Science of Clothing Comfort
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Lecture - 18
Tactile Aspects of Clothing Comfort (contd.)

Hello everyone. So, we will continue with the discussion on objective assessment of a fabric handle characteristics to access the tactile response of fabrics. And we have discussed the subjective assessment in our earlier talk, and we have started the objective assessment.

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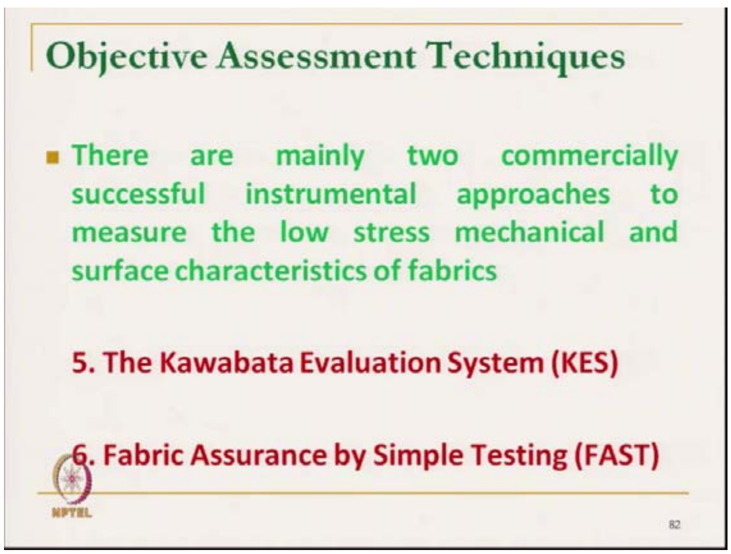

And basically commercially as we have mentioned that there are two set of instruments available for objective assessment; one is Kawabata Evaluation Systems KES, and another is that Fabric Assurance by Simple Testing FAST system.

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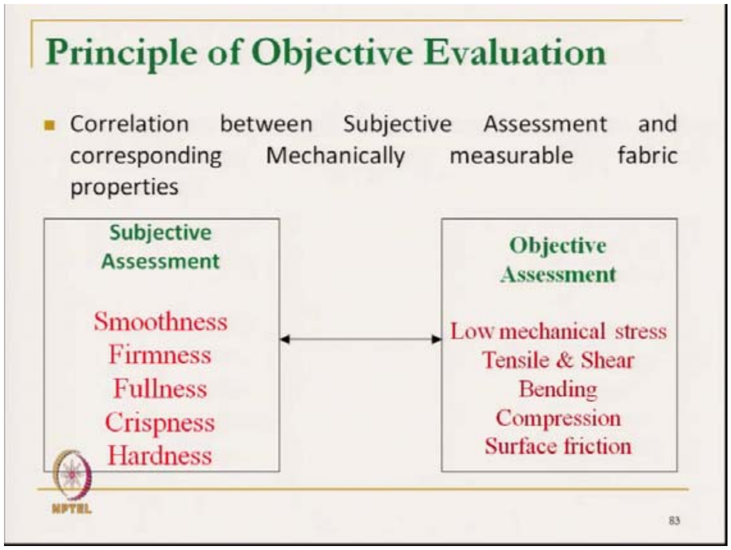

So, the correlation between subjective and objective assessments are there; that basically that any subjective assessment we can correlate with the by measuring the objective fabric characteristic like mainly low stress mechanical characteristics tensile, shear, bending, compression, and fabric surface characteristics. All this we can correlate with the tactile responses like smoothness, fullness, crispness, hardness, and which ultimately we get the tactile sensations.

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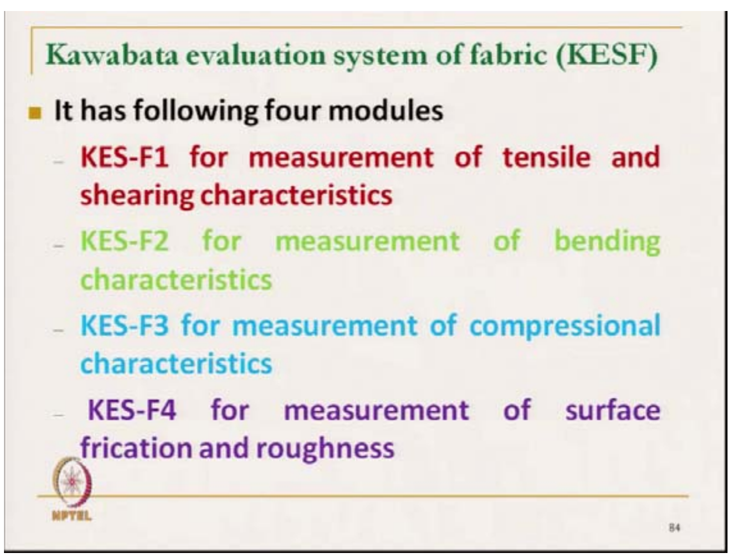

So, Kawabata evaluation system for fabrics, it has got four different modules; KES-F1, KES-F1 which measures the tensile and shear related characteristics at low stress level, and KES-F2, which measures the bending related characteristics, 3 measures the compressional characteristics, and 4th is a measurement of surface friction and surface roughness. So, we will discuss all these instruments all these modules one by one, and their all the parameters what so they measure, their principles in details, we will be measuring and their test parameters.

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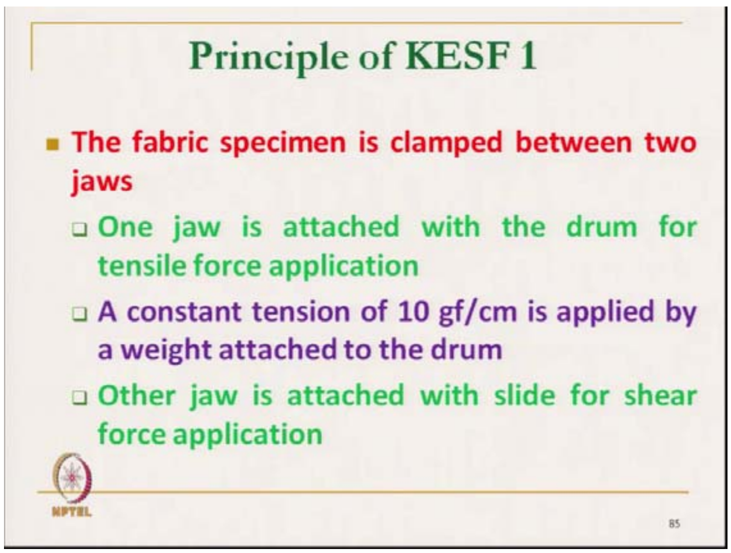

So, the KESF 1 where fabric sample fabric specimen is clamped between two jaws. One jaw is as we have mentioned it is a drum, which rotates both clockwise and anticlockwise direction, and which by rotation it imparts tensile load. So, the fabric is fixed in one jaw, which is the drum. And a constant tension is applied, which is 10 gram force per centimeter. Just to keep the fabric in a straight condition, and it is done by weighting system weight is attached to the drum. And other jaw, which is attached with the slider, which is for application of shear force.

