l length ok. And, here this L capital L is the length of the total strip ok, from there $l_0 = 0.1337L$, it is the length of the strip and this one is a smaller length. So, $C = L \times 0.133\ 7 \times f(\theta)$

is given here and θ we can calculate which is again function of deflection.

So, from there and a l_0 is a constant for a particular type of loop, for heart loop this is the constant value only d value; d value is a function of the stiffness. So, stiffer the fabric the d value will be the d value will be low. And, that changes the θ value and θ value changes the function of θ value and from there we can calculate. So, this is the process we can calculate. And, this method is used this method basically we can use for very very flexible fabric, which were we cannot use the Shirley stiffness tester this is a point where it is a gripping point. Now, we will start the Low Stress Mechanical Characteristics measurement.

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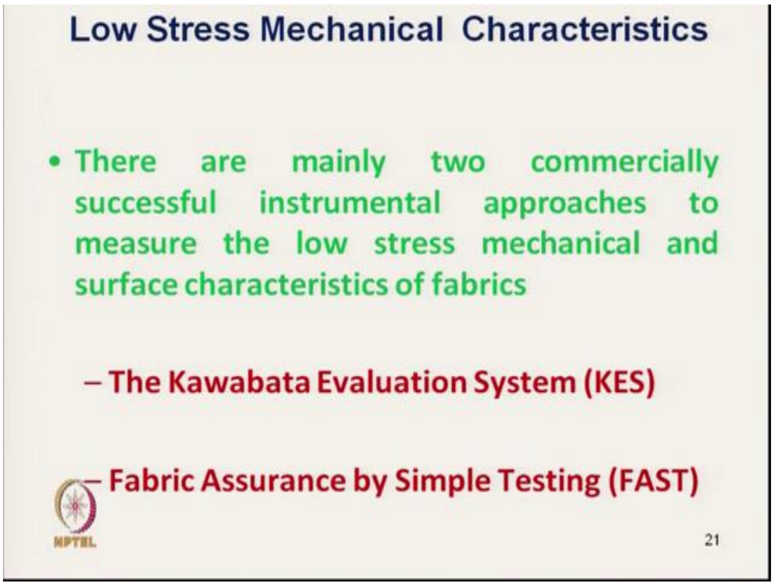

So, there are mainly two commercially successful instrumental approaches. Why it is called instrumental approaches, because it is not the single instrument, this is a set of instrument, and we get the data from each and individual instrument and used for evaluation or interpretation.

So, these 2 commercially successful instrumental approaches to measure the low stress mechanical and surface characteristics of fabrics, which are actually used to measure to determine the handle characteristics of functional textiles. These methods are the Kawabata Evaluation System KES and the Fabric Assurance by Simple Testing. In short it is called FAST. KES and FAST methods are used to measure the low stress mechanical characteristics of fabrics.

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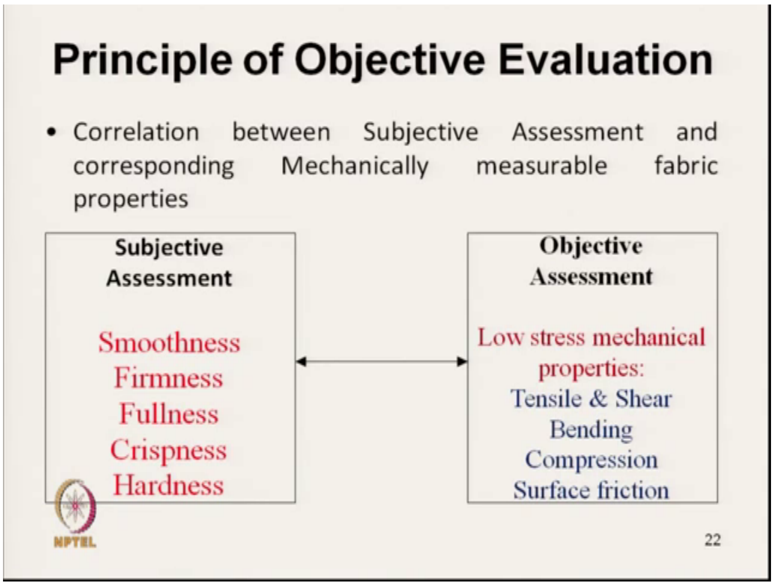

So, all this low stress mechanical characteristics earlier used to measure by subjective testing, but this objective methods actually they are correlation between subjective assessment and corresponding mechanical measurable fabric properties. These are the subjective assessments, like smoothness, firmness, fullness, crispness, hardness this we can actually determine subjectively. This we cannot measure directly the by objective method, but they are correlated with the objective assessment by low stress mechanical properties.

