Science of Clothing Comfort
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Lecture - 30
Moisture Transmission & Clothing Comfort (contd.)

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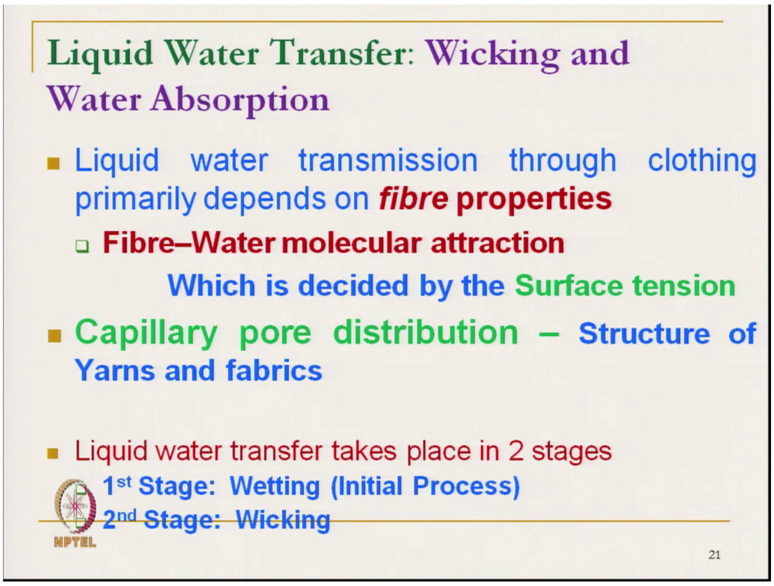

Hello everyone. We will continue with the liquid to water transmission through textile material. So, liquid water is transmitted through wetting and wicking. First let us try to understand what is wetting, wetting means actually absorption of liquid water liquid; and wicking means transmission of that liquid ok. First the fabric the textile structure has to absorb. If it cannot absorb, it cannot transmit ok.

So, liquid water transmission through clothing primarily depends on the fibre characteristics that we have discussed ok. So, fibre-water molecular attraction that is the surface tension. So, if the surface tension is actually low surface tension, then it will get spread ok. So, then it will move it, so which decide which is decided by the surface tension. And capillary pore distribution, so structure of pore, structure of yarn, structure of fabric, so the different types of structure with so one is the characteristics, then the fabric or yarn characteristics. So, liquid as we mentioned liquid is transmitted in 2 stages. First is initial stage is wetting, then it is wicking.

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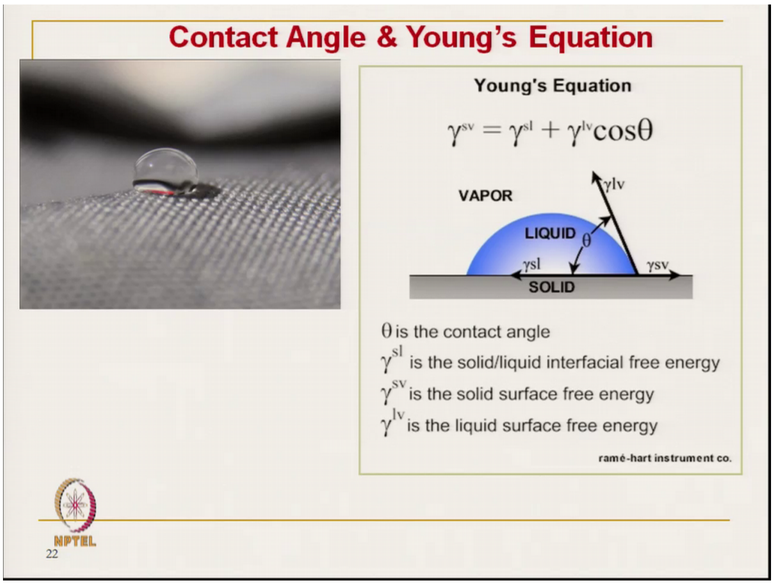

So, wetting actually is governed by the classical equation, it is by Young's equation.

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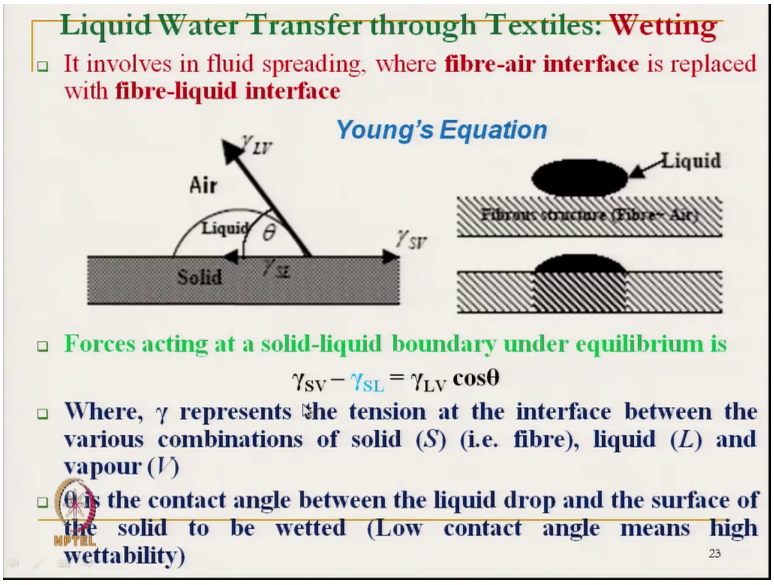

So, the Young's equation is here. It is gamma SV that means solid and vapour minus gamma SL is solid and liquid is equal to gamma LV liquid vapour and cos theta, where theta is a contact angle. So, it involves the fluid spreading, where fibre-air; fibre-air interface within the structure. So, in case of dry condition in dry condition fibre and air interface is there, there is no water. And when water comes into the fibre, if it wets in the structure that means, fibre air interface is actually replaced by fibre liquid interface ok.

So, forces these are the forces, different forces acting at solid-liquid boundary under equilibrium condition that means, this gamma SL, it is acting in the left wise direction due to the liquid presence of liquid solid-liquid. And gamma LV liquid vapour is acting at the direction of the tangent of this droplet. So, this total effect totalthese force is balanced by the gamma LV liquid solid vapour solid and vapour the solid gamma vapour is equal to this cos of this liquid vapour plus SL ok.

So, where gamma represent the surface tension; tension at the interface between the various combination of solid that is fibre, liquid that is say sweat or water and vapour means air. And theta is the contact angle between the liquid droplet and surface of the solid to be wetted, and low contact angle means it is a high wettability. And as we reduce, so this picture which is at the top, which has it has got very low contact angle that means, it this surface will not be wet because of this low contact angle. If it is low contact angle what does it mean, this contact angle low means it is a this value is because it is high ok, this at lower contact angle. So, this is becoming high, so that is why it will not actually wet.