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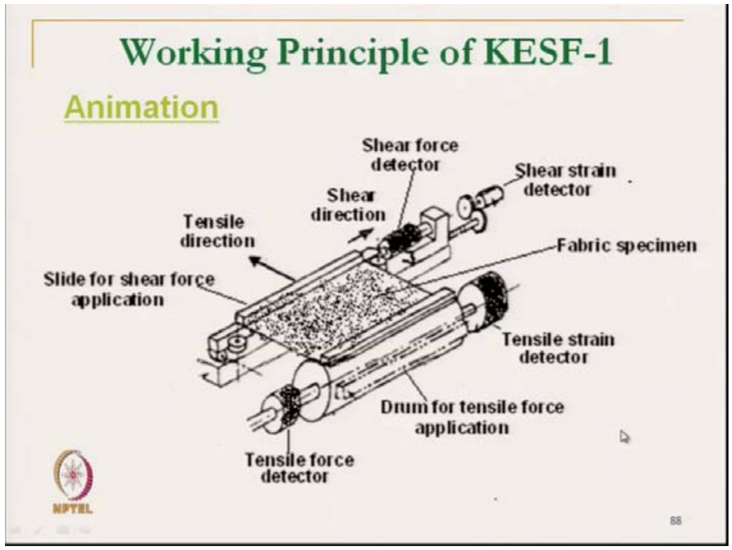

So, this is the schematic diagram of the system, where this one dotted, this one is a fabric specimen. And it is attached with the jaw that is a drum. The jaw is fixed on a drum. Another jaw is this one, which is placed on a slider. So, the rotation of the drum imparts tensile load, and this and the sliding of this jaw, other jaw is it is imparts the shear load. And as this drum rotates, because they this shear and this tensile mode, they cannot work actually simultaneously; one at a time, we can get. So, this for tensile load application, this drum has to rotated clockwise, so that it is the fabric gets extended.

And the amount of load applied is measured by there is a torque sensor, the tensile force detected which is torque sensor, and that rotates and it measures the torque applied, and ultimately we can get the tensile force applied on the fabric. Another measurement is that the extension, which is detected by there is a sensor tensile, strain sensor, which is actually which measures the angle of rotation of this drum. From there, if you know the diameter of this drum, we can convert it to strain.

On the other hand, the other side this slider moves laterally, which is parallel to the drum to impart the Shear force. And the force required to slide is measured by this shear force detector, so this it measure the amount of force required. And the amount of slide that is angle of shear can be measured by the displacement of this slider, which is measured by this shear strain detector, this angle we can measure. If you know the distance between the drum and the slider and amount of slide, so we can measure the shear angle, so that way we can get the four different parameters we get; one is the tensile force we get, tensile strain we get, Shear force we get, and Shear strain we can get.

And another thing this drum, they it rotates clockwise for extension; and for recovery, it rotates anticlockwise. So, here in Kawabata system, this gives total complete loading and unloading curve. So, this is true for shear also. So, shear it gets the shearing, when it moves from left to right direction. And similarly, when it moves from right to left, it is a recovery shear recovery.

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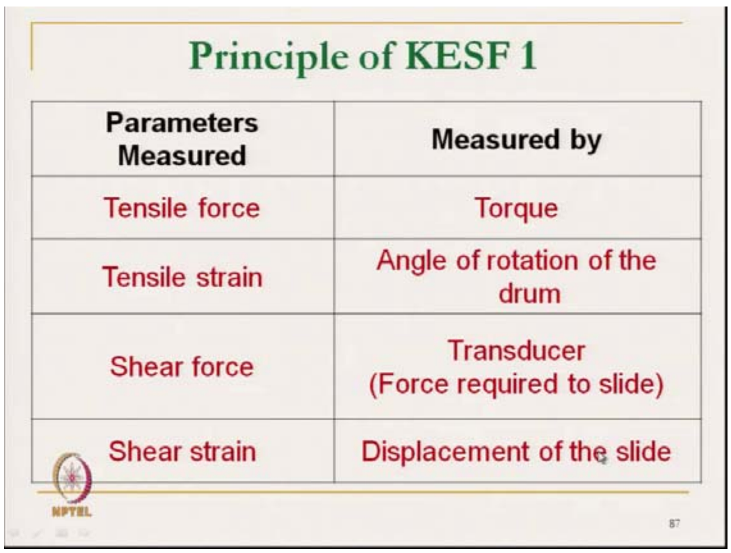

So, tensile force is measured in terms of torque, as we have mentioned. Tensile strain, angle of rotation of drum, we can measure; shear force, by force transduced transducer; and shear strain, displacement of the slider, so that way we can get.

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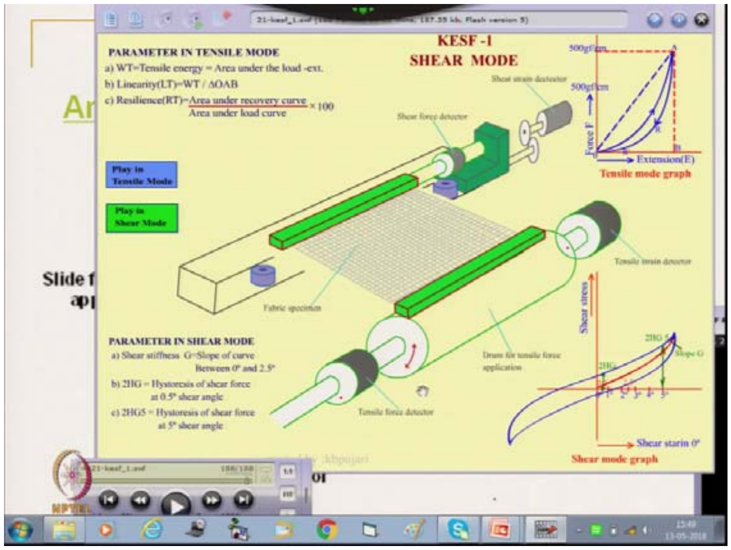

And ultimately, we can get the complete animation. Like let us see the animation here, here in this the instrument, as we know that it works in both tensile and shear mode. So, first let us see if it works in the tensile mode, so where the slider is fixed, slider does not move, only this drum moves. So, when drum is moving clockwise direction, actually fabrics gets extended; and when the drum moves anticlockwise direction, it returns.

So, let us see once again play, it is a moving clockwise direction, so the displacement the extension is increasing and load is increasing. So, it is actually it will go up to the preset limit of say 500 gram per centimeter that is a preset limit is maximum limit is there, and after that it will automatically return to its original position. So, we will ultimately get loading extension; and returned this curve loading, unloading curve, we will be getting.

And this is the tensile curve from tensile graph; we get basically three parameters we get. One is WT, which is tensile energy. Tensile energy WT in a KESF system, we denote this value WT. WT means the energy required during tensile extension, and that that is nothing but it is an area under the loading curve.

Similarly, it is a linearity LT. Linearity is expressed in terms of LT. LT means, it is a tensile energy. This area under the this loading curve, the total area under the loading curve divided by area under the loading curve divided by total area of this triangle a o AOB, this triangle. If the curve that means, if the fabric follows pure Hook’s law, then this linearity will be 1. That way so, what is the how much it is deviated from the linearity, that it shows; maximum value will be 1.

So, WT means it area under the loading curve divided by this area totally, it is always less than linearity will be always less than 1. So, though that if it is close to 1 that means, it will give you as the indication, it is a totally elastic, it is within elastic region, so that way that we can get idea about the loading behavior of the (Refer Time: 10:45) what is the behavior.

And third one is the resilience; resilience is nothing but area under the recovery curve that is R recovery curve and divided by area under the loading curve, it is expressed in terms of percentage. So, if linearity so, resilience is 100 percent, what does it means, it means that loading and unloading it follows the same curve same path, so that way we can get the three parameters from these tensile curve.

And let us see when it moves in shear mode in shearing mode. We will see that the slider is moving sidewise. And now, it is moving, a slider is moving back, now we will see once again, so slider is moving towards from left to right, so there is a shear deformation. And it is a shear force, shear stress, and shear strain. It is shares strain in terms of angle , so it is removing, and it is coming back again, and again it is a going back. So, this is the initial position. So, this way we will get a shear hysteresis curve, this curve is shear hysteresis. So, here the slider moves sidewise.

Now, let us see the shear stiffness G, shear stiffness is expressed in terms of G, so which is actually slope of curve between 0 degree and 2.5 degree. So, between 0 degree and 2.5 degree, what is the initial slope of the curve that is called shear stiffness? So, if stiffness is high, the slope will be high, so that is why this is the shear stiffness.