These low stress mechanical properties are tensile and shear characteristics very low stress tensile characteristics. We are not talking about here the stress up to the end point breaking point here we are talking about the very low stress which is actually used for fabric handle characteristics. And, shear then low stress bending characteristics, low stress compression characteristics, and surface frictional characteristics, or surface roughness characteristics. If, we combine all or some of the characteristics this objective assessment value, we can get we can predict the subjective assessment value.

Like crispness, fullness, they are directly related with all this low stress mechanical characteristics we will discuss in detail.

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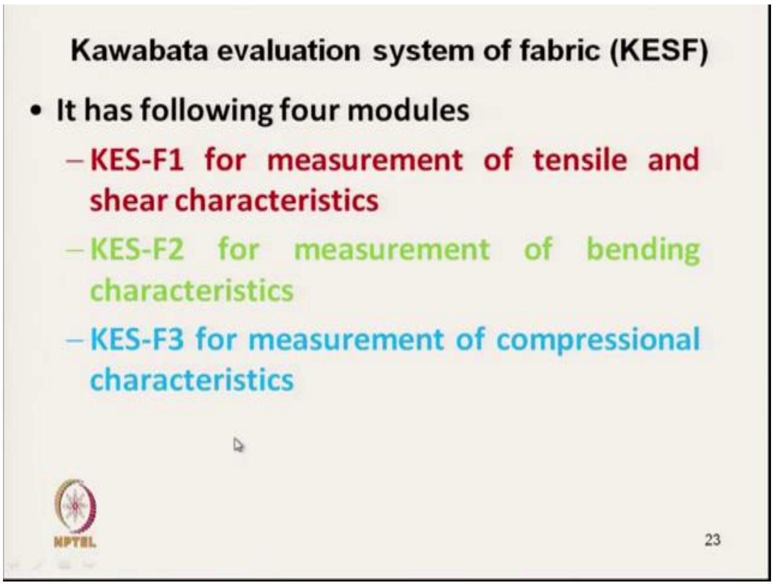

And, this kawabata evaluation system it has got 4 modules in module 1 KES-F1 which is used for measurement of tensile and shear characteristics. KES-F2 is used for measurement of bending characteristics. So, where the bending means it is not at very high level, it is all the low stress at lower extent of bending. Similarly, in KES -F1 the tensile characteristics is, it is at a very low level of stress ok, similarly for shear characteristics.

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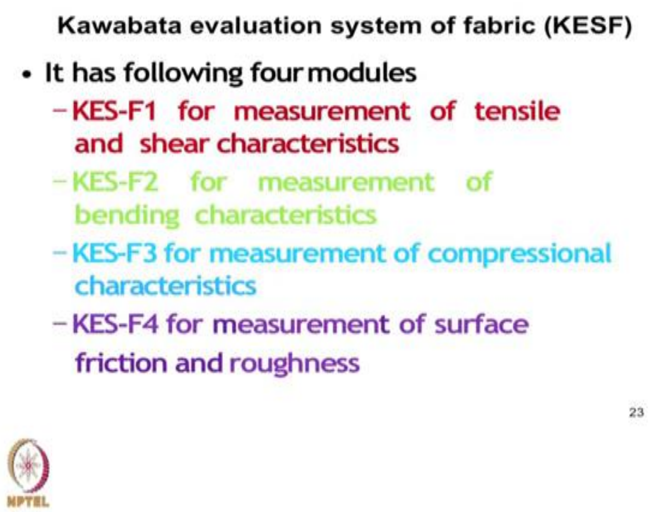

KES –F3 it is for measurement of compressional characteristics ok, and KES-F4 for measurement of surface friction and roughness characteristics. Now, the speciality of

KESF methods are here we measure both in loading direction and also in the unloading direction, be it tensile, shear, bending, compressional, even for the frictional characteristics. We can get the data for each and individual point and accordingly we can analyse. So, if we if it is tensile characteristics, it will stretch the fabric will measure the all the data during elongation and also during unloading will get all the data ok whereas, the fast systems these are much simpler.