So, normally what we need, we need this value, this SL solid and liquid. This surface tension between solid and liquid, it has to be low. What does it mean? This lower value of solid-liquid mix this left hand side, it is a high. If it is high that means, the is if this solid liquid vapour this liquid vapour that liquid characteristics, if it is constant, if we consider this liquid vapour is constant. And if it has to be high that means, the theta has to be low, which means that lower contact angle or lower surface tension between solid and liquid fibre and the that fluid that liquid that will make the fabric or structure wet, because it will help in wetting.

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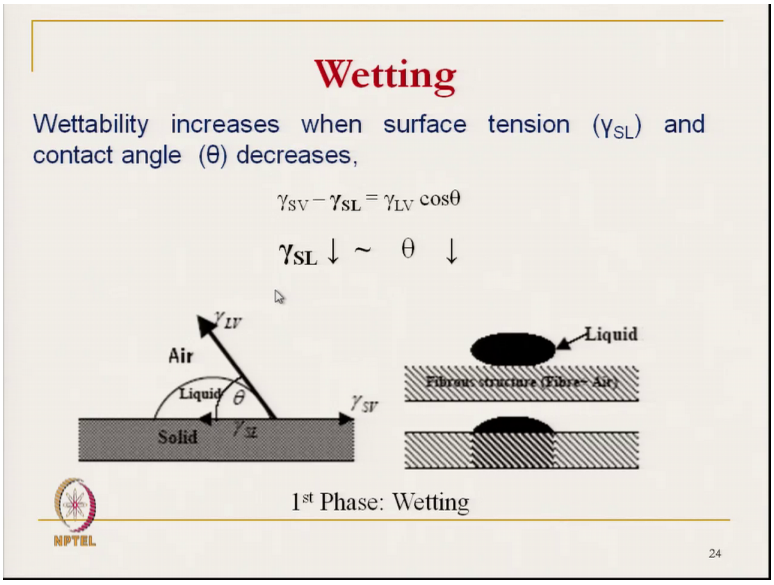

So, that means at lower value of solid-liquid means lower value of theta that contact angle that that which will actual which increases the wettability. So, wettability increases, when surface tension between solid and liquid and both surface tension, and also the contact angle either both of these should be low decreased or at least one of this should be low, so that we have to see. Like for a particular fibre like say let us say example of polyester, polyester is a particular polymer which has got a particular constant value of surface tension that means, gamma SL with a water that means, this we if we cannot change this value.

If it is constant, then we can do another thing by reducing the theta. And this theta, we can reduce by redesigning the cross section that means if we use the circular polyester, the theta will be different, then if we use different cross section. And a the study source f as the shape factor increases, the contact angle reduces. And if we can reduce the contact angle, and it will immediately wet, so that is the typical actually the principle, which we use for high active sportswear, high active clothing made of polyester. Just to enhance the wetting wettability characteristics by reducing the thickness ok.

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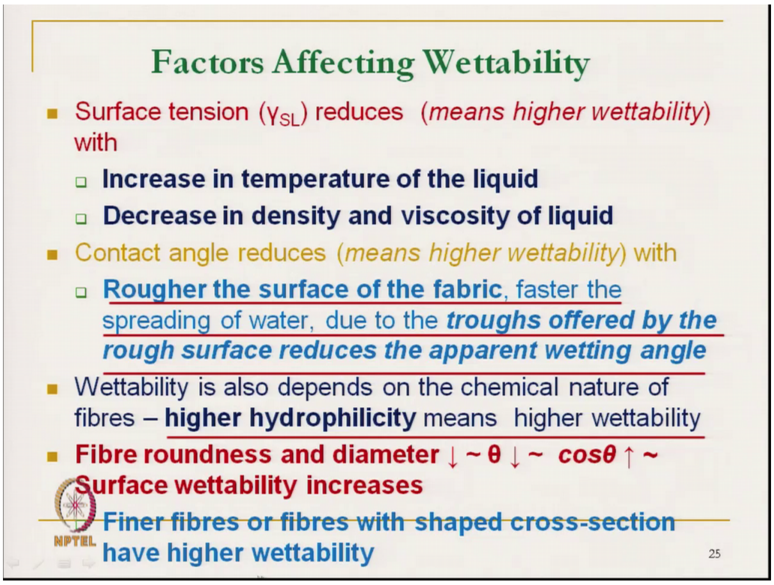

So, what are the factors, which affects the wettability, the surface tension obviously means the surface tension reduces means higher wettability. And it reduces with increasing in temperature. So, if we increase the temperature of the environment, temperature of the atmosphere, the surface tension will reduce that means, a fabric which is a surface, which does not wet at low temperature with a particular liquid let us say water at high temperature it may start wetting, because the surface tension changes at the at high temperature.

Surface tension reduces with the decrease in density and viscosity of the liquid. If the liquid viscosity is reduced or density is reduced, surface tension will reduce, so that we have seen that we can change the surface tension by adding some chemical in water that means, it changes the viscosity. By reducing the viscosity, we can reduce the surface tension. A particular fibre, it does not wet in normal condition. But, if we add some waiting agent, adding wetting agent means, we are trying to play with the viscosity or density of the fluid, so that actually changes the surface tension, and then does it gets wet. And then this is the surface tension. Then wettability also changes, as we have mentioned it is by reducing the contact angle.

So, contact angle is reduced by roughening the surface of the fabric. A smooth fabric surface may not have actually wettabilty wetting characteristics. So, rough rougher surface of the fabric faster is the spreading of water ok, due to trough offered by the rough surface reduces the apparent wetting angle that is wetting angle is reduced. The common example is that a fabric in say highly pressed condition, if we drop water, it will not immediately getting absorbed.

But, fabric after use same fabric after use if you drop water, because it will immediately take the it will wet it will absorb the liquid. This is basically due to the increase in roughness of the surface. Very smooth Calder fabric, initially will not take up water that is due to the actual apparent wetting angle is reduced ok. So, rough surface of the fabric, so it enhances the wetting. So, if we can design the fabric surface little bit rougher surface, then our wetting will be very high, so that is why the little we can we can design the cloth in that way.

Wettability also depends on the chemical nature of fibre that is higher hydrophilicity means higher wettability, because that will absorb moisture. So, these are the factors. If we know all these factors that means, we can control the wetting characteristics. Fibre roundness or and diameter, so if we reduce the roundness or reduce the diameter that means, it is contact angle will reduce apparent contact angle or apparent wetting angle will reduce, so that means a fabric rounder fabric rounder fibre round fibre circular fibre will have higher wetting angle, it will have higher wetting angle that means it will not wet properly.

And if we deviate from the roundness that means deviation from roundness means we are increasing the shape factor. If we increase the shape factor what will happen, apparent angle will reduce, which means that cos theta will increase that means, surface wettability will increase. Similarly, if we reduce the fibre diameter, so normal polyester normal polyester if we make say, we prepare a fabric out of normal polyester, it will may not it may not absorb moisture, it may not wick, it may not get wet quickly, but it has been observed.