And next is that hysteresis of shear. So, hysteresis of shear, which is expressed in terms of 2HG at, if it is at 0.5 degree shear angle. So, these are the shear angle, this is 1, 2, 3, 4, 5. So, here at 5 degree, and it is a 0.5 degree. At 0.5 degree, what is the hysteresis? The distance between the article distance between the loading and unloading curve in that that means, shear stress difference in shear stress in the loading direction, unloading direction at angle 0.5 degree that is that is expressed in terms of 2HG.

Another next term is 2HG5, when the shear it is a shear hysteresis at 5 degree. This is the 5 degree. At 5 degree shear strain; the difference is what is the difference? The difference is expressed in terms of the 2HG5 that is the hysteresis. So, these three parameters we get from here, and three parameters from the tensile characteristic. So, KES-F1 gives total six parameters. So, this six parameters are used in expressing this characteristics is expressing the tactile characteristics, fabric handle, we will discuss. Now, we have seen there are two different types of curves we get, and we can get six different characteristics.

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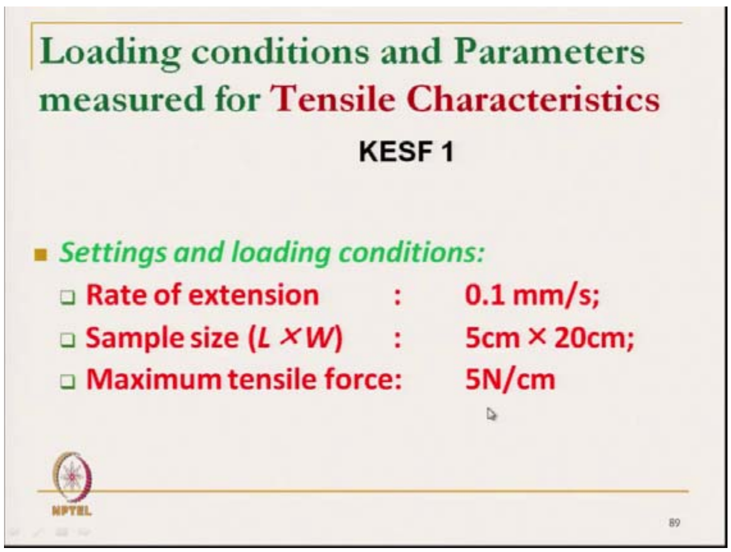

So, the settings, here is a rate of extension is 0.1 millimeter per second that is a fixed. That rate, it is a loading the tensile characteristics if we measure that means, at that rate it will the drum will rotate. And the sample size is lengthwise it is a short, lengthwise it is a 5 centimeter; and widthwise, it is a 20 centimeter. This is if you see this length is 5 centimeter and widthwise it is a 20 centimeter, which is the fabric specimen size. And maximum tension is 5 Newton per centimeter that is the maximum tension is up to that tension it goes, and then this drum gets signal from the load sensor and it starts returning, so that is the maximum. And accordingly, it keeps one rotating, it is repeats.

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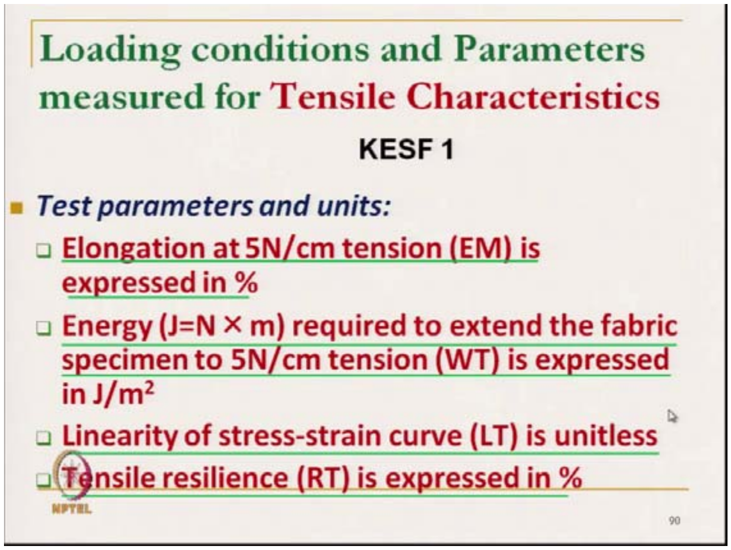

Now, test parameter as we have seen the elongation at 5 Newton per centimeter tension EM is expressed in terms of percentage. Energy under the loading curve is required to extend the fabric specimen to 5 Newton per centimeter tension is expressed in terms of joule per square meter. Linearity is unit less, as we have discussed. And tensile resilience RT is expressed in terms of percentage. These are the parameters, which we get from tensile characteristics along with their units.

Similarly, so these are the units; extension in terms of percentage, energy in terms of Newton meter and or a joule per square meter, and linearity unit less, and tensile resilience, it is in terms of percentage.

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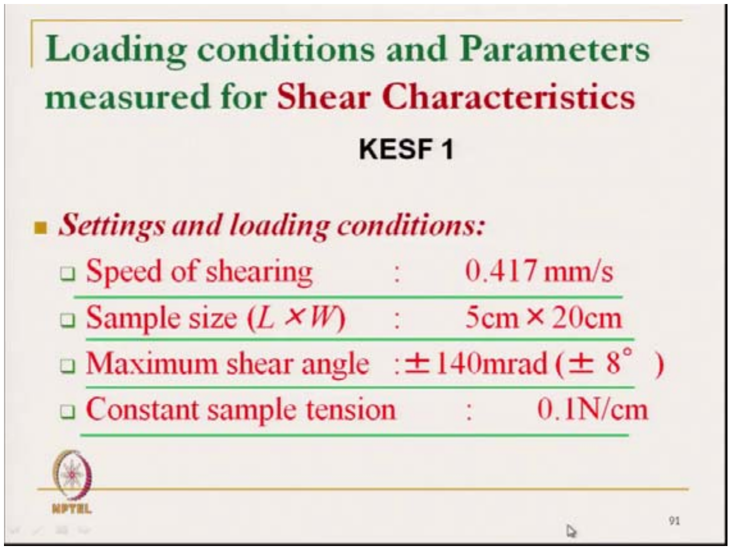

And if it see the shear characteristics, the sample size specimen size will be same, but the same specimen we will use. But, here sliding speed is approximately 0.4 millimeter per second that is the sliding speed. And maximum shear angle is 140 milli radian, it is typically around plus minus 8 degree that at that up to that angle. So, we take the value up to 5 degree measure, but it goes the curve goes up to 8 degree. The hysteresis, which we have seen, it is up to 5 degree. And constant sample tension is 0.1 Newton per centimeter.

The same as that in tensile, it is initial tension. At this tension, it is kept constant for shear. Just to keep the specimen tight. Otherwise, if the specimen is in slack condition, we will not get any shear force. So, this is these are the characteristics.

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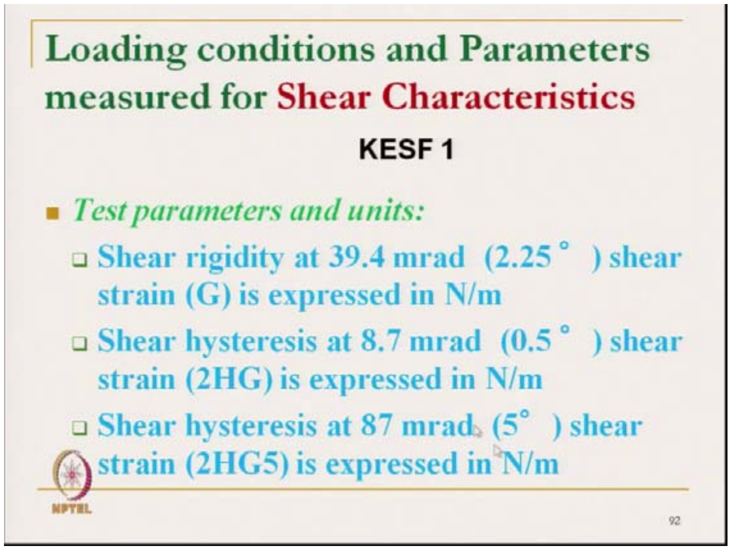

And the test parameters which we get, we have already discussed, we get three parameters. Shear rigidity at 39.4 milli radian, 2.25 degree shear strain, it is expressed in terms of Newton per meter. Shear hysteresis, it is at 8.7 milli radian, it is 0.5 degree angle, which is expressed in 2 by 2HG. And shear hysteresis at 5 degree 2HG5 is expressed in terms of Newton per meter. So, this shear so, here we get all this in KESF, we get all these parameters.