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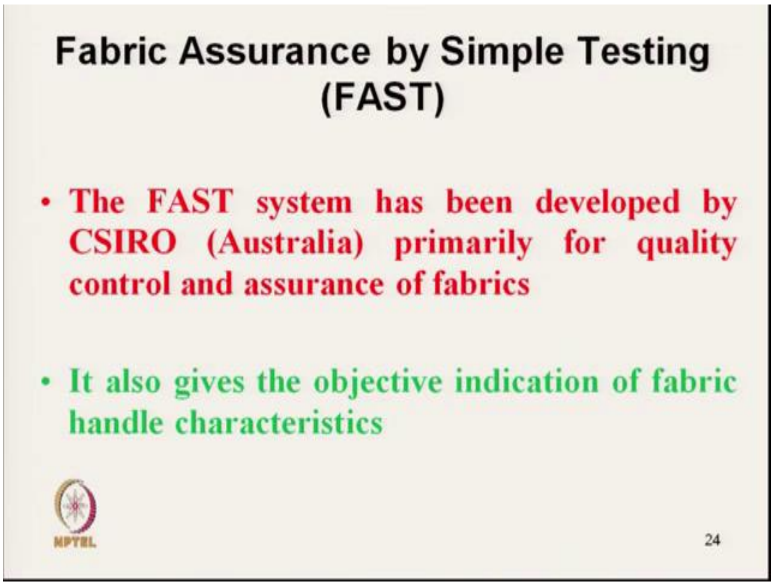

So, and it has been developed by CSIRO Australia and primarily for control and assurance of fabric quality ok. And, it also gives the objective indication of fabric handle characteristics. Now, the difference between FAST system and the Kawabata system, in FAST we do not get the value or data in between during the extension or during compression. We get only value at end point ok. And, it is a discrete data we get and we analyse the data whereas, in KESF method we get data the overall data total curve we get ok.

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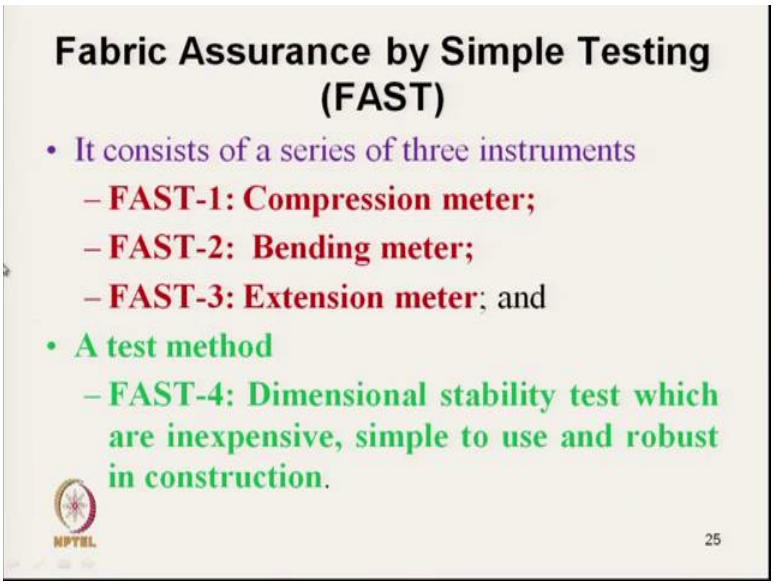

The FAST method it consists of a series of 3 instruments and, one test method ok. The instruments are the FAST-1 which measure the compression, it is called compression meter. FAST-2 measures the bending characteristics a bending meter it is similar to that of Shirley stiffness tester and FAST-3 itself extension meter. In addition to all these 3 we have a test method, which is called FAST-4, which is not an instrument, it is a it is a just a test method where we measure the dimensional stability ok.

And, it is a this methods are basically it is a inexpensive and this is also only a guidelines ok, from where we can measure the dimensional stability, hygral expansion and relaxation shrinkage we can measure. So, first we will start with the Kawabata Evaluation System of Fabric KESF system. So, we will start with the first module, which is KESF-1 which measures the 2 characteristics ok.