If we prepare a fabric made of say micro denier polyester very fine polyester, it immediately get sweat absorb. So, this is mainly due to reduction in theta apparent contact angle ok. So, the all these factors are very important, if you understand this factor, if then we can design the clothing properly ok. So, this fibre roundness and fibre diameter, it is very important for designing the clothing for high activity ok. Finer fibre or finer with shaped cross-section have higher wettability, so that is why we use for extreme high activity clothing, we use this type of fibre.

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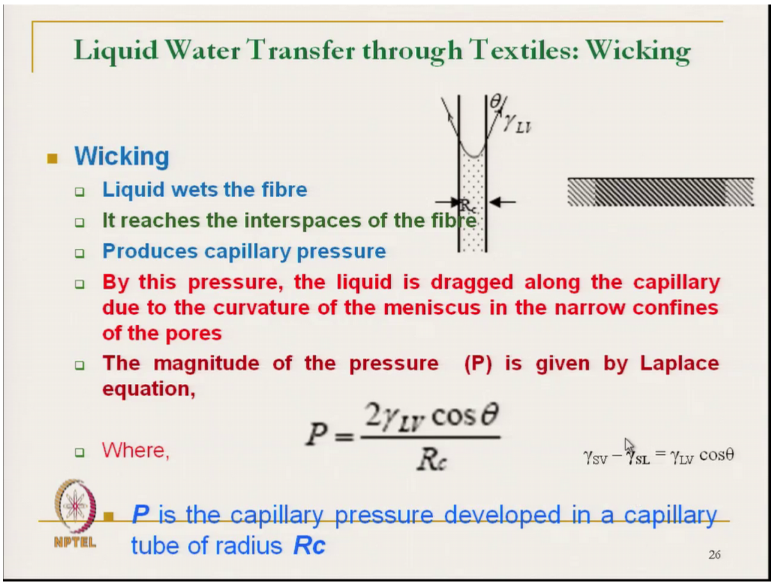

Now, after wetting so if the fabric the water remains in the fibre fabric structure, it will not going to help. This is actually this will help in absorption, but clothing comfort if we want to have proper clothing comfort, the water transmission is also important. So, water transmission takes place through wicking. The phenomena of water transmission through the clothing, through the fire structure is known as wicking.

So, wicking before wicking so liquid wets the fibre, so it wets the fibre and penetrates inside the structure so liquid is penetrating inside the structure it reaches to the interspaces between fibre. So, these have say fibre, it has reached in the interspaces between the fibre that means the pore it reached inside the pore, and where capillary pressure is generated. So, as soon as it reaches inside the pore, there capillary pressure is generated. And by this pressure, the liquid is dragged through the capillary due to the this curvature of the meniscus. This curvature actually, it depends on the contact angle ok.

And the magnitude of the pressure this pressure is given by the Laplace law. Here the classical Laplace law, it is this is the Laplace law, where the p p is the capillary pressure. And gamma LV that we have seen the gamma LV is the surface tension between liquid and vapour. And this gamma LV cos theta is nothing but gamma SV minus gamma SL that means, this gamma SV normally we do not change, the gamma LV sorry gamma SV

SL gamma between surface tension between solid and liquid gets changed depending on the conditions and accordingly this numerator of this equation changes.

And this P is the capillary pressure, and Rc is the radius of the capillary that means the whatever the distance between the fibre, fibre to fibre distance that means, pore diameter pore radius, this is the radius ok. This shows that if we increase if we decrease the R c that means, finer pore will create higher pressure. So, for finer pore that means, if the pore size is the pore diameter is large, it will not be able to create that pressure that means, the water after penetrating inside the structure will remain there. To transmit that water, we have to have a R c lower value.

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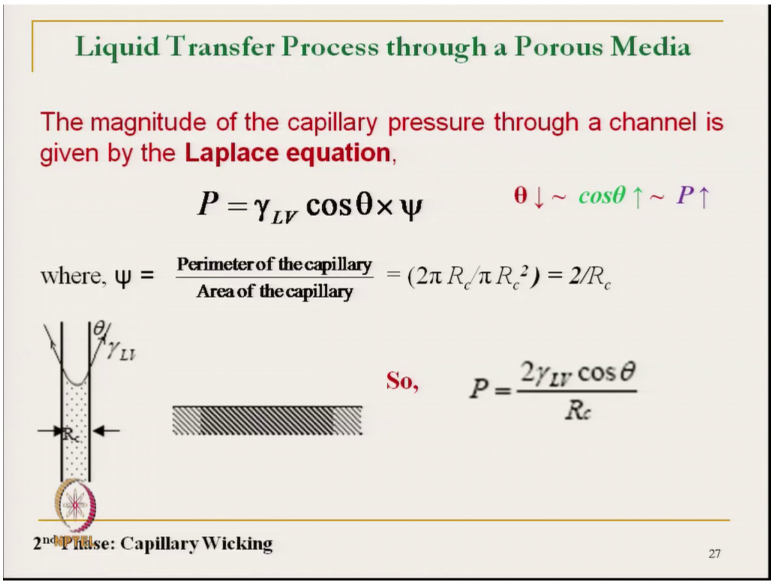

Now, we can see once again, this magnitude of the capillary pressure, this is equal to gamma LV cos theta into psi. What is psi? It is a perimeter of the capillary. If we see the capillary as a circle, it is a cylindrical capillary that is my perimeter of the capillary divided by the cross section of the capillary area of the capillary, which is nothing but that perimeter of capillary is 2 pi R c divided by pi R square c that is 2 by R c that is a psi is nothing but 2 by R c. If we replace this 2 by R c that means, this is the formula that this is the classical formula of Laplace law.

So, Laplace has got here assumption is that the capillary is the circular cylindrical capillary. So, it the psi if we can use, for any sorts of capillary shape ok. And here if we see that as the contact angle reduces if the contact angle reduces that means, cos theta will increase. Contact angle reduce means cos theta will increase that means, P will increase. So, what it shows that at lower contact angle means lower contact angle that means, lower surface tension between solid and lower contact angle means lower surface tension between solid and liquid means higher wetting that we have seen earlier, and also it means that higher pressure.

So, if we can design a clothing or if we can design a structure, which gives lower contact angle or if you can select a fibre, which will give lower contact angle that will give very good wetting quick wetting, and also generate very high pressure of liquid transmission wicking pressure. So, this contact angle is extremely important. And contact angle, we can manage with different factors we have discussed by managing the type of fibre, shape of fibre, structure of surface. And we can achieve higher wetting and higher rate of wicking. And this wicking also depends on the diameter of the pore.

