

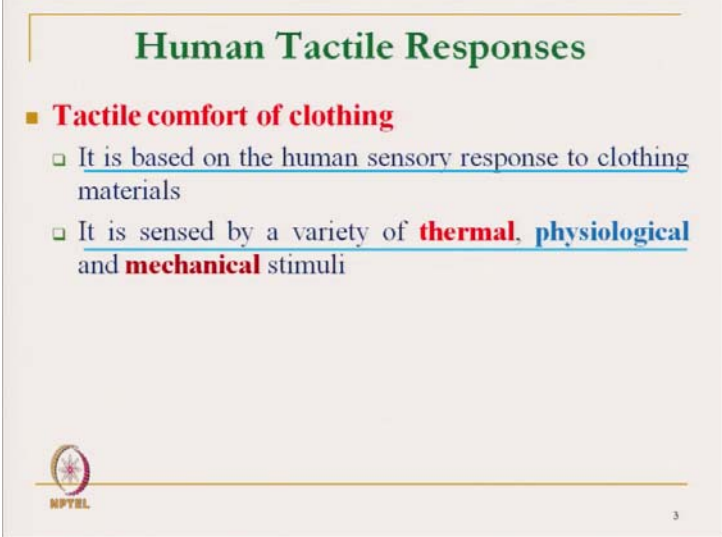
**Science of Clothing Comfort**  
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**Department of Textile Technology**  
**Indian Institute of Technology, Delhi**

**Lecture - 15**  
**Tactile Aspects of Clothing Comfort**

Hello everyone. So, today we are going to start the topic Tactile Aspects of Clothing Comfort. In earlier topics we have discussed about the psychological aspects of clothing comfort or overall it is a psychological aspects of comfort. And, then we have discussed the neurophysiological aspects. There we discussed about various measurement technique, psychophysical, psychophysics laws of psychophysics, then neurophysiological aspects we have discussed the various sensors available in our skin; mechanical sensors, thermal sensors, present in our skin.


Now, in this segment of tactile aspects of clothing, what we are going to discuss here? What are the different factors of clothing actually activates the sensor and ultimately we get sound feeling? So, from here onwards, we will discuss about the tactile aspects of clothing comfort. So, here now tactile aspects of clothing comfort means tactile comfort sensation. So, what is that?

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**Human Tactile Responses**


- **Tactile comfort of clothing**
  - It is based on the human sensory response to clothing materials
  - It is sensed by a variety of **thermal**, physiological and **mechanical** stimuli

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So, tactile comfort of clothing is based on Human Sensory Response to clothing material. Like design of clothing, type of material we use. So, how this textile material actually actuates our sensory responsive.


So, it is sensed by variety of stimuli. Different type of stimuli, that may be thermal may be physiological, or may be mechanical, when actually you wear clothing. And, ultimately it gives overall tactile response.

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**Human Tactile Responses**

- **Mainly TWO types of tactile responses generated due to CLOTHING**
- **Prickliness, scratchiness**
- **Handle related characteristics i.e. The sense of touch of fabric**

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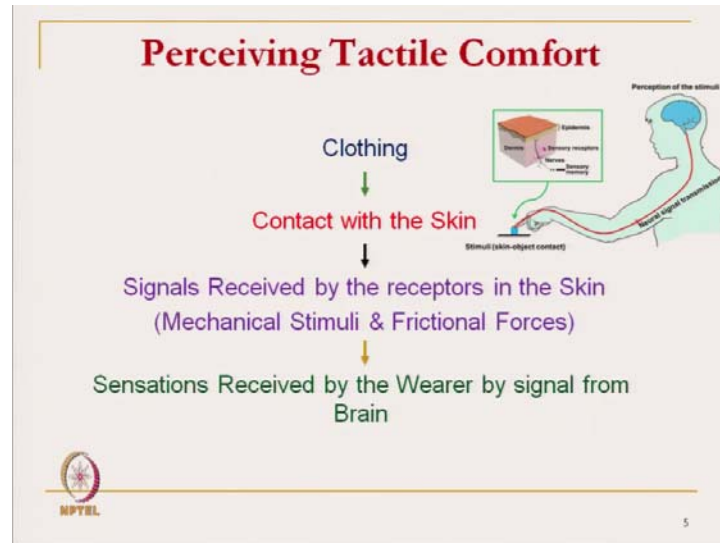
So, if you see overall tactile response now, the thermal aspects we will discuss in next segment. Here, we will discuss the mechanical aspects of tactile a comfort. So, if we divide the tactile responsive broadly, we can divide in 2 types. First is prickliness, scratchiness, rubbing, this type of itching, this type of sensation gives some uncomfortable feeling.

And, we will discuss various aspects of prickliness, scratchiness, what are the different factors? Which actually controls the prickliness, scratchiness, if you understand this then you can develop fabric of comfortable in nature. And, next aspect fabric handle related characteristics which is actually sense of touch or pressure.

So, in earlier segment as we have discussed that in neurophysiological sensation and which we received by our different types of sensors, that touch pressure this, but effectively this sensation is received by the fabric mechanical characteristics.

So, here we will discuss what are the mechanical characteristics? How can you evaluate these mechanical characteristics? What are the factors affecting these mechanical characteristics? So, handle related characteristics, which is basically sense of touch.