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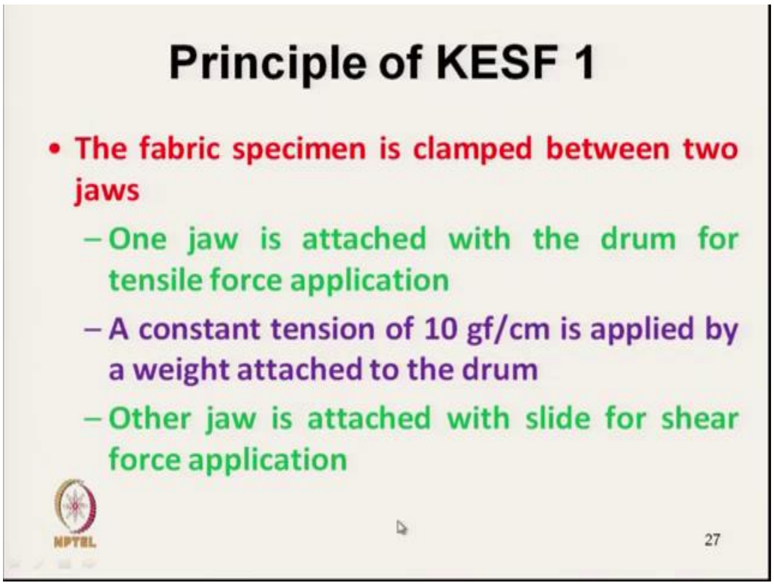

A tensile characteristics and shear characteristics, the fabric specimen is clamped between 2 jaws ok. So, for any tensile characteristics we need 2 jaws ok. Here, similarly we have to have 2 jaws for clamping the fabric; one jaw is attached with the drum for measurement of tensile force. So, there will be one jaw, the drum will rotate as the drum rotates it will apply the force.

A constant tension of 10 gf/cm is applied by weighing which is attached to the drum. So, a constant weight is hung on that and then it is gripped and other jaw is attached with the slide for shear force application. So, one is one jaw is a slide another jaw is a drum.

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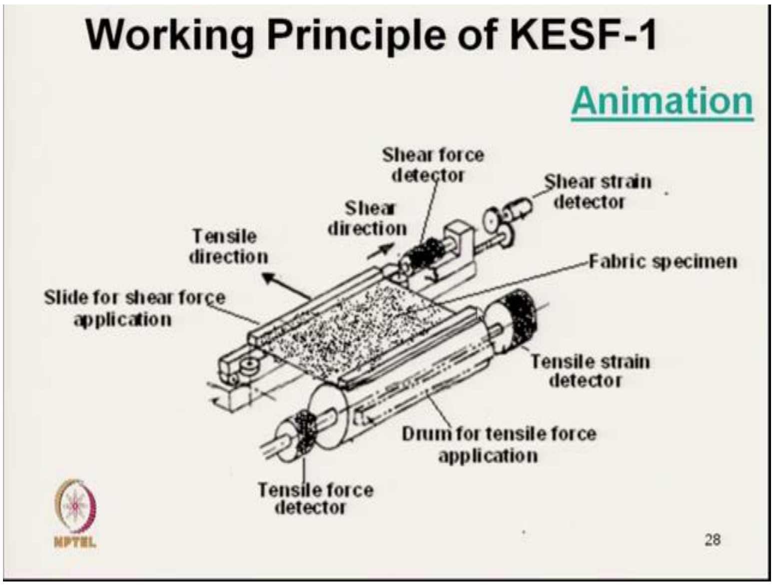

So, this is the picture and here this is the rotating drum and this one is fabric specimen ok. And, one jaw, this is jaw which is attached with the drum. As, the drum rotates this will extend the fabric stretch the fabric and the load will be applied on the fabric specimen. And, other jaw which is connected with the this slide this is shear for measurement of shear.

So, this slide is at is the other jaw; that means, when the instrument works in tensile principle, tensile force principle, in that case thus this slide this other jaw will be stationary only this drum will rotate. So, as the drum rotates this will apply the tensile force on that on the specimen, and the elongation we can measure by the this the tensile strain detector. Here strain detector this strain detector works on a, this measures the angle of rotation. So, this angle of from this angle of rotation, if we know the diameter of the drum we can convert it to the how much extension is applied.

And, this tensile force detector which is nothing, but a torque sensor so, the torque required to rotate this drum is actually is converted to the form that is the tensile load ok. So, from these 2 sensors one is tensile strain detector and tensile force detector, we can get the value of the stress strain. We can completely get the stress strain curve and after rotating, after straining, predetermined length, this drum will automatically start rotating in other direction. And, it will record the value for the load and extension during the unloading time. Similarly, once this instrument works on sliding mode that is the on the to measure the shear in that case the drum will be stationary.

So, one should remember in this instrument although we measure both tensile and shear, but they are not simultaneous. Once the tensile measurement is over then the drum will be stationary in then the sliding, the slider other jaw will start moving. It will start moving laterally in left to right direction and again it will come back from right to left direction. Here again we have 2 sensors; one is that the shear strain sensor again by the rotational angle from the rotational angle and if we know the gear ratio, we can calculate the shear strain.