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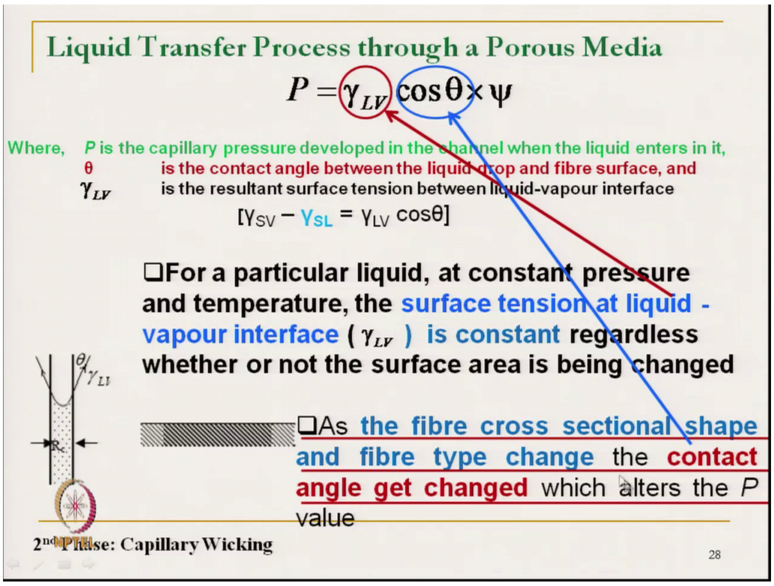

So, for a particular liquid, at constant pressure and temperature, the surface tension at a liquid-vapour liquid-vapour interface is constant. So, if as already mentioned, I have already mentioned that at if the constant at a certain pressure and temperature, this surface tension remains constant. So, regardless whether or not the surface is being changed ok, my surface area is being changed. So, if the surface area changes, it actually does not get affected.

So, if the for a particular fibre temperature and pressure remains constant, this is not going to change, so that means, the P will remain constant, because this is not changing. On the other hand, as the fibre cross sectional shape changes and fibre type changes the contact angle also get changed ok, it alters and which actually drive which controls the pressure. So, pressure here for a particular condition the capillary pressure is not dependent on the surface tension between liquid and vapour, but the contact angle, because which is changed due to the cross sectional shape and type of fibre ok.

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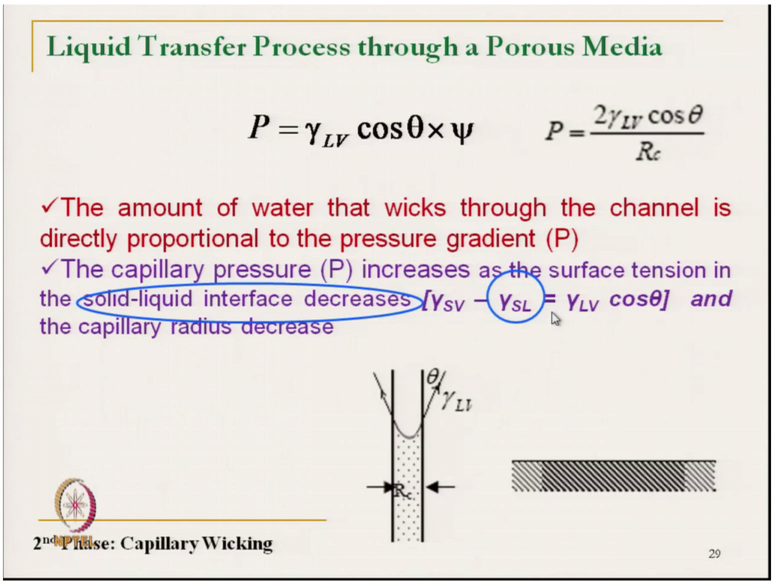

And the amount of water that wicks through the channel is directly proportional to the pressure. So, if the pressure is high, so if we can control the pressure, so we can control the quantity of water, it is getting transmitted. So, it is controlled by the theta controlling theta and by controlling the diameter of the pore, pore radius (Refer Time: 23:57). The capillary pressure P increases as the surface tension in the solid-liquid interface decreases. So, if it decreases, if so surface tension decreases, then we can it this value will increase, gamma LV cos theta will increase and also the capillary radius decreases. So, these two parameters control the capillary pressure ok. Solid and solid-liquid interface, so the surface tension between solid-liquid interface, we can control.

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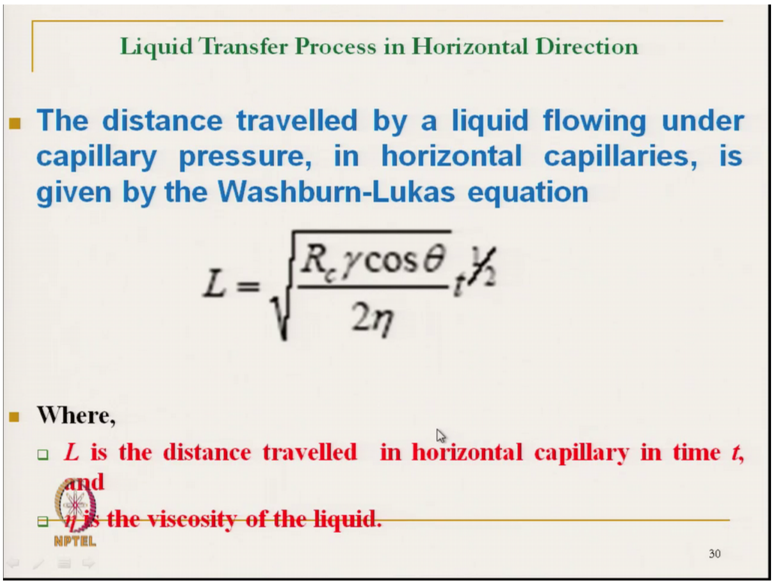

Another part is that the what we have discussed till now, it is the capillary pressure is its it works against gravity. It actually this is the vertically, it transmitted sometime in many occasion the liquid get transmitted through the horizontal pore. And it is actually controlled by the governed by the Washburn- Lukas equation, this is the equation.

L is the length of the liquid the distance travelled horizontal in the horizontal capillary. If the capillary is horizontal and eta is the viscosity of the liquid. So, and this is almost related to this. So, R c means the capillary radius, if the L proportional to the capillary radius that means, if the capillary radius increases, the L will also increase.

The cos theta if it cos theta increases that is the, so theta decreases, so capillary the length travelled will decrease. And it is inversely proportional to the eta that is the viscosity. So, for as viscosity increases, definitely the length travelled will reduces ok and with the temperature sorry time with the time it will also increase. So, this is the equation, which is used to know the length travelled by the liquid in horizontal layer. Now, we will start we will discuss different based on this basic understanding, we will try to see the different study result. And try to correlate with the basic theories.