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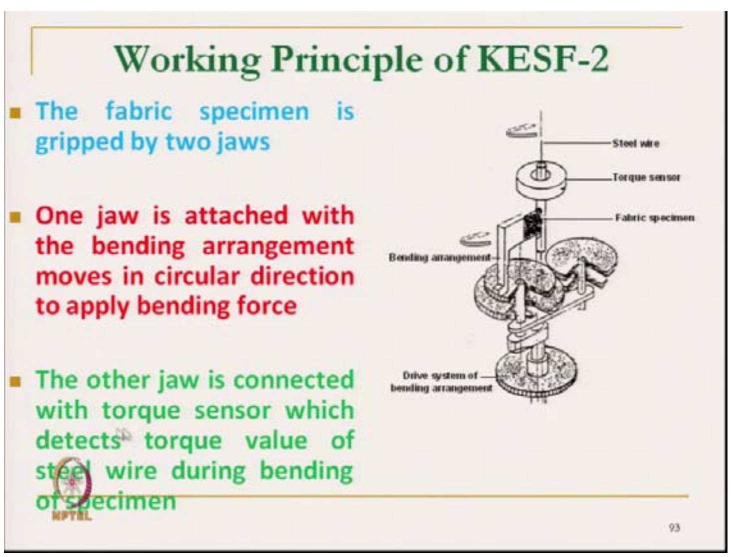

And now, we will discuss the principle for KESF-2. So, this module it measures the bending rigidity bending characteristics of fabric. Shear, we can see the fabric is the play again gripped with the help of two jaws. One jaw it is a strain, this measure it is a torque sensor is there. This torque sensor it is here, which is gripped (Refer Time: 19:09). Another jaw is, which is actually make movement bending arrangement. So, one is torque sensor, another is bending arrangement. And here is the fabric specimen.

So, one jaw is attached with the bending arrangement. So, this is bending arrangement. And it moves along with this system. So, total with this system, if this is attached with the it gives gets drive from the motor, as it moves due to this arrangement, this total bending management it takes the fabric sample, thus it actually it bends like this. And again it comes back, it is bends and come backs. So, this is the way this work (Refer Time: 19:53).

And the other jaw is connected with the torque sensor, which detects the torque value of the steel wire. This is steel wire, it is it is hanging on the steel wire; so, steel wire during bending of specimen. So, if we can measure the torque, so we can convert it in terms of the force measurement. So, bending of force and bending and by this bending arrangement, we can measure the amount of bending or in terms of angle or something.

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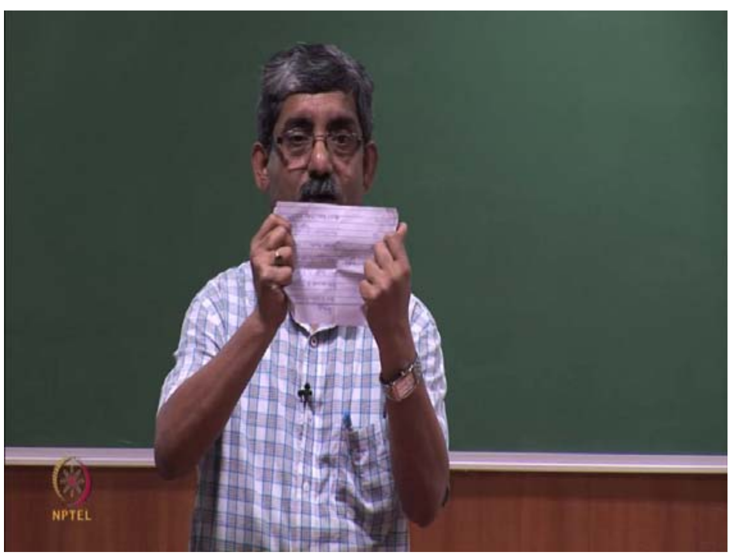

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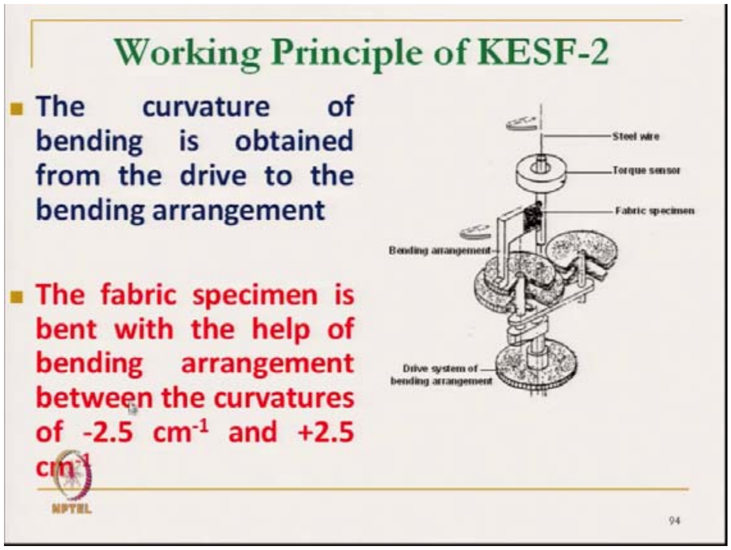

The curvature of bending, it is basically whatever the curvature, we can measured. If we know the distance and if we know the movement, we can measure the curvature. In the curvature area we can what is the movement from there, we can measure the curvature of bending is obtained from the bending arrangement. And the fabric specimen is bent with the help of bending arrangement between minus 2.5 per centimeter to plus 2.5 that is the curvature. At that curvature within that curvature it bends, so that means, the fabric moves in forward direction and also at the backward direction.

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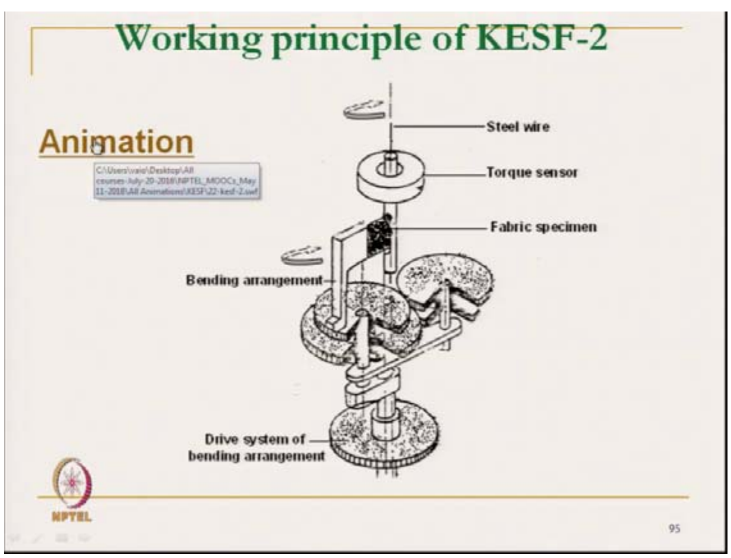