How much shear it is taking place. And, the shear force detector here, it is again it is nothing, but again torque sensor it is a torque required to slide this slider is calculated from there we can get the shear stress and shear strain value.

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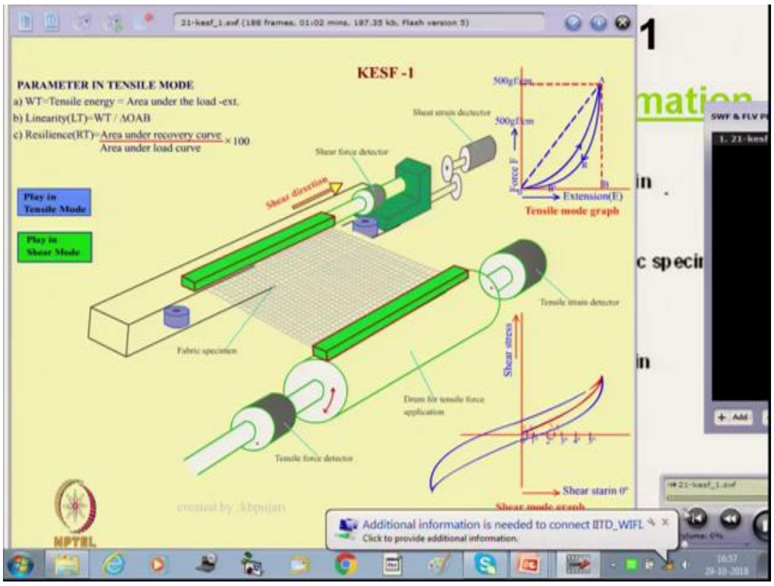

Now, let us see the animation here. Here this is the fabric sample fabric specimen the drum is there and it is a fabric is clamped on the drum and another is on the this slider. And, here it is a tensile strain detector which will detect the rotation of the drum and here is the tensile force detector, which is nothing, but a torque sensor and here is the shear strain detector and shear stress detector ok. Now, we will start here the animation first we will start with the tensile mode.

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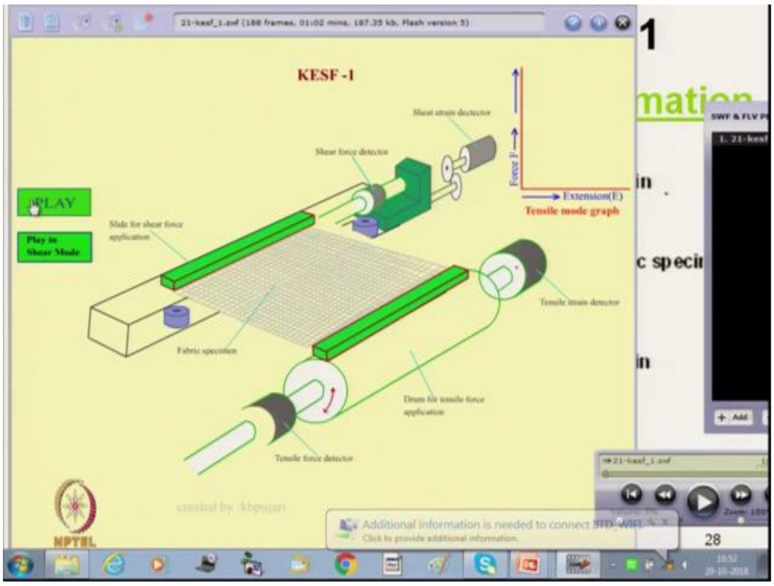

Now, we have started. Now this drum is rotating in clockwise direction. So, fabric is getting stretched, extension is taking place and it is a plotting. So, elongation is there after receiving the predetermined mass the predetermined force that it is 500 gf/cm it is coming back again. So, it completes 1 cycle and from there we can calculate various parameters, just we will discuss here.

The parameters here we can get 3 parameters here. From this loading and unloading curve ok, stress strain curve, this is the elongation and here is the force; force elongation curve here we will get the first parameter it is a WT, which is tensile energy; that means, the tensile energy during the loading curve ok. So, it is a area under the loading curve that energy required to load, stretch the fabric, it is which is expressed in terms of WT. Next is the linearity LT linearity of the curve which is nothing, but WT the energy required for extension and if the curve was straight line; that means, it will form a triangle the area of this triangle; that means, linearity of the curve (LT) = WT/ area of the triangle AOB, this AOB triangle.