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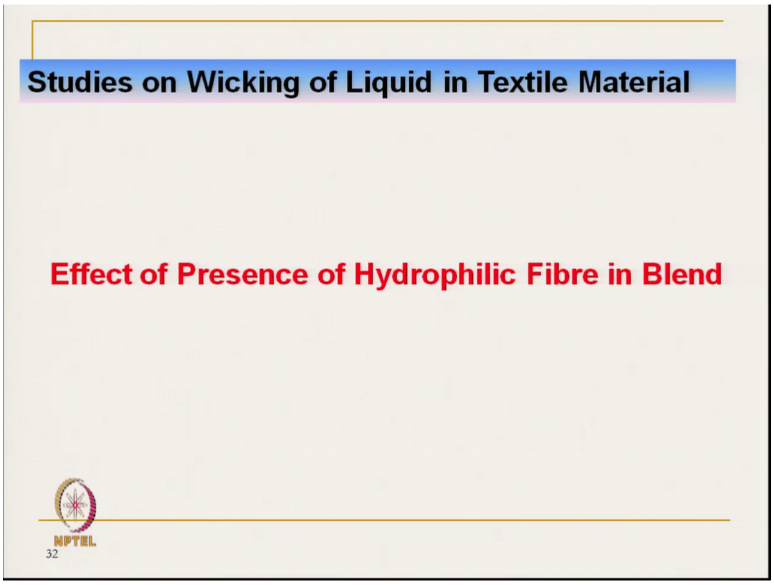

So, first we will see the effect of presence of hydrophilic fibre in the blend. So, hydrophilic fibre means the fibre, which actually gets wet immediately. So, if it wets, so it that means the fibre is absorbing the liquid, and how is it controlling the wicking characteristics.

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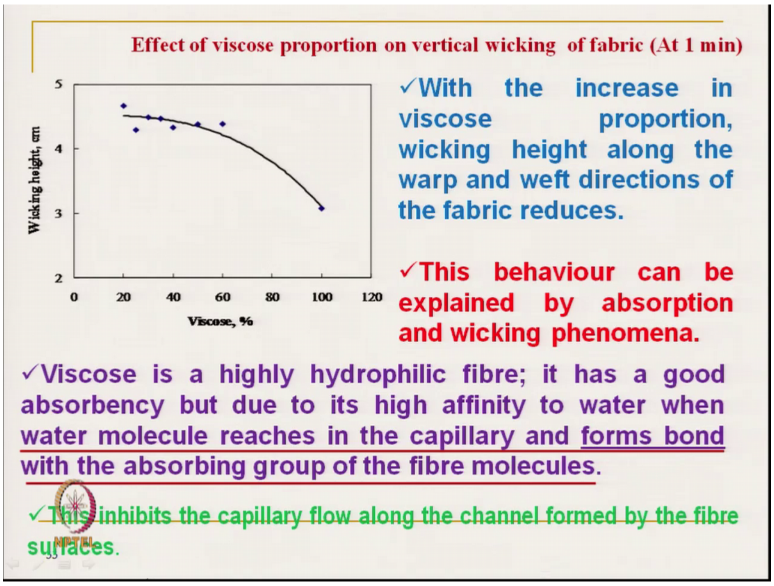

This graph shows the in x axis the proportion of viscose fibre. This is actually made of fabrics made of the polyester and viscose. Polyester being hydrophobic and viscose is hydrophilic. The proportion of viscose is changed from say 20 percent to 100 percent.

So, 20 percent viscose means 80 percent polyester. So, accordingly is 100 percent viscose, there is no polyester 100 percent polyester.

So, and the y axis is wicking height particle wicking height after 1 minute. So, at 1 minute the wicking height is measured. So, this is the curve, which shows as the viscose content increases that means fibres proportion of hydrophilic fibre increases. The moisture the liquid transmission the wicking height is reduced. So, if we increase the viscose content, the wetting will be very high it will wet. But, with the increase in the proportion of viscose wicking height along the warp and weft direction of the fabric reduces. Both warp and weft direction, we have seen it reduces. This behaviour can be explained by absorption and wicking phenomena, so that absorption and wicking phenomena we have discussed.

Viscose is highly hydrophilic fibre, it has got good absorbency, so it absorbs very nicely. Immediately, it will take into the structure, which is the first principle basic requirement of any liquid moisture transmission, but due to high affinity of water. When the water molecule reaches to the capillary inside the capillary, it forms bond with the absorbing group of the fibre molecule. So, whatever in a fibre molecule there are absorbing groups, it forms bond with the water molecule. And it does not allow actual to travel it fast, so that is also important.

Apparently it looks odd, because it absorbs moisture, but it is absorb a liquid, but it is not transmitting. And that is this understanding is very important to design clothing for high activity, where sweating rate is very high. It forms bond ok, so that is why, this the sweating rate that wicking rate is very low. It reduces as the viscose content is high, so that means if we have to design a clothing for high activity, so in that case we have to be very careful of selecting the fibre. Actually, this molecule that is the group that is the bond formation with the observing group actually, it inhibits the capillary flow along the channel formed by the fibre.

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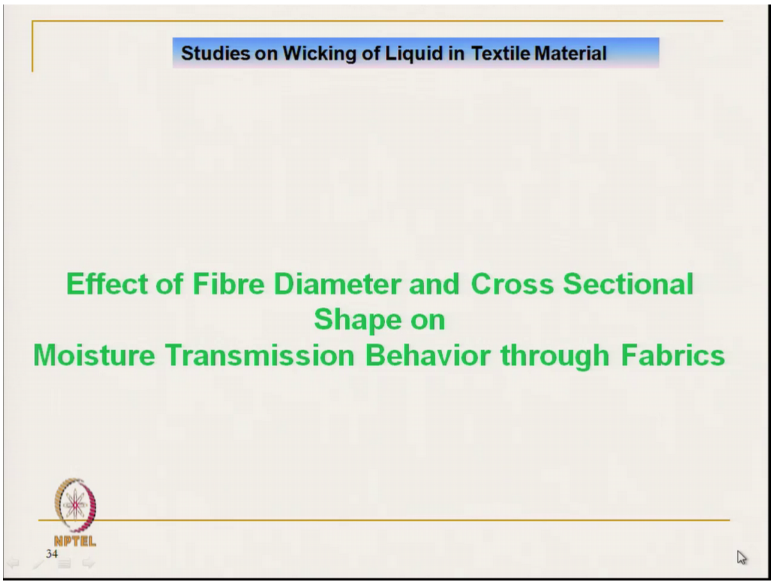

Next is that how to enhance this moisture transmission by changing the shape of the fibre ok. So, if what are the factors, how the fibre diameter and cross sectional shape affect the moisture liquid moisture transmission through fabric.