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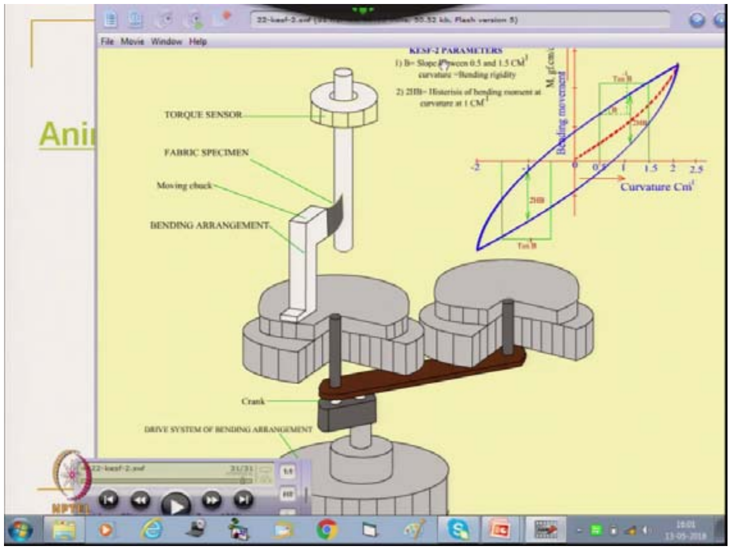

So, if we see the animation, we can see, this is arrangement. And due to this arrangement, fabric makes it (Refer Time: 21:15) bends. This is due to this bending of this moment of this jaw gives the curvature the x-axis. And here it gives whatever due to the bending, the other jaw due to this torque sensor, it gets the torque value, which is converted in terms of bending moment. So, bending so we can see the bending force, we can get. Now, just try to see, this is the bending other direction, again it is coming back in this way, it moves, so we can see.

And ultimately, we get different parameters bending. Now, let us see what the parameters are. Here, we get two parameter. One is the B that is slope between 0.5 and 1.5 curvature. So, this is the; so, between 0.5 and 1.5 what is the curvature, we can get we can express in terms of B. Another is 2HB, the hysteresis at 1 centimeter. This is at this value, what is the hysteresis, so we get is bending hysteresis and bending rigidity. So, bending two terms we get, B and 2HB.

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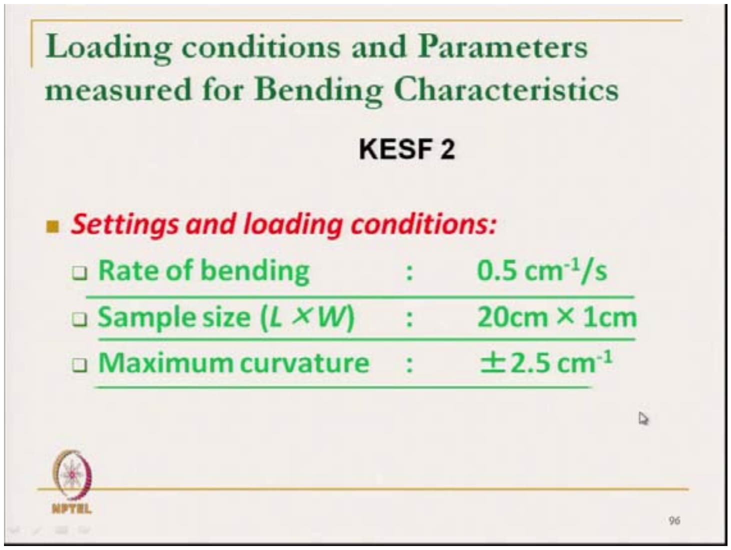

So, here again setting and loading condition is that, the rate of bending is 0.5 per centimeter per second. So, this is the curvature 0.5 and the 05 curvature per second at that rate. Sample size again, it is a 20 centimeter in length and 1 centimeter in width, so that way fabric is bent on that. Maximum curvature is plus minus 2.5 centimeter per centimeter that is maximum curvature.

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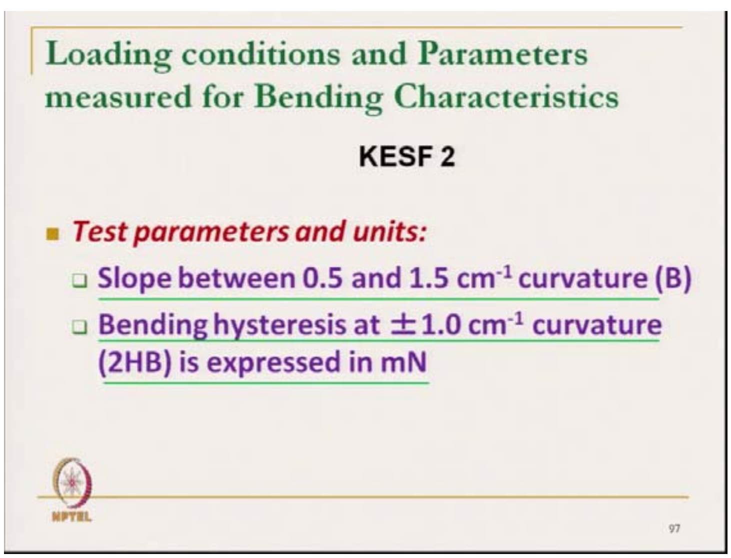

So, test parameters, what we get, we have already mentioned that curvature in terms of B we get. So, slope between 0.5 and 1.5 curvature. And bending hysteresis at plus minus 1 curvature (Refer Time: 23:43) 2HB, it is expressed in terms of milli Newton.

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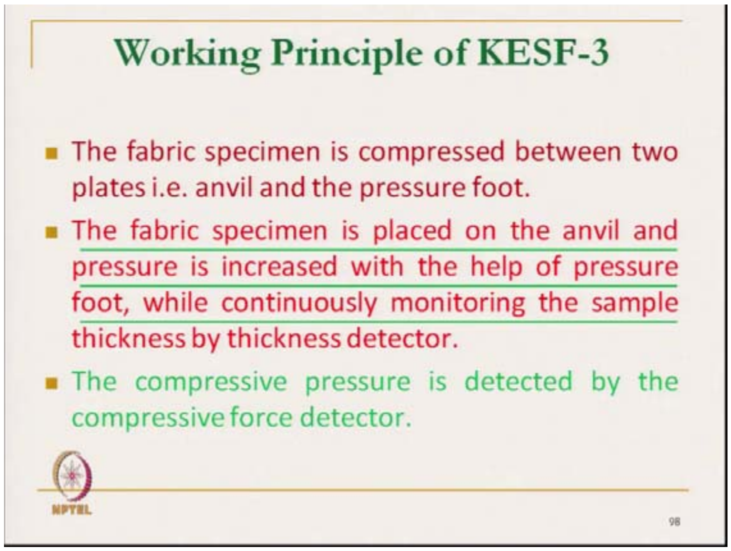

Now, coming to the KES-F3 system; this is actually it is it measures the compressional characteristics at low stress level. So, here the fabric is compressed between two surfaces; one is anvil, which is actually (Refer Time: 24:12) which the fabric is placed, another is pressure foot. And the fabric specimen is placed on the anvil and the pressure is increased with the help of pressure foot, while it is continuously monitoring the thickness, so by the thickness detector. So, ultimately we get thickness verses pressure curve. And compressive pressure is detected by the compressive force indicator actually that is any load indicator load cell, we can get.