That means, if the curve is linear then the value of the LT linearity would have been one. And, as WT is less than the area of this triangle; that means, this value will be LT value will be less than 1. So, from there we can actually get idea about the linearity of the curve. Similarly, resilience RT resilience during stretch which is nothing, but the area under the recovery curve that is R recovery curve, divided by the area under the loading curve which is equal to multiplied by 100. So, resilience if the resilience is 100 percent; that means the recovery curve will follow exactly to that of the loading curve.

If they are actually coinciding; that means, the fabric will be highly resilient. So, from these 2 values that is the area under the recovery curve and area under the loading curve, we can get idea of the resilience. Resilience characteristics is that characteristics, where it actually return it is it come backs from the deformation, it can be a tensile resilience, it can be compressional resilience, it can be of any form of deformation. So, we need a fabric with very high resilience.

So, that is why resilience characteristics we can get from the area under the loading curve and area under the recovery curve. Now, this instrument, now we will see what will happen, when it works on the shear mode. Now, once it is moving on shear mode this drum will be stationary. Now, this slider will move, move from right to left and left to right and we will get the shear curve ok.

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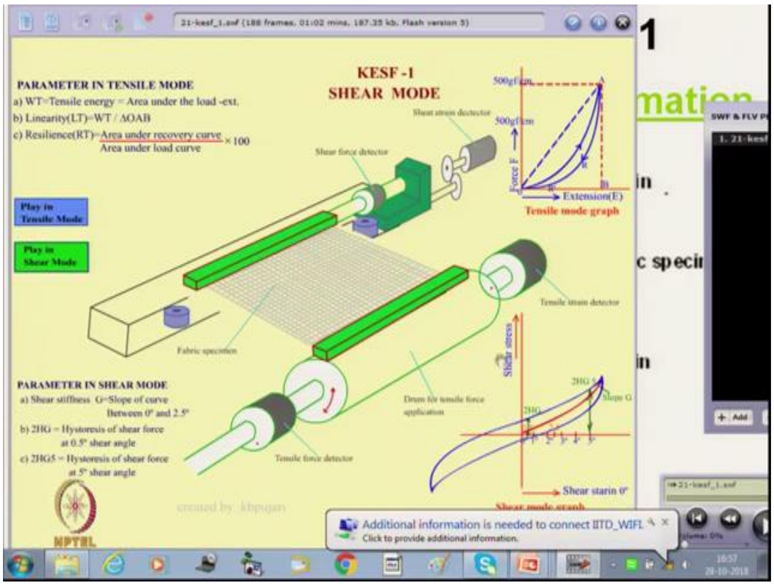

Here we are getting the shear strain and shear stress curve. So, from this shear curve because it is not following the same path, when during shear and during again, when it is a repeating, it is not following the same path while shearing and when it is coming back . This is basically due to the hysteresis, this phenomenon is known as the hysteresis, which is basically it is a characteristics of textile material, due to the frictional characteristics of frictional force which is restricting the shear. So, shear stiffness which is nothing, but slope of curve between 0 to 2.5^0; so, this curve if we take the slope between 0^0 shear to 2.5^0 shear.

So, that will give us the value of the shear stiffness G. Another parameter which is 2HG which is nothing, but the hysteresis of shear force at 0.5^0 shear angle. So, if we take the shear angle here we are we have maximum 5^0 shear angle it is here. So, we can get the shear angle here. At 0.5^0 shear angle, if we take the hysteresis this will be 2HG. And, if we take the shear hysteresis at 5^0 shear angle, that is the 2HG5. So, the here in shear mode we get 3 parameters so; that means, in KESF 1 module we get total 6 parameters, 3 parameters for tensile mode and 3 parameters for shear mode ok. Now, let us see the test parameters.

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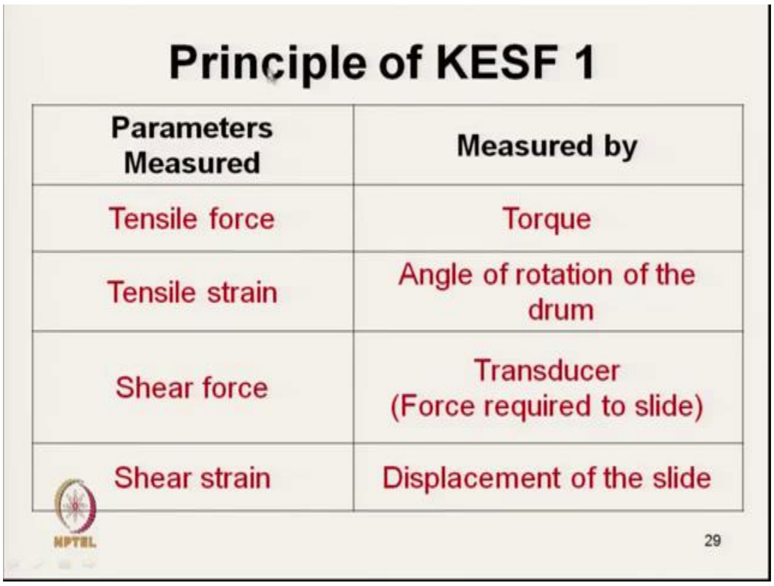