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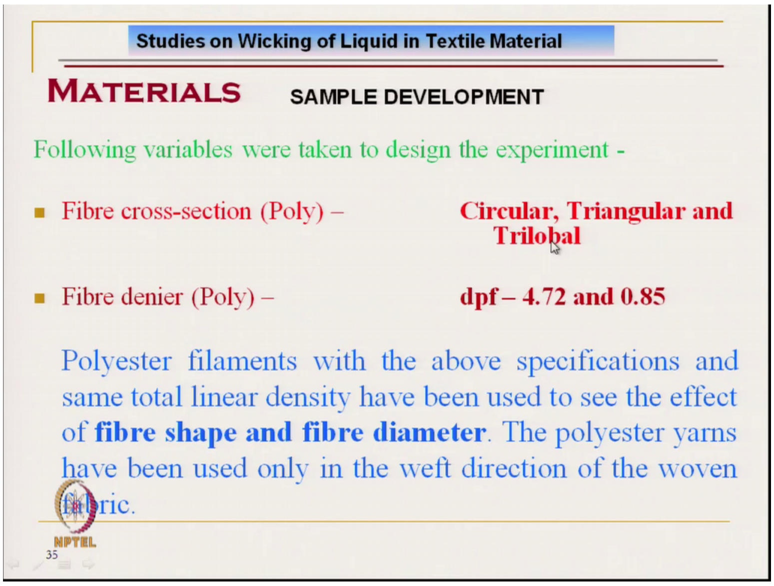

So, in this study what we have done, we have used the polyester fibre with different cross sectional shape. One is the circular cross section, triangular cross section, and trilobal cross section. Three different cross section of polyester fibres have been used with same denier 4.72 denier fibre, another fibre which we have used although in circular fibre, which is micro denier imager, so 0.85 denier. So, two types of denier we have used, one is the higher denier normal denier 4.72 denier, and this are the filament which we have used. And this circular, triangular, and trilobal filaments are of 4.72 denier and circular polyester of 0.85 the very fine denier.

So, what here what we have tried to understand, the effect of fibre diameter that is micro denier and the shape factor on the transmission characteristics that is liquid transmission that means, its effect of the contact angle. How the contact angle is changing, how the so the we have tried to change the contact angle by changing the shape factor; the polyester filaments with the above specification and the same total linear density. So, linear density of the filaments were same total denier. To see the effect of fibre shape and fibre diameter that is why we have selected.

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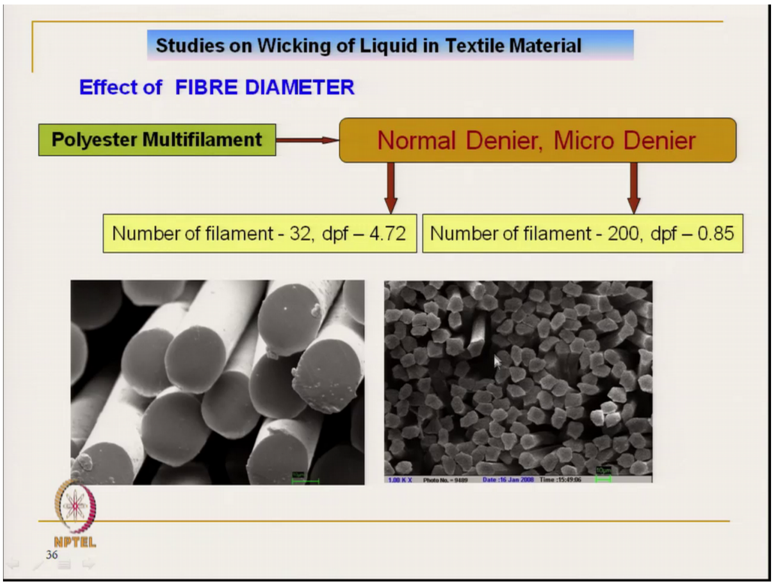

Now, the polyester multi filament it is a normal denier 4.72 denier per filament and number of filament is 32 filament. And here 0.85 denier and number of filaments are 200. So, typically we have tried to keep the total denier of the filament same and these are the cross section. This is the circular polyester normal circular polyester of normal denier 4.72 denier; and this is a circular microdenier polyester microdenier normal.

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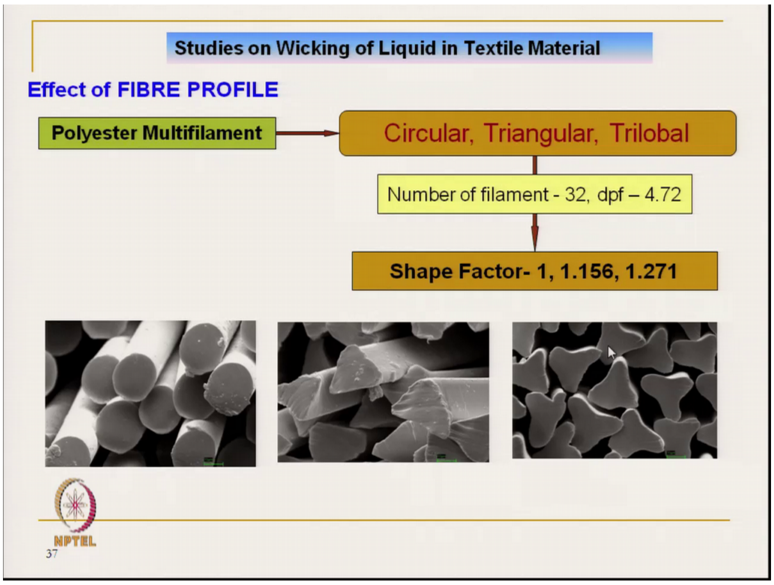

And polyester multifilament in circular triangular and trilobal of this specification 32 denier per filament 32 filament and denier per filament 4.72 and this shape factors are circular is of shape factor 1, triangular with shape factor 1.156, and trilobal has got shape factor of 1.275. So, these are the 271. These are the different shape factors. And we can see the cross section; this is the circular section, so circular triangular and trilobal cross section. So, trilobal has got higher shape factor due to the very high specific surface area.

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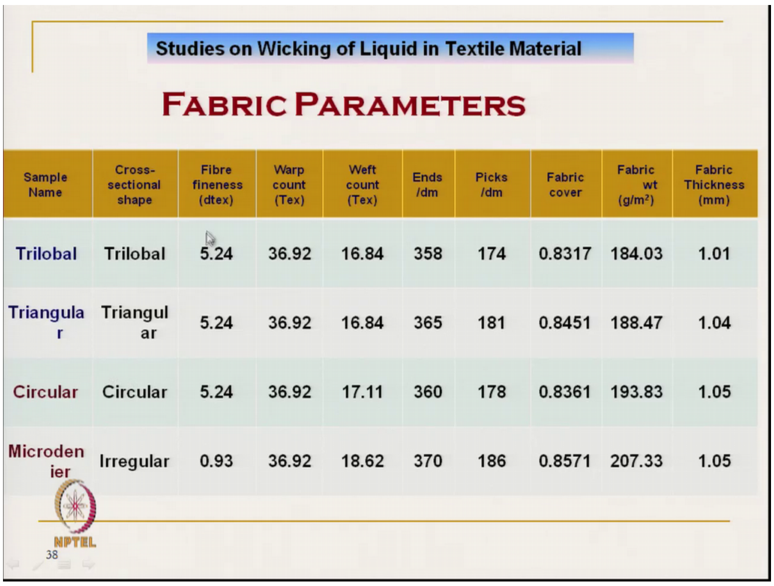