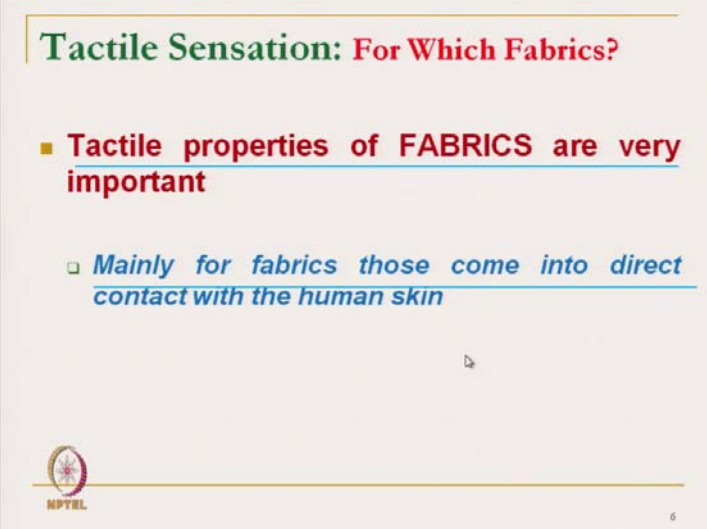
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So, how do you perceive the tactile comfort? Basically, clothing due to different mechanical characteristics like bending rigidity. It is an extensibility, it is a surface characteristics friction. So, this all these characteristics actually stimulates our sensory, which are present in the skin. So, when these fabrics are in contact with our skin, it gives signal to the skin.

So, our skin receives signal from fabric. Suppose the fabric is rigid, our sensors gets certain type of sensation. If it is rough, it will get different sensation, if it is flexible it will get different sensation. So, these mechanical stimulation or different types of frictional force, it gives signal to our skin. Those sensors present in the skin, as we have discussed, it sends signal to our brain, which evaluates. And, ultimately we perceive certain comfort feeling.

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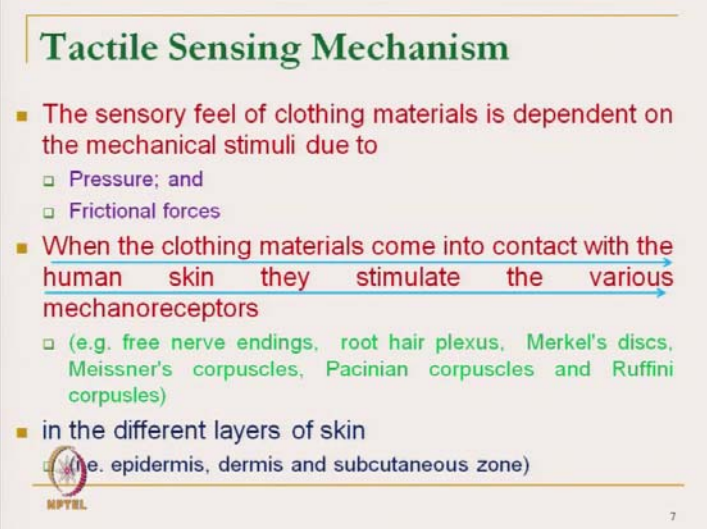
**Tactile Sensation: For Which Fabrics?**

- **Tactile properties of FABRICS are very important**
- *Mainly for fabrics those come into direct contact with the human skin*

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So, which fabric gives best maximum sensation? The tactile sensation, it is important for those fabrics, which are in contact with our body. Although, other fabrics which are not in contact with our body, those fabric send indirect sensation. Suppose over a very soft fabric, if you wear a very stiff fabric, it will give indirect sensation, but mainly we should very careful about those fabrics which come into contact with our skin.

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**Tactile Sensing Mechanism**


- The sensory feel of clothing materials is dependent on the mechanical stimuli due to
  - Pressure; and
  - Frictional forces
- When the clothing materials come into contact with the human skin they stimulate the various mechanoreceptors
  - (e.g. free nerve endings, root hair plexus, Merkel's discs, Meissner's corpuscles, Pacinian corpuscles and Ruffini corpuscles)
- in the different layers of skin
  - (e. epidermis, dermis and subcutaneous zone)

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So, this is very important. Now, let us see the tactile sensing mechanism, the sensory feel of clothing material is dependent on the mechanical stimuli due to pressure, frictional force.


So, pressure and frictional force, which actually sends signal to our skin. When it comes into contact with our body and it stimulates various mechanical receptors. So, when the clothing material comes into contact with our body, our skin stimulate various mechanical receptors, these receptors as we discussed; they may be free nerve ending, root hair plexus, Merkel's discs, and all these types mechanical receptors. And, they are present at different layers of our skin that we have discussed; it is epidermis, dermis and subcutaneous zones. So, they receive the signals of mainly pressure and friction from the fabric and we get sensations.

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**Most Tactile Sensitive Parts**

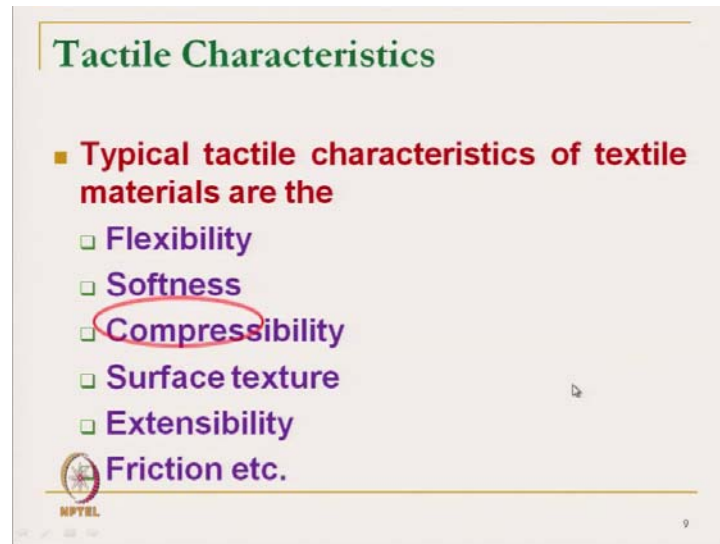
- **The most tactile sensitive skin areas of human body are**
  - The face;
  - The torso (central part of the human body which extend the neck and limbs); and
  - The hand