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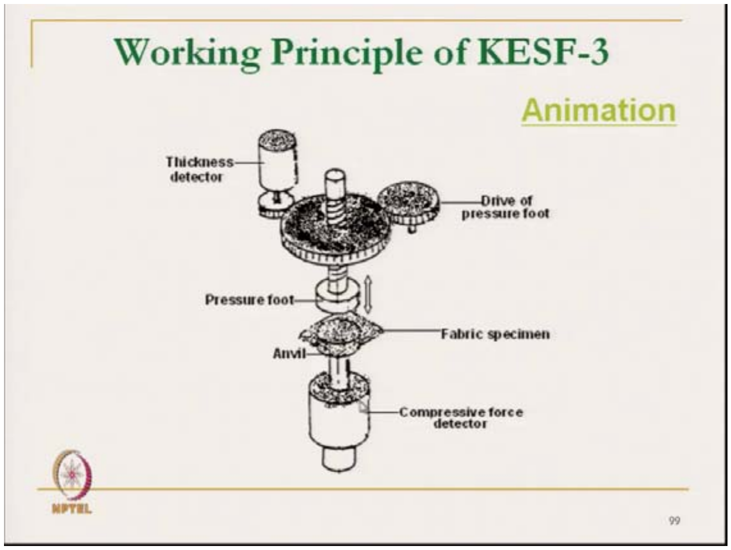

So, if we see the animation, so this is the compressional module KESF-3 module. Here this one is anvil, it is a plate on which fabric sample specimen is placed; and this is the pressure foot. And the compressional force detector, it is connected with the anvil. And here it is a thickness detector, which actually it drives; here is a drive arrangement which actually rotates.

And due to rotation, this pressure foot moves up and down. And this is due to the rotation of this a thickness detector, we get the thickness value. And they are interlinked. So, as soon as a maximum pressure is reached. This is the signal is sent to the motor, and it reverse. So, in this way, it moves up and down. And compression and recovery takes place.

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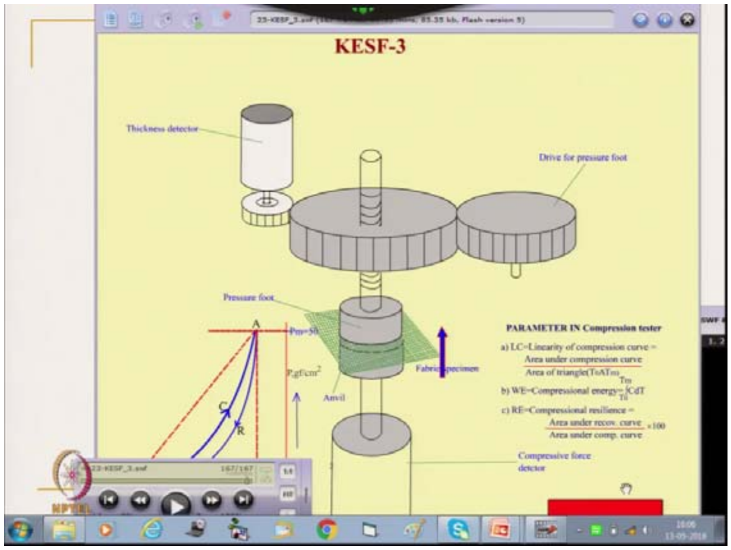

Let us see, so the fabric is placed between anvil and pressure foot ok. And now, the compression due for the (Refer Time: 26:09) this drive, it is started it is going upward. And then again after reaching certain predetermined force, and it comes backward. So, in this way, it moves upward and downward, we can get compression and recovery curve.

And from here if we see, we get (Refer Time: 26:33) three parameters we get here typical. And in addition to that, with this parameter we get the thickness value also. So, LC is the linearity of compression curve, it is similar to the linearity of the tensile curve. So, linearity of compression curve is area under compression curve by this triangle area, it is a $T_oTT_0AT_m$. T_0 means, we can say this is the T_0, and this is T_m. And this at thickness at 0 almost lower pressure thickness; and it is a maximum thickness. So, this triangle and the ratio between this area under this curve and this area of this triangle gives the linearity. Again here the linearity gives the indication of the behavior compressional behavior.

Second is the compressional energy area under the compressional curve, so that is the C curve. And recovery RE compressional resilience is that area under the compressional curve and by area under the recovery curve. So, this again this gives the indication of the how the compression and recovery takes place. And linearity shows the nature of compression. So, these three parameters along with another parameter, which is the thickness.

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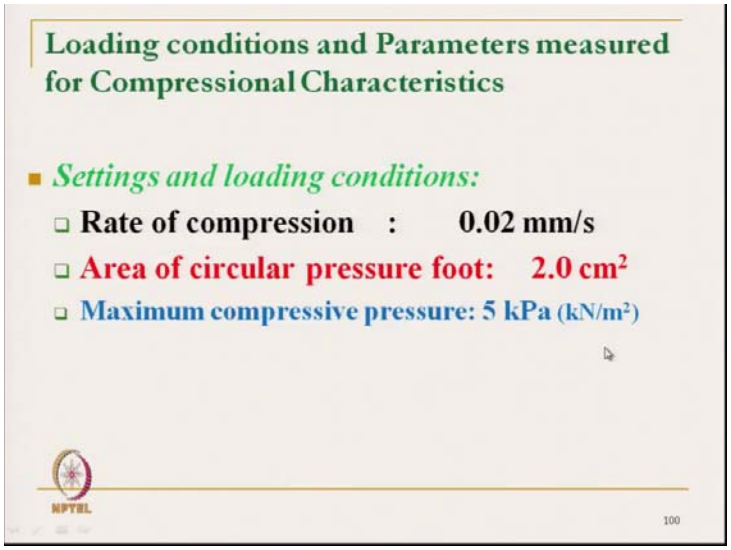

So, here the setting or loading condition is that, it is a rate of compression is at 0.02 millimeter per minute that is at that rate the compression will take place. Area of circular foot is 2 square centimeter. Maximum compressive pressure is 5 kilopascal or 5 kilo newton per square meter that means after that reaching that value, it will automatically come back.

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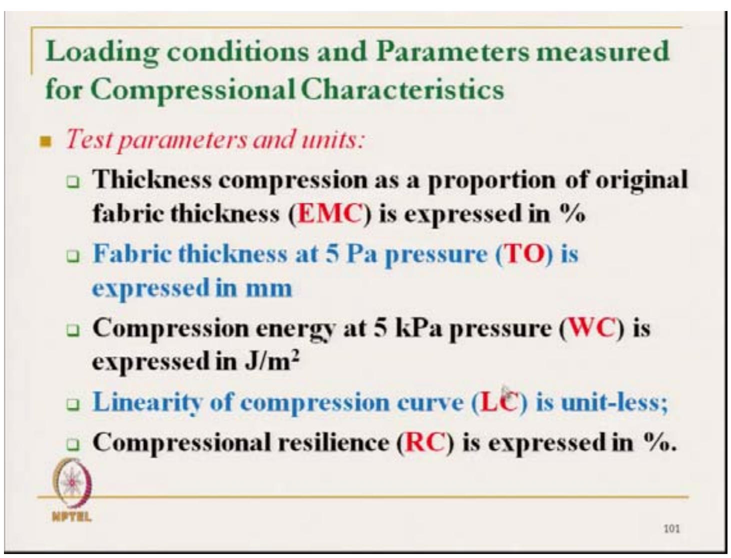

The test parameter is that, it is a thickness compression as a proportion of original fabric thickness EMC is expressed in percentage. So, thickness original thickness of fabric we can get. And fabric thickness at 5 Pascal pressure is it is expressed in terms of TO. TO is at lowest pressure, the thickness TO. And WC as we have seen the compressional energy at 5 kilopascal that is what is the area under the curve, and linearity of compression LC, and compressional resilience RC. So, these are the parameters. Typically we get four parameters along with the EMC that is the thickness compression percent.