Principle of KESF 1

Parameters Measured	Measured by
Tensile force	Torque
Tensile strain	Angle of rotation of the drum
Shear force	Transducer (Force required to slide)
Shear strain	Displacement of the slide

Now, as I have already mentioned the parameters measured is tensile force which is indirectly measured through the torque required to rotate the drum. Tensile strain, angle by angle of rotation of the drum shear force is by a transducer, which is force required to slide the slider. And shear strain is which is nothing, but by displacement of the slide and this working principle we have already explained discussed here.

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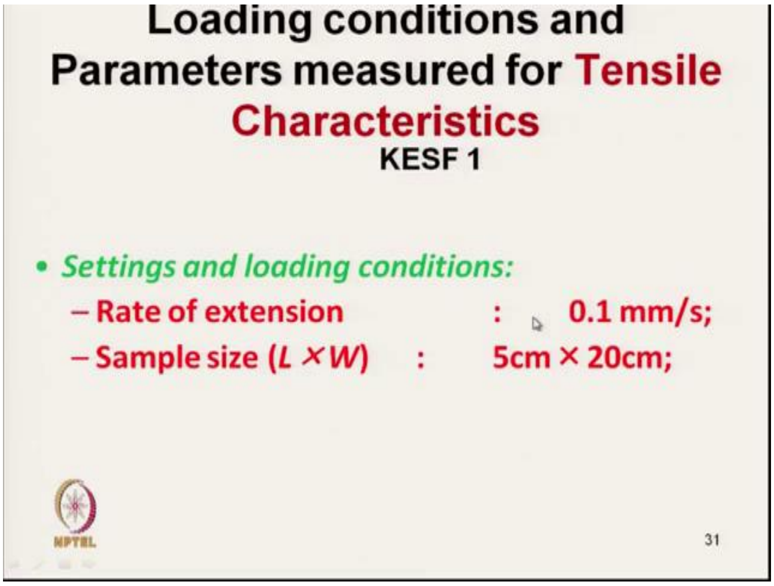

Now, parameters for measurement of tensile characteristics are the loading conditions and parameters are here, the setting and loading conditions are rate of extension, here the rotational speed of the drum is actually maintained in such a fashion. The rate of extension is actually 0.1 mm/s. And, sample size is length multiplied by width is length here is a smaller we should remember.

Suppose, if it is the sample size this will be the length and the width will be 20 cm, that is how this is the grip and in this way it is stressed and maximum tensile force is 5 N/cm. So, these are the loading condition. So, the drum will come back, will start rotating in the other direction once it is reaching 5 N/cm, that much force.

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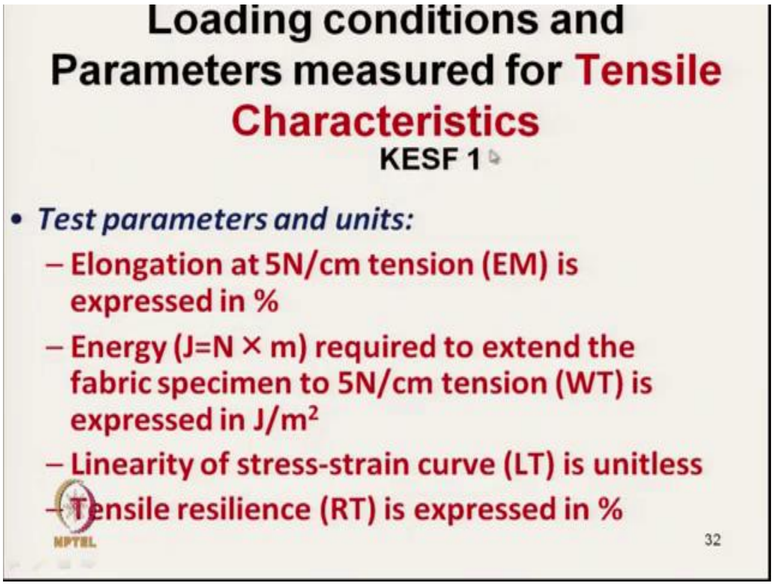

The characteristics which are measured; so, parameters measured for tensile characteristics are KESF 1 which is test parameters and units are elongation at 5 N/cm tension, which is EM is expressed in %.