Sample Name	Cross-sectional shape	Fibre fineness (dtex)	Warp count (Tex)	Weft count (Tex)	Ends /dm	Picks /dm	Fabric cover	Fabric wt (g/m²)	Fabric Thickness (mm)
Trilobal	Trilobal	5.24	36.92	16.84	358	174	0.8317	184.03	1.01
Triangular	Triangular	5.24	36.92	16.84	365	181	0.8451	188.47	1.04
Circular	Circular	5.24	36.92	17.11	360	178	0.8361	193.83	1.05
Microdenier	Irregular	0.93	36.92	18.62	370	186	0.8571	207.33	1.05

So, let us see the fabric parameter. We have tried to keep the fabric parameter almost same. Now, here fibre denier fibre fineness is 5.24 decitex ok. And here it is a in form of decitex, it is a 93 ok. This is the decitex trilobal and microdenier. Typically it is a irregular cross section; it is not exactly circular cross section; it is a irregular cross section we have got. And the warp count we have kept constant weft count is almost constant, so that is a measured value. Ends per inch we have tried to keep this is after fabric is being made it is constant almost. And the picks per decimeter is kept ultimately this one.

And what you have got the fabric cover factor almost constant cover factor. And fabric mass per unit area we have tried to keep almost constant, but this is little bit higher. And fabric thickness is almost constant. So, what we have tried to see the to eliminate the effect of fibre fabric parameter, we have tried to keep the fabric parameter constant only here difference is that the fibre cross sectional shape and diameter of fibre.

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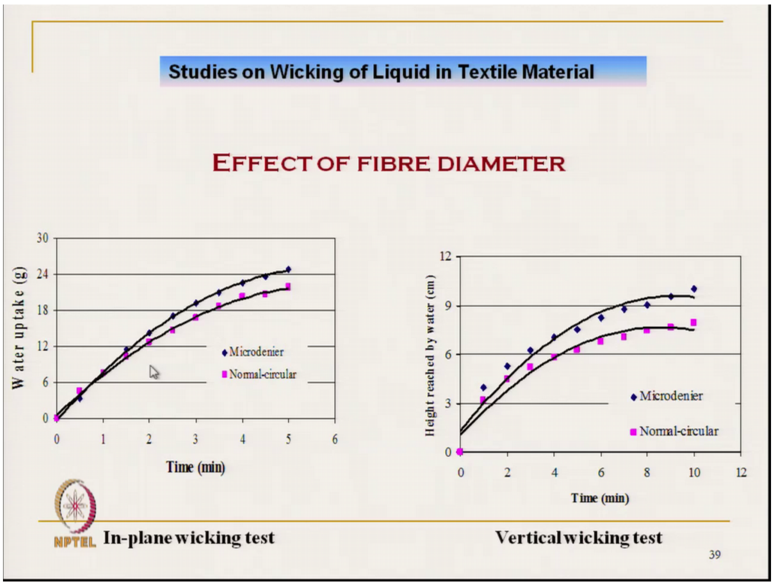

The effect of fibre diameter when we see we have seen that the microdenier fibre gives the wicking rate wicking height or wicking water uptake at higher rate by then the normal circular polyester. And height reached by water that is wicking height it is also high, so that means, if we use microdenier polyester as compared to normal polyester, it will give higher absorption higher with water uptake and higher rate of wicking, so that is how we have to select the fibre.

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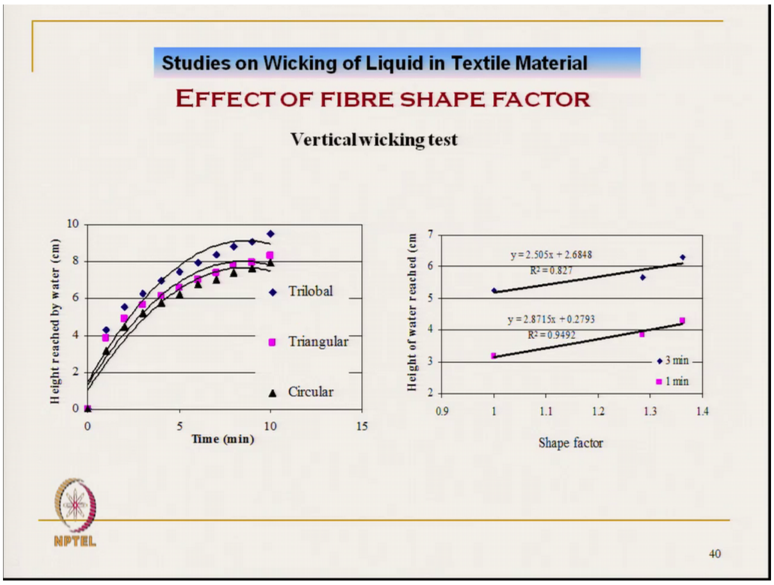

Next is that the effect of shape factor. So, the trilobal with higher shape factor trilobal with higher shape factor gives very high wicking rate. Followed by the triangular and circular has got least. So, we have we can see that with the increase in the shape factor, the wicking height increases for same polyester. And here this is the with the shape factor wicking height. So, if we compare if we just plot a curve, the shape factor versus the wicking height, it increases linearly ok, and at different time level. So, this is at a 3 minute; after 3 minute, if we see the wicking height and after one it always increases linearly.

So, there is a linear increase in wicking height with the shape factor, so that which shows if we have to increase the wickability, we have to first select the fibre which is not in hydrophilic in nature like cotton you should avoid or viscose we should avoid. Then we have if we select a fibre which is hydrophobic in nature that means a polyester if you select, then we have to select a cross section with higher shape factor. And if we have the option of microdenier fibre filament and normal denier filament, we should we must go for the microdenier filament. And in similar is the case for inplane wicking, earlier it was vertical wicking. In inpalne wicking, it gives the same trend the reason is exactly same.

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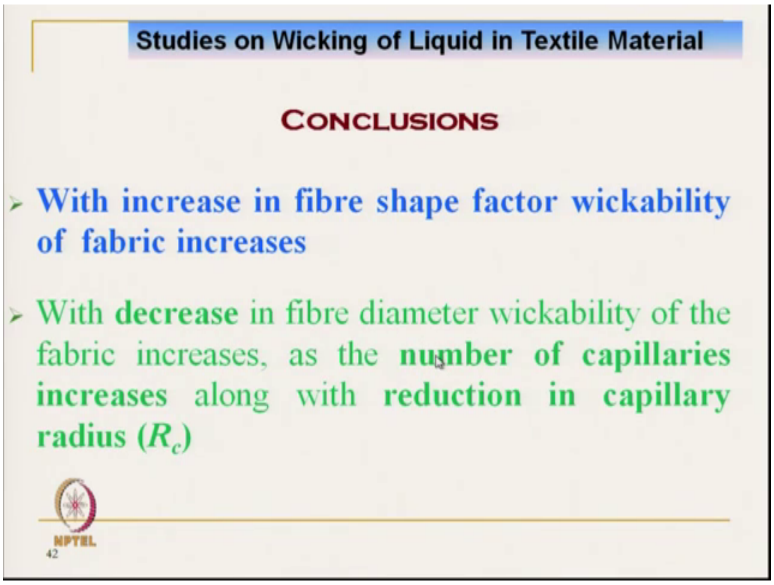

We can conclude here with the increase in fibre shape factor wickability of fabric increases. With decrease in fibre diameter what does it actually show the wickability of fabric increases as the number of capillary increases. So, number of capillary with lower capillary diameter that is the reason of the wickability. And also it has been observed at lower diameter fibre diameter the apparent angle contact angle also reduces ok.