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So, most tactile sensitive parts are basically 3 parts of our body. Those are most sensitive parts. One, face is a most sensitive part because as we know that when we use any textile material for face wash or face wipe or something, we need extremely soft one. Because, face is very sensitive to tactile sensation. Next, comes the torso, the main actual central part of our body which extend neck to limb. Because, that is very important here we get maximum tactile response, because area of the torso is very high so, most of the part is very sensitive. So, we should be very careful of using fake clothing for this type of area. Because, we get maximum prickle sensation, maximum itching sensation,

maximum scratching type sensation in this part and third one is the hand. So, this part is very sensitive and we should be very careful of selecting fabrics for this type of cloth.

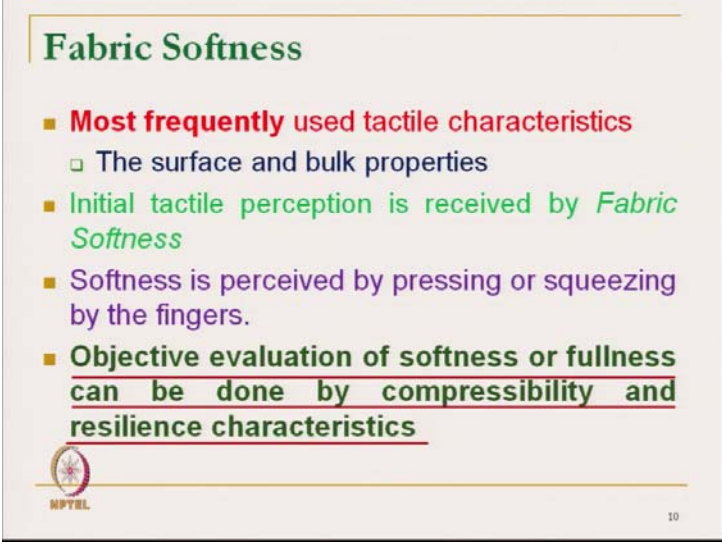
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The tactile characteristics of textile materials are typically these are; flexibility of material whether the fabric is flexible or stiff that gives tactile sensation, whether a fabric is soft or hard. Then it is whether it is a compressible or not, whether it is a rough surface texture or it is a smooth that we get, whether the fabric is extensible or not, if it is extensible it will give less pressure on our body. So, that gives a direct tactile sensation of our body, frictional characteristics, whether it gives a rough sensation or not.


So, these are the basic fabric related characteristics, we will see how to measure all this characteristics to know what type of tactile sensation, it will give? So, among all, if you see although it may not be that much important, but we broadly see tactile characteristics, we first measure softness by pressing by thumb or finger. So, widely used, most frequently used tactile characteristics of clothing is surface bulk.

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**Fabric Softness**

- **Most frequently used tactile characteristics**
  - The surface and bulk properties
- Initial tactile perception is received by *Fabric Softness*
- Softness is perceived by pressing or squeezing by the fingers.
- Objective evaluation of softness or fullness can be done by compressibility and resilience characteristics

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So, it is an initial tactile perception, if the fabric is not soft then we actually whatever may be the other characteristics, we normally say it is not tactile, soft, comfortable, but there are other characteristics which are very important. So, how do you perceive softness? First is, by squeezing with help of fingers, the objective evaluation of softness or fullness can be done by compressibility. So, we can by hand we can squeeze it, but if you want to measure, if you want to compare the actual value. So, we can measure the compressibility or compressional resilience.

So, we will see how to measure? So, this can be done by compressibility and resilience characteristics.

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**Assessment of Tactile Characteristics**

- Objective assessment of the tactile characteristics of fabrics can be done by assessing the *Low Stress Mechanical Properties (LSMP)* of fabrics
  - **Bending**
  - **Shear**
  - **Extension**
  - **Compression**
  - **Surface roughness**
- **Methods of Measurement of LSMP**
  - Kawabata Evaluation Systems for fabrics (KESF) and FAST (Fabrics Analysis by Simple Tests)

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So, if you see all those tactile characteristics, we can measure by measuring the low stress mechanical characteristics. What are low stress mechanical characteristics, these are bending? So, it is low stress mechanical characteristics is important for our clothing for tactile characteristics. There are 2 types of mechanical characteristics; one is high stress mechanical characteristics, where we actually test the fabric up to end point, it is a upto it is a breakage point maximum point.

But, here in low stress mechanical characteristics, we use very low stress to deform the fabric. So, like bending, bending we use the low stress, very low amount of test bending stress, which actually fabric encounters during work state. Next is shear; shear is nothing, but it is a deformation when the force is applied in a parallel opposite direction. So, that is shear. The fabric with low shear stress will give better tactile comfort. So, fabric should have very high shear strength with low stress, the very classical example is if we wear, if we prepare a clothing from a material from other than textile material like polythene sheet.