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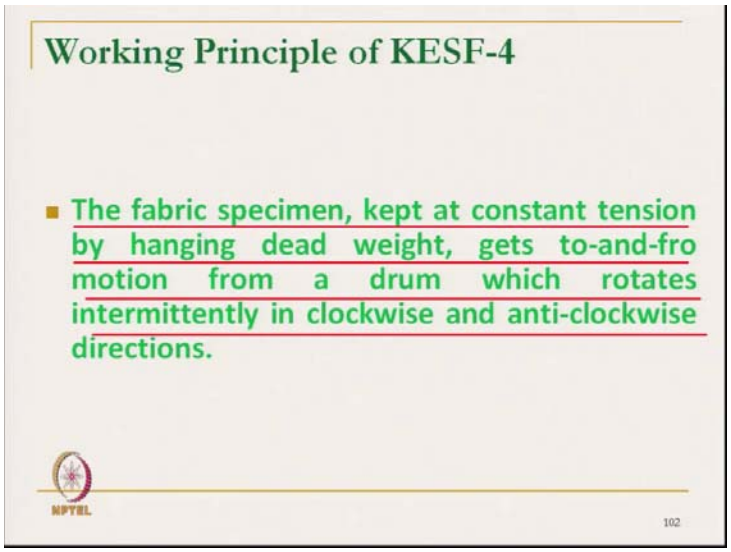

Next one and last module is that it is a KESF-4. Here it is a very important in terms of the tactile comfort of clothing is concerned. So, here it measures the surface characteristics of clothing. Surface characteristics in terms of two parameters; one is the friction, another is it is surface roughness. So, if we see the principle, here fabric specimen, it is kept under a constant tension, where a constant load is actually by hanging a constant load constant weight, and gets to-and-fro motion.

So, fabric at constant load gets to-and-fro motion. And this motion is actually we get from by the rotation of drum, it rotates intermittently, clockwise and anticlockwise motion, so that way the fabric moves. Fabric is under constant tension, and it moves to-and-fro by rotation clockwise and anticlockwise rotation of a drum. So, this way the fabric gets its motion.

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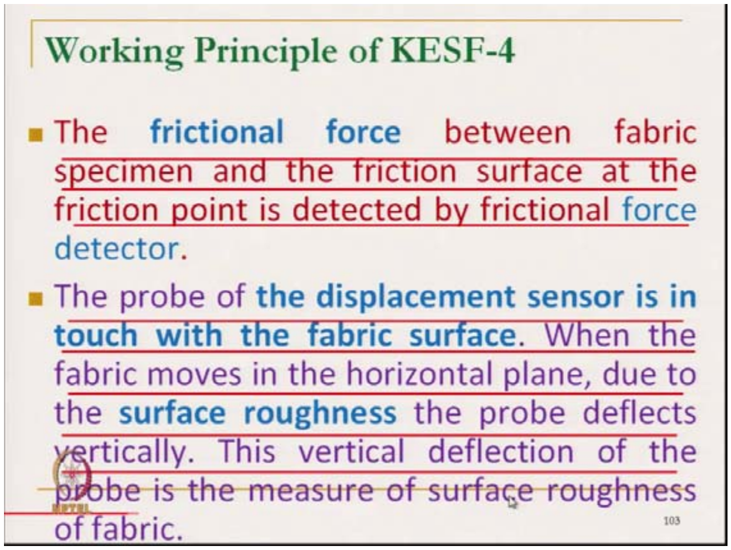

And the frictional force between the fabric specimen and the friction surface, we may change we may select any other surface, standard surface is there, but we can select any other surface, at the friction point to detect the frictional force So, frictional force is detected by the force detector. And the surface roughness is detected by the displacement detector, where the probe is placed on the fabric surface, and when fabric moves. Laterally the due to the uneven surface of the fabric, the probe moves vertically. The vertical movement of the probe due to the horizontal movement of the fabric specimen gives the indication of the surface roughness. So, vertical deflection of the probe is the measure of surface roughness.

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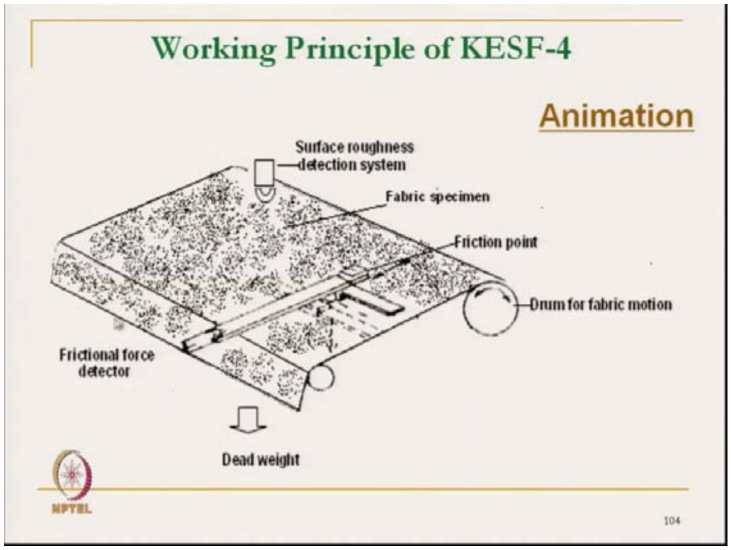

Now, now let us see the working principle. Now, this is the fabric specimen. One constant dead weight is hanging, constant load to keep the fabric at certain stressed condition certain load condition, so that there it is free of any wrinkle or any looseness, because we are going to measure the surface roughness, for that the fabric has to be straight. And there are two detectors. One is that force detector, this is the force detector, and this is the point it is a friction point. So, the friction surface if we select, this is a fabric sample. If we select the friction surface, will be the same fabric or any standard surface any and any metal, so we can place that friction surface here.

And then this total system is placed on the fabric, and with a certain normal load. Standard normal load is there here it is placed. And this is the friction point. So, you know the normal load, and as soon as the drum rotates clockwise. This drum actually rotates clockwise and anticlockwise. So, when this drum rotates clockwise, the fabric starts moving from left to right direction, and frictional force is generated, and which is detected by the force detector here. This rod is connected with the force detector, so this is being pulled, and there the force is after detected here.

And another detector, which is (Refer Time: 33:57) detects the surface roughness. This is the surface roughness detector, which is nothing but the displacement detector any LVDT type any detector, so which in detects the displacement. So, when it moves fabric moves laterally, so this detector due to the surface roughness, this detector moves vertically, this will move vertical up and down. If the fabric is very smooth, suppose any polythene sheet, any sheet material, there we want to be any vertical movement. So, level of (Refer Time: 34:31) extent of vertical movement, it is actually it indicates the roughness.

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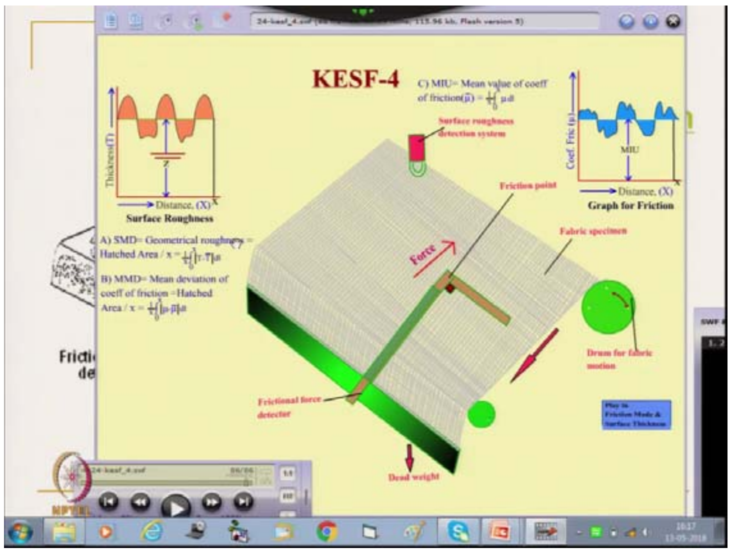

So, let us see the animation here, so try to see. The drum is rotating clockwise. So, fabric is moving in this direction. So, force detector is detecting. And here this side it is giving the frictional force. So, frictional force we know if we know the normal load, so it directly gives the coefficient of friction value.

And here, this is the distance travelled, and we get this value the coefficient of friction versus the distance travelled. And ultimately, if we measure the mean of this value, so this is called MIU mean value of coefficient of friction. So, MIU is a parameter, which is which gives the indication of the mean friction value. So, here all other parameters constant, speed, and normal load, these are constant, we can get the MIU value, which is nothing but the mean mu value mean friction null coefficient value.