So, elongation EM means at 5 N/cm that is the elongation %, energy in N m which required to extend the fabric specimen up to 5 N/cm tension which is WT it is energy, that is the area under the loading curve linearity of stress strain curve LT, which is used unitless I have already explained, tensile resilience RT which is expressed in terms of %, which is the ratio of the energy required for recovery curve and the loading curve, which is the tensile characteristics these are the tensile related characteristics.

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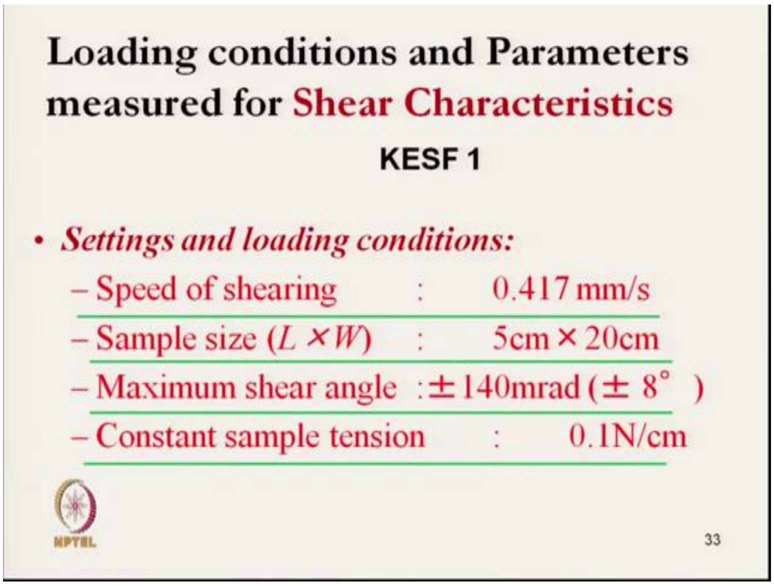

And the shear related characteristics; for that setting and loading conditions are the speed of shearing is 0.417 mrad/second. That is the sliding speed sample size remains same because we use the same sample size, maximum shear angle is $\pm 8^0$ which is equal to 140 mrad. And constant sample tension is point 0.1 N/cm these are the setting and loading conditions.

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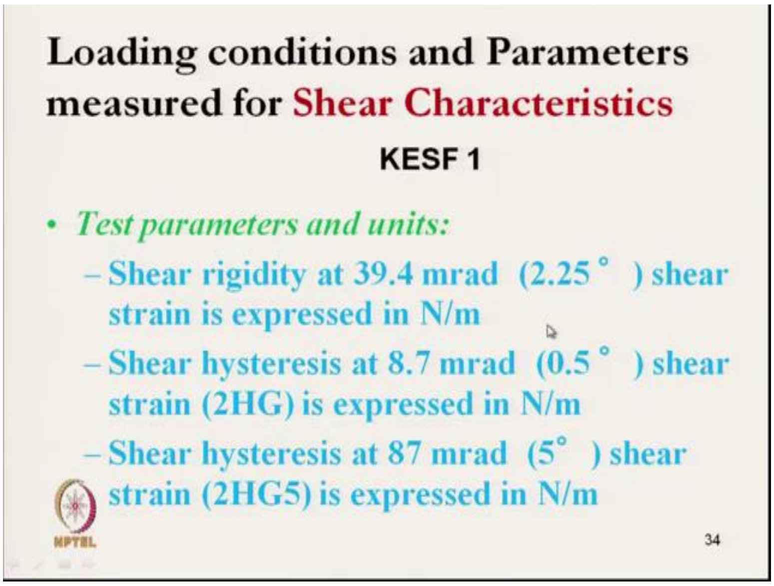

And, the loading condition and parameters measured are the shear rigidity is nothing, but at 2.25^0 ok. So, it is at 2.25^0 shear strain is expressed in terms of N/m which is nothing, but 39.4 mrad.

Shear hysteresis is at 0.5^0 that is 2HG and shear hysteresis at 5^0 shear strain, which is 2HG5 is expressed in terms of N/m ok. So, these are the parameters related to KESF 1 for the shear characteristics and for working principle of KESF 2. We will discuss in the next class. Till then thank you.

Thank you for listening.