We can incorporate any other characteristics of polythene sheet. If you want permeability in a polythene sheet, we can punch the holes, if you want softness, we can make a very soft, very flexible, very soft one, we can make very good surface texture, but in a polythene sheet or any planar material, we cannot incorporate shear, we cannot reduce



shear stress to a greater extent, because it is characteristics is a continuous material, but for textile material uniqueness is due to interlacement of yarn can move freely.

So, that is how the shear is characteristics is extremely important, which helps a clothing to actually accommodate our body posture. If we move our body, if you change our body posture, the clothing automatically take safe, with very low shear stress, but if the shear stress is very high. So, then it will unnecessarily impart pressure on our skin and ultimately we get uncomfortable sensation. Next is the extensibility. The extensibility is extremely important, because the low stress extensibility means if the fabric is made of very highly rigid structure. So, then due to movement of our body it may restrict our body movement.

So, at least at low stress the extensibility should be little bit high. Similarly, compressional characteristic, it should be soft enough then surface roughness, which is very important, which gives the indication of scratchiness. If the surface is rough, it will generate high friction and we will feel uncomfortable. So, we have to measure this low stress mechanical characteristics. So, there are various methods evolved, but 2 successful commercial instruments are set of instruments available.

One is Kawabata evaluation system for fabric KESF system. Another is the fabric analysis by simple test FAST. Although FAST is not actually developed for measuring the tactile characteristics, but indirectly we can get the tactile characteristics, we will discuss each and every characteristics methods in detail.

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**Tactile Characteristics and Tactile Responses**

As far as the tactile responses are concerned, all the **low stress mechanical characteristics (Fabric tactile characteristics)** directly or indirectly stimulate the touch, pressure, roughness and other mechanoreceptors of human skin (*human tactile responses*)

Fabric tactile characteristics → Human tactile responses

**Prickliness ?**

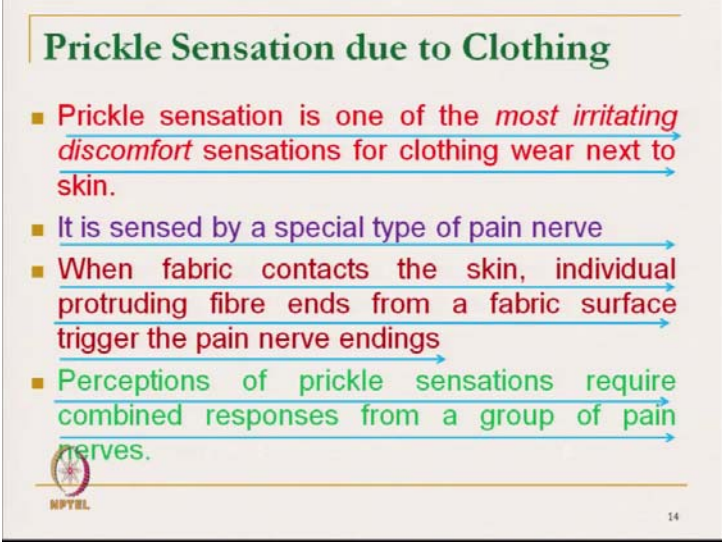
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Now, the tactile characteristics and tactile response so, fabric tactile characteristics, these are actually directly related to what are the responses will be received? So, as far as the tactile responses of our body is concerned, these are all low stress mechanical characteristics of fabric, which directly or indirectly stimulate the touch, pressure, roughness and other mechanoreceptors of our body.

So, if we understand fabric low stress mechanical characteristics. We can indirectly, we can directly guess what type of actual response we will get tactile response. So, basically fabric tactile characteristics is directly related with the human tactile response. So, if a fabric is a friction is high, frictional coefficient is high, then it will definitely give a roughness characteristic rough, it will actually try to pull the skin along with the fabric movement. So, give different sensation.

So, we will start with characteristics, which is it is a prickliness, which actually we can we cannot measure it not directly, low stress mechanical characteristics, low stress mechanical characteristics we can say, we can call it as handle characteristics; touch, pressure, and all this. But, prickliness is entirely different which is not basically it does not come under the low stress mechanical characteristics. It is not even friction. So, prickliness is basically gives maximum uncomfortable nature if the fabric is prickle.

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**Prickle Sensation due to Clothing**

- Prickle sensation is one of the *most irritating discomfort* sensations for clothing wear next to skin.
- It is sensed by a special type of pain nerve
- When fabric contacts the skin, individual protruding fibre ends from a fabric surface trigger the pain nerve endings
- Perceptions of prickle sensations require combined responses from a group of pain nerves.

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So, prickliness sensation is one of the most irritating discomfort sensations of clothing, which we actually wear next to our skin. So, even if we can wear discomfort sensation of a stiff fabric or maybe a fabric give little bit higher pressure.


But, if fabric gives prickle sensation, then we will feel tactile, we will feel very uncomfortable. And, that we in last segment, we have discussed, the prickle sensation we get some nociceptor. So it is sensed by special type of pain nerves that we have discussed, which are present close to skin surface in melanin epidermis. So, when a fabric is in contact with the skin individual protruding fibre. Actually a group of protruding fibre excites the pain nerves endings. And, it is not a single fibre that we have discussed, it should be a group of fibre and it should actually act on a minimum area that we have discussed in last class.