So, another parameter we get from this deflection. For vertical deflection, it is actually shown the thickness, thickness at different point, we can indicate from this value. So, this is the deflection. So, this deflection means, it is a change in thickness at different point. And here x-axis is the distance travelled. So, from here, we get the SMD and MMD. What is SMD; is the geometrical roughness. Geometrical roughness is the area of highest area, the area of highest zone. This is the geometrical roughness, so whatever it and that means, higher area will be that means, higher roughness, because what is the deflection of the thickness of (Refer Time: 36:42).

And another is the MMD mean deviation of coefficient of friction. So, from here, we can get what is the mean deviation of friction. So, the mean deviation so, SMD we get that means, geometrical roughness value we get, then MMD we get, What is the deflection of friction deviation of friction. Another is the MIU; it is a mean frictional coefficient. So, from here, we get three more parameters. So, if we talk the total parameters, we will get approximately 16 parameters we will get from these four module.

Now, we cannot evaluate our handle characteristics in isolation. So, this four from, because if you want to know the friction, it is ok; if you want to know the compressional characteristics, it is ok. (Refer Time: 37:41) use module three if you want to know the frictional characteristics, we if you will use KESF-4. If you want to use a shear or tensile characteristics, we can use module one. But, if we want to know the total handle related characteristics or total tactile response related characteristics, we have to take care of the all total all four modules ok.

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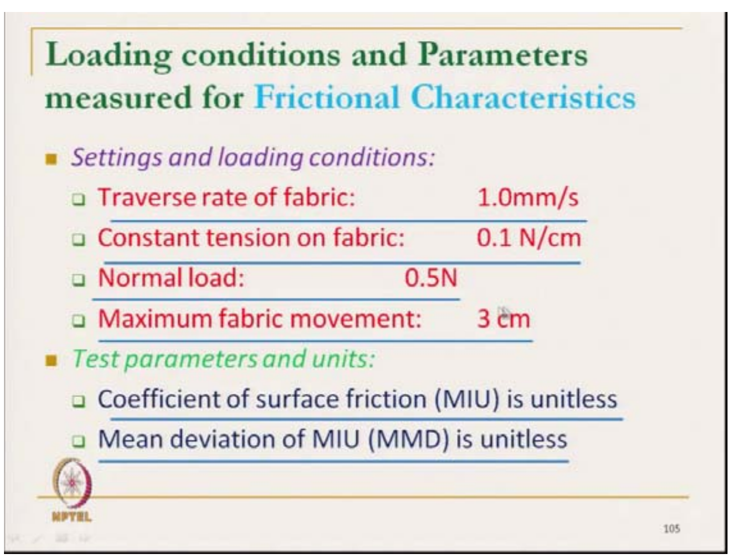

So, these settings are that traverse rate of a fabric is 1 millimeter per second. Constant tension 0.1 Newton per centimeter, normal load during a friction, it is a 0.1 Newton that is a fixed load (Refer Time: 38:24) at that load, the friction takes place. Maximum fabric movement is 3 centimeter. So, 3 centimeter it moves one direction, and then it comes back. So, test parameter MIU and MMD it is that we have discussed, both are unit less.

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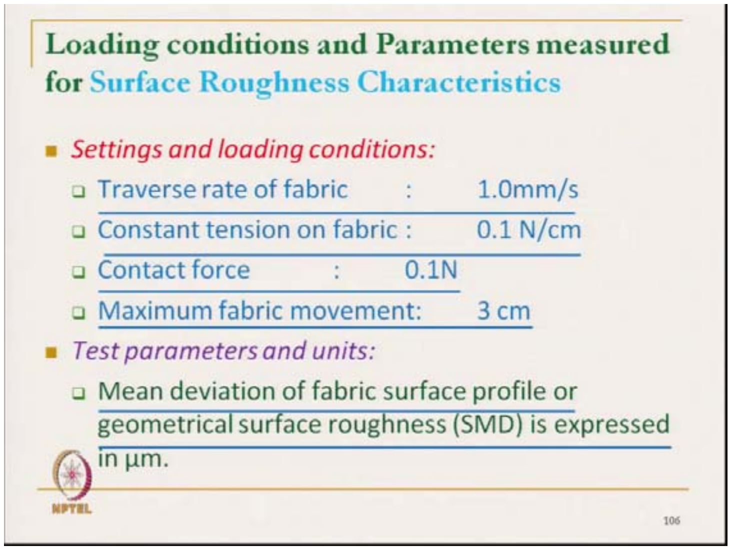

And another is for surface roughness, its traverse rate is same. And constant tension it is same. And the contact force is 0.1 Newton. Earlier case, we have seen it is a 0.5 Newton for friction; for thickness say, it is a 0.1 Newton. If we cannot have very high force, otherwise it will not give if the in case of soft fabric, it will not give the variation.

So, ultimately we want to know the variation in thickness. And maximum fabric movement is same, because we measure both the characteristics at a time through 3 centimeter movement. So, test parameters; we which we get it is SMD geometrical surface roughness; it is it is expressed in terms of micron. So, these are the all these parameters we get from.

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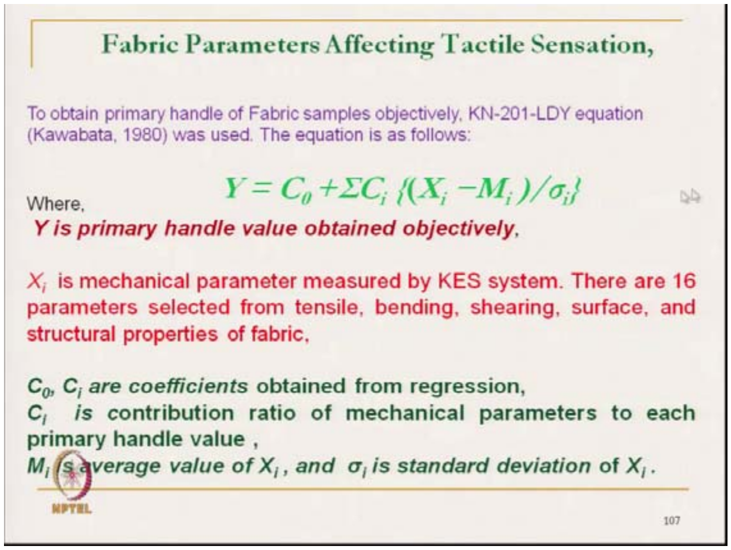

And after getting in KESF system, it is already it is installed it is a basically the one software one equation is installed KN-201-LDY, they might have come with the latest one also, but this says the equation, they get this is the generalized equation. This generalized equation

$$Y=C_o+\sum C_i / (X_i-M_i)/\sigma_i$$

So, what we have tested 16 parameters. So, all these mechanical parameters are here. This is the mechanical parameter like linearity of compression curve, and linearity of or tensile energy, these are the curve. So, these are we can we have all these parameter. So, each parameters it expressed in terms of X_i, and it is a mean value of that X_i. And this is the standard deviation of X_i. So, this is the value.

And ultimately, here we get the coefficient. So, coefficient these are the coefficients obtained by regression analysis. And C_i is the contribution ratio .C_o is the actually it is a coefficient it is a constant, but C_i is a constant it is a contribution ratio, so which means for X_i say X_i means tensile energy, suppose out of 16 parameters of one (Refer Time: 41:47). For tensile energy what is the contribution of X_i for that particular value, particular parameter. So, this is this gives very nice indication very good indication for this for a particular parameter. And M_i is the average value of X_i, and this is the standard deviation.

And we will see next in next class we will see with example for different parameters, different handle related parameters, different tactile parameters, this C, the contribution value changes for a particular significant value of significant quantity. So, there are 16 parameters available, but all the parameters may not be significant for a particular handle response. So, for significant responses, there are values we can see in the next class.

So, till then, we will stop here.

Thank you.