So, fibre ends; the perception of prickle sensation for that we require combine response from group pain of nerves. So, it is not the single nerve, it is a group of nerve, if gives signal then we will get prickle sensation. And, actually that is given by a large number of hairs covered with certain minimum area.

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**Assessment of Prickliness in Fabric**

- **It can be measured by assessing**
  - **Hairiness of Yarns Used;**
  - or**
  - **Surface Hairiness of Fabrics**

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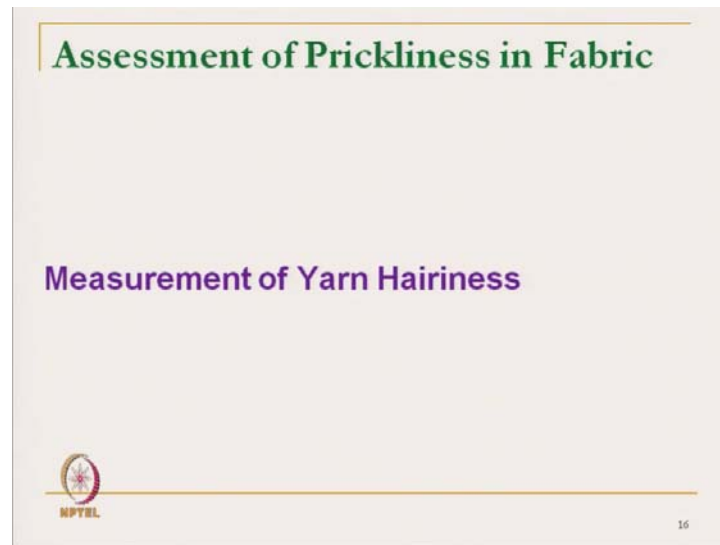
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So, now, how do you access the prickle sensation? So, to access the prickliness of fabric so, we have to access the protruding fibre, number of protruding fibre.

We know that we need certain number of protruding fibres, but how do we access this? So, it can be measured by measuring the hairiness of yarn used to produce the fabric and by measuring the surface hairiness of fabric, if we have measuring technique to measure the surface hairiness of fabric, then we can directly measure. But this type of instrument are normally not available to all the industries, most of the industries for them they can actually get the hairiness value for a particular fabric and then get certain idea about the prickliness sensation.

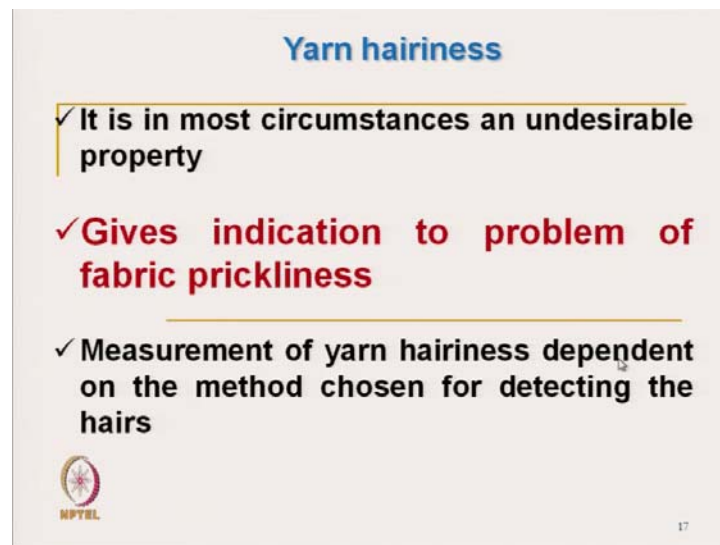
So, although measurement of hairiness is not the hairiness of yarn is not the only criteria, we have to see the length of the hair, we have to see the diameter of the fibre. So, all this concept, all this information along with the hairiness value will give indication of a material of a fabric, which will have prickliness or not.

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So, first we will discuss the different standard methods of measurement of yarn hairiness here we will discuss 3 standard methods of measurement.

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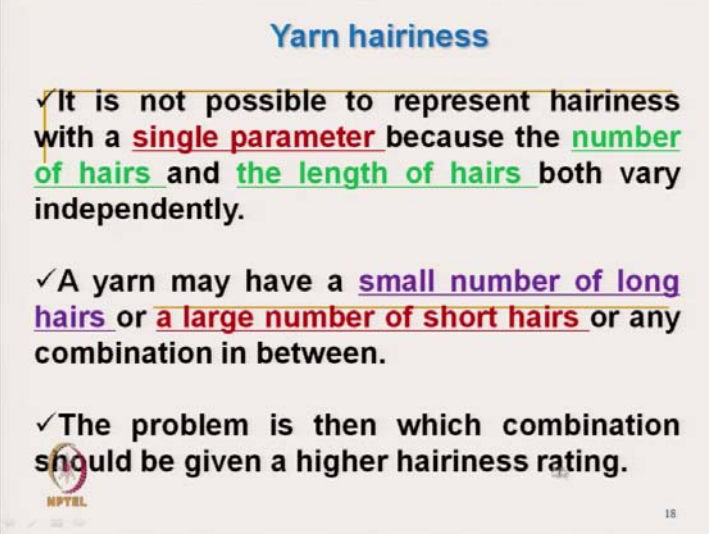


Yarn hairiness is in most circumstances, these are undesirable properties of any material. So, why in most circumstances? In some of the application, we need some special effect, some hairy effect, we may like or maybe some brushing effect, we may try to incorporate to get more warmth, but in most of the cases, it is a undesirable property as far as a appearance of fabric is concerned, also it gives indication of the problem of fabric

prickliness. So, you must know how to measure the fabric yarn hairiness? So, measurement of yarn hairiness actually depends on the method chosen.

So, one method may give a number of hairs, another method may give total length of hairs projected. So, depends on the type of measurements. So, we will start with the method, which is actually not possible to normally give a single parameter.

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**Yarn hairiness**

- ✓ It is not possible to represent hairiness with a **single parameter** because the **number of hairs** and **the length of hairs** both vary independently.
- ✓ A yarn may have a **small number of long hairs** or **a large number of short hairs** or any combination in between.
- ✓ The problem is then which combination should be given a higher hairiness rating.

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Single parameter means if we try to measure the length of a number of hairs per unit length; that means, you should know what is the length of the hair? So, that combination is required and also that another method which gives the total length of hairs protruding above the hairy yarn surface.

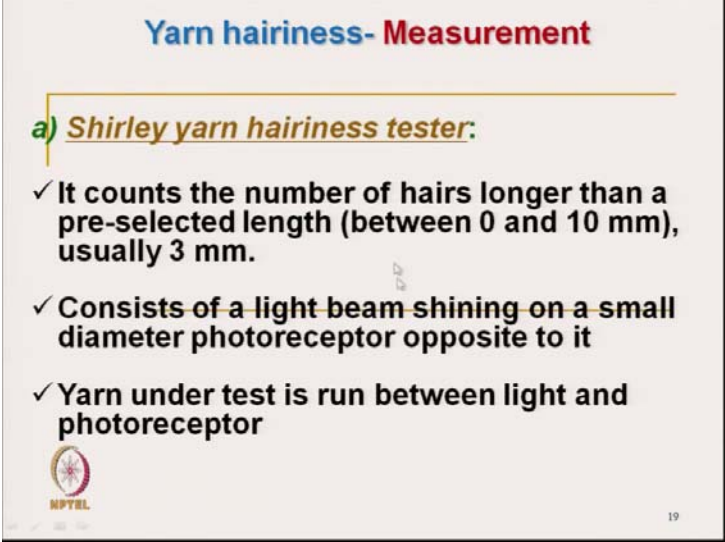
But, this total length sometime gives wrong impression about the prickliness. Should we go for higher hairiness, if it is single fibre end of a long hair, it gives the total length of hairs; one hair of say 10 millimeter gives a one hair length, another 10 hairs of 1 millimeter length.

So, ultimately it gives the same value so, 10 millimeter of hair, but if you see the prickliness sensation, these two yarns will give different sensation, but at least we get some idea about the hairiness.

So, yarn may have small number or long hairs or large number of short hairs or any combination. So, these are of any combination. So, these techniques will give us fair idea

about the hairs. So, problem is that then, which combination should be actually given a higher hairiness rating. So, higher hairiness rating is a relative term for prickliness sensation. We may consider lower hairiness sensor, but here the length of hair is very important, we must know the length of hairs.


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**Yarn hairiness- Measurement**

**a) Shirley yarn hairiness tester:**

- ✓ It counts the number of hairs longer than a pre-selected length (between 0 and 10 mm), usually 3 mm.
- ✓ Consists of a light beam shining on a small diameter photoreceptor opposite to it
- ✓ Yarn under test is run between light and photoreceptor

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So, first we will discuss the yarn hairiness measurement by Shirley Yarn hairiness tester.

So, in this method, counter is there, it counts the number of hairs longer than specified length. So, that specified length is normally it is a 3 millimeter, 3 above, 3 millimeter of length that is above the yarns surface, whichever hairs projected above the yarn surface, whichever more than 3 millimeter it will count as one hair. And, we can also measure, we can pre-select the length up to 10 millimeter. 1, 2, 3 like 10 millimeter length, we can preselect and count the number of hair. And, it consists of a beam of light, which is actually projected through a small actual diameter. It is going to the photoreceptor.


And, in between the light source and photoreceptor, the yarn will be passing. And as a single hair is passing through in between, this will actually interact the light sensation. So, yarn under test is run between light and photoreceptor.

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**Yarn hairiness- Measurement**

**a) Shirley yarn hairiness tester:**

- ✓ **As the hairs pass between the light and receptor, the light beam momentarily broken and an electronic circuit counts the interruption as one hair**
- ✓ **Only the hairs within the aperture are counted, because total no. of hairs is proportional to this count.**



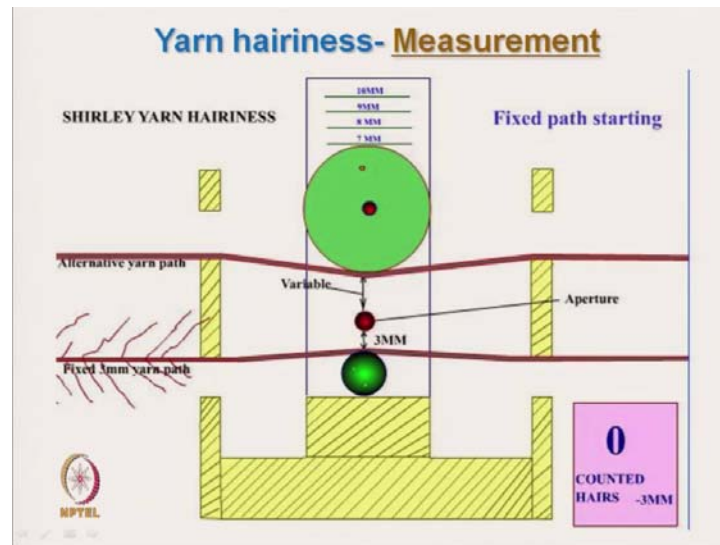
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And as the hair pass between the light and the receptor, the light beam momentarily breaks, an electric electronic circuit counts the number. How many times, it has broken the light signal. So, what it does? There is an aperture and through that aperture, when the hair is moving that will be counted.

Hair is actually present throughout the surface evenly and it is assumed, that the total hairs are proportional to the number of hairs at that particular surface. At the top surface, if light is projected through the top of the yarn surface. So, we cannot actually measure the total number of hairs, but assume that it is proportional.



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Like, here in this instrument, you can see the yarn it has got 2 types of slots, which is this is a fixed yarn path, which is actually 3 millimeter and this is the aperture.

This one is aperture and through, which light signal is passing and this is the hairy yarn and it will move through this fixed path. And as soon as one hair is moving through this, it will count as a single hair, but we can see that it is not, it cannot measure the hair in this side opposite side or other side. Only the hairs which are actually passing through this aperture this will be counted. And, it is assumed that hairs are evenly distributed. And another slot is alternate slot which is actually, we can change the path distance, this is the variable distance, which can be from say 1 millimeter to 10 millimeter depending on this guide.


This is a very well guide this can be lifted upward and downward and depending on that, we can measure it, count and this is a counter. And, let us see the animation. Animation for the fixed path. Now, yarn is moving with a fixed path of 3 millimeter now. Now this hair is cut now it is as soon as the one hair is moving through this, it is cutting and see less than that length this hairs are not been counted. So, any hair more than 3 millimeter length of this surface will be counted. So, this is the counter, which actually count the number of hairs, which actually gives the indication of the hairs, this is the fixed path and we get the count.

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**Yarn hairiness- Measurement**

**a) Shirley yarn hairiness tester:**

- ✓ The instrument has two sets of yarn guides.
- ✓ The lower set leads the yarn over a guide at a fixed distance of 3mm from the receptor.
- ✓ The upper set leads the yarn over a movable guide which can be set at a distance of between 1 and 10mm from the receptor



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The instrument has 2 sets of yarn guides. So, lower set lower guide gives a fixed length and the upper guide gives the variable set of length that we can measure.

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**Yarn hairiness- Measurement**

**a) Shirley yarn hairiness tester:**

- ✓ The total number of hairs in a fixed length of yarn is counted by counting for a given time, the yarn running at a known speed.



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And total number of hairs in a fixed length, how we can measure and count? And, and if you know the length of the yarn, then you can convert it to the number of hairs per unit length. Now, next is the Zweigle hairiness tester.

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**Yarn hairiness- Measurement**

**b) Zweigle hairiness tester :**

- ✓ This apparatus counts the number of hairs at distances from 1-25 mm from the yarn edge
- ✓ Measuring principle is similar to that of Shirley instrument
- ✓ But here a set of photocells which are arranged at 1, 2, 3, 4, 6, 8, 10, 12, 15, 18, 21, and 25 mm from the yarn



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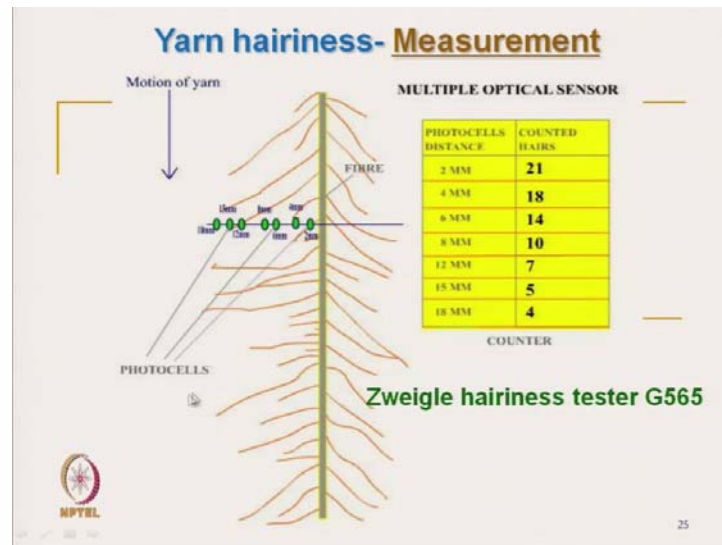
So, the main drawback of the Shirley hairiness tester was that it can measure it can keep the hairiness for a particular length at a time ok. We cannot get the more than one length at a time. So, Zweigle hairiness tester, it gives the value in a single test in a for a single yarn we can get hairiness at different hair length that it gives. So, it is a from 1 millimeter to 25 millimeter length, it gives it is a it directly gives the idea about the prickliness sensation. The apparatus counts the number of hairs at a distance from 1 to 25 millimeter from the yarn edge.

Suppose it gives the hairiness 2 to 3 millimeter or around that large number of hairs; that means, we will have an indication, that it will give this yarn, if we use for to make fabric it will give prickle sensation.

On the other hand, if it does not give up to 10 millimeter, hairs it is almost very less number. And, above that more than that; that means, it will not give us prickle sensation, we can that will be may be used for other application or they that may create other type of problem, but at least prickle sensation we can get clear idea from this instrument. And the measuring principle is exactly same as Shirley instrument here again the light source will be actually momentarily cut and it will be measured and here the typically the set the distance is 1, 2, 3, 4, 6, 8, 10, 12, 15, 18, 21, and 25 millimeter from yarn surface.

So, we will get wide range of data in place of single data in Shirley hairiness tester now. this is the instrument.

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Here, these are different optical sensors fixed at different fixed length and these are the number of hairs counted. Now, as the hair moves depending on the length of the hair, we can we will get the number of hairs. Now, let us see hair is moving depending on the number of hairs at a certain distance, we will get all this data.

So, this is actually cumulative value ultimately it gives a cumulative value. So, we will get this type. So, what does it show? If we say, if we get this data; that means, the more than 18 millimeter is of 5. So, more than 15 millimeter it is 7. So, say 15 to 18 millimeter there are 2 hairs. So, accordingly, we can get. So, if we you want to get the number of hairs and ultimately we can calculate, how many hairs will be there in yarn surface? We can calculate how many hairs will be there on fabric surface per unit area? And we can get the prickliness sensation.

Typically hairs less than 3 milli around, 3 millimeter or less than that creates problem. And with a stiff fabric, fibre diameters are higher.

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**Yarn hairiness- Measurement**

**b) Zweigle hairiness tester :**

- ✓ The yarn is illuminated from the opposite side of the photocells and as the yarn runs past the measuring station the hairs cut the light off momentarily from the photocells

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- ✓ The instrument measures the total no. of hairs in each category for the set test length
- ✓ Fixed yarn speed 50 m/min



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So, the yarn is eliminated from the opposite side of the photocell as the yarn runs past the measuring station. Hairs cut the light off momentarily from the photocell, it cuts. And, the instrument measures the total number of hairs in each category and it has got a fixed speed of 50 meters per minute. So, accordingly we can calculate the count of yarn.

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**Yarn hairiness- Measurement**

**b) Zweigle hairiness tester :**

- ✓ The zero point, i.e. the position of the yarn edge relative to the photocells is adjusted
- ✓ A further set of photocells is used to locate the edge of the yarn during the setting up procedure



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So, there are different photocells, you can adjust the photocells based on the yarn surface.

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**Yarn hairiness- Measurement**

**c) Uster Tester (Hairiness meter attachment) :**

- ✓ **Optional attachment of Uster Evenness Tester**
- ✓ **A parallel beam of IR-light illuminates the yarn as it runs through the measuring head**
  
- ✓ **The direct light is blocked from reaching the detector**
  
- ✓ **Only the light that is scattered by fibres protruding from the main body of the yarn reaches the detector**

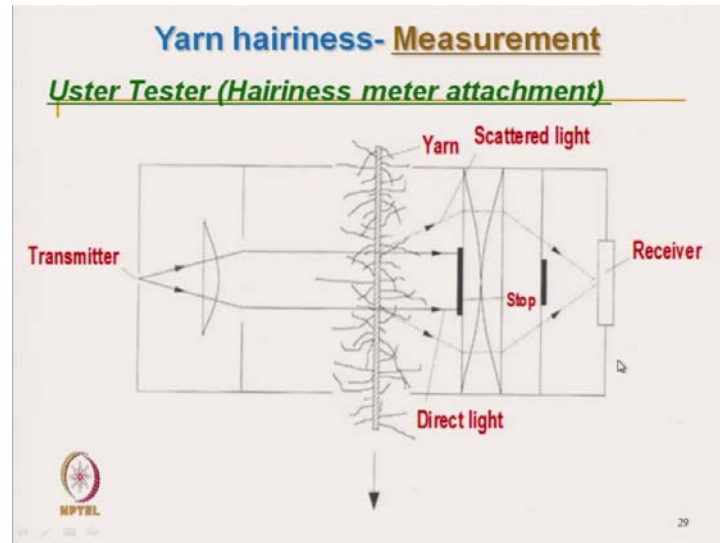
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Next is the hairiness tester by Uster, which is actually an additional attachment of Uster evenness tester, that during evenness testing, we can actually attach this tester attachment for yarn hairiness. Here the measurement technique is entirely different. Here, we do not measure the length of hair length of hair present, here we measure the total length of hair. We measure as in earlier Zweigle and Shirley tester, we measure the number of hairs present above certain specified length.

But, here in Uster tester, we measure the total length of hair. So, how do you measure? We cannot measure the length of hair directly; here we try to measure the hair length indirectly. Indirectly, we measure by light scattering principle. And, Optical attachment is there in Uster Evenness Tester where infrared light is illuminated on the yarn surface, when it is moving through and the infrared light which actually moving directly comes from an aperture of certain diameter So, light will be blocked, that particular light will not reach to the receptor; that means, that if there is no yarn, light is there, the aperture will block the light. So, that will not reach up to the sensor. So, it will sense there is no light. It will receive the light which has been scattered by the hairs protruding fibres. The intensity of that light will be captured and it will give indirect sensation, indirect measurement of total length of hairs, suppose, one yarn is moving on filament yarn if you move.

So, as there is no hairiness. So, it will not scatter the light, light will not reach up to the sensor. So, it will only receive the signal from those light which have been actually scattered by the protruding fibres.

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And, so, this is the setup. So, here it is an IR transmitter. And the light which is actually projected here; it has actually been converted to the parallel beam of light, suppose, there is no yarn. So, this is the light, actually the direct light and here it is a light stop array. This is the direct light. And, there is a light stop arrangement, this light will be stopped here. It will not reach up to the receiver. We will stop here today, we will continue with this in the next class.

Thank you.