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Next is the study on fabric constructional parameter on wicking properties of high active knitted sportswear. Earlier what we have seen it is oven fabric. Now, we will try to see the effect on the knitted fabric. And here again what we have used here the polyester fibre. And this fibre actually these fabrics have been actually procured from actually international brand high active sportswear, which we have taken mainly soccer and tennis.

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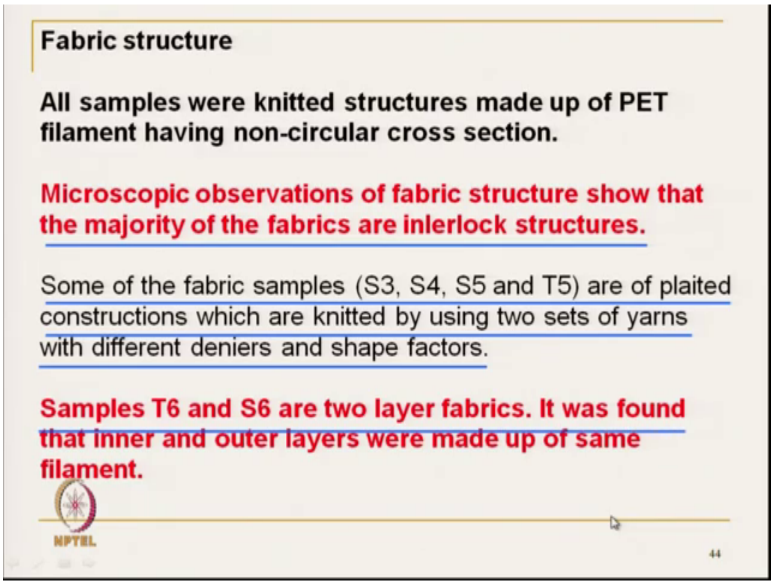

So, the all the samples what we have observed after collecting the fabrics we have observed this fabrics are knitted structure. So, high active sportswear is mainly the structure is of knitted, correct I say knitted structure and they are made of polyester ok. And most of them almost all the fibres used filaments used are non-circular in nature. They are not in circular they are actually they are a deviation from circular circularity.

Microscopic observation of fabric structures shows the majority of the fabrics are of interlock in nature. So, why they are using interlock that we will discuss. So, interlock fabrics are used some of the fabric samples. So, S means soccer, and T means tennis ok, those are high active sports are plaited. So, most of the fabrics are interlock in nature. And some of the fabrics we have seen it is of plaited structure which are knitted, but using two sets of yarn with different denier and shape factor.

So, in plaited structure, so two sets of yarns are used of different structure, different denier or different shape factor. And there are fabrics, which has are also double layer in nature. So, two layers inner layer and outer layer made of same filament. So, there are three types of structures have been observed one is most of the fibres fabrics are interlock in nature; and some fabrics are of plaited structure using two different fibre of different shape factors, because these are just to have manage the high rate of moisture. So, finer denier or courser denier or different shape factor ok. Interlock structure, plaited structure and layer structure ok, double layer structure.

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Details of fabric samples

Sample code.	Fibre type	Fabric structure	Fibre cross sectional shape	Shape factor	Filament linear density denier	Yarn linear density denier
T1	PET	Interlock	Elliptical	1.087	1.50	85.5
T2	PET	Interlock	Elliptical	1.096	1.50	82.2
T3	PET	Interlock	Elliptical	1.083	1.70	81.0
T4	PET	Interlock	Hexagonal , Triangular	1.053, 1.095	0.80, 4.90	165 177
S1	PET	Interlock	Hexagonal	1.054	1.50	96.9
S2	PET	Interlock	Hexagonal	1.055	1.40	83.5
S3	PET	Plain plaited	Flat , Hexagonal	1.240, 1.047	1.34, 0.84	53.3, 166
S4	PET	Float plaited 2/1	Flat, Hexagonal	1.240, 1.047	1.34, 0.84	53.3, 166
S5	PET	Float plaited 1/1	Hexagonal, near circular	1.072, 1.021	1.50, 1.00	61, 170
T5	PET	Float plaited 2/2	Hexagonal, Elliptical	1.065, 1.087	1.50 1.50	85.2, 245
T6	PET	2 layer	Hexagonal	1.054	1.20	77
S6	PET	2 layer	Hexagonal	1.055	0.92	82.8

These are the fabrics. So, here we will see the T 1, T 2, T 3, T 4, T 5, T 6, six fabric structure six clothings were taken from high active tennis cloth. They are meant for tennis. And S 1 to S 6 they are meant for the soccer ok. And what has been observed here the all the fabrics all the fabrics are made of the polyester. And these are the polyester multifilament here. So, polyester multifilament yarns are used. And main structure fabric structures are interlock structure, most of the fabric plane plaited, float plaited and two layer structures as I have mentioned.

And different types of cross section heads are used. This cross sections are elliptical cross section it is not basically it is a directly circular cross section they are tried to use the variation. Variation variation from the deviation from the circulating means enhancing the shape factor. Enhancing shape factor means the enhancing the wickability and transmission characteristics. So, elliptical cross section, hexagonal cross section, triangular cross section, flat cross section, so these are the different cross sectional shapes are used ok, and where the shape factors have been measured. So, these are the different shape factors.

And a flat five that flat filament has got very high shape factor of 1.24 shape factor. So, there are different types of cross section with different shape factors. And also the deniers of filaments are also different ok, different deniers of filaments. And linear density of total linear density of filaments are used. So, these are the details of the fabric samples which have been used in the studies.

So, so what the conclusion here what is the finest way which you have observed, so for its high active sportswear where mainly we have to manage the liquid in moisture vapour in liquid form because at very high rate. So, we have to use the knitted structure. Knitted structure is mainly here is used for ease of body movement, because of that high because it is a stretchable in nature. So, body movement is required.

Polyester fibres are used, no natural fibre, no hydrophilic fibre, because it has to wet quickly it has to transmit moisture quickly, moisture should not be retained inside the structure. It should not react with the, it should not form bond with the water that the moisture should not form with the fibre, and fabric structures are interlocked. Fibre shapes are non circular with higher shape factor. So, with this idea they have the fabrics are been made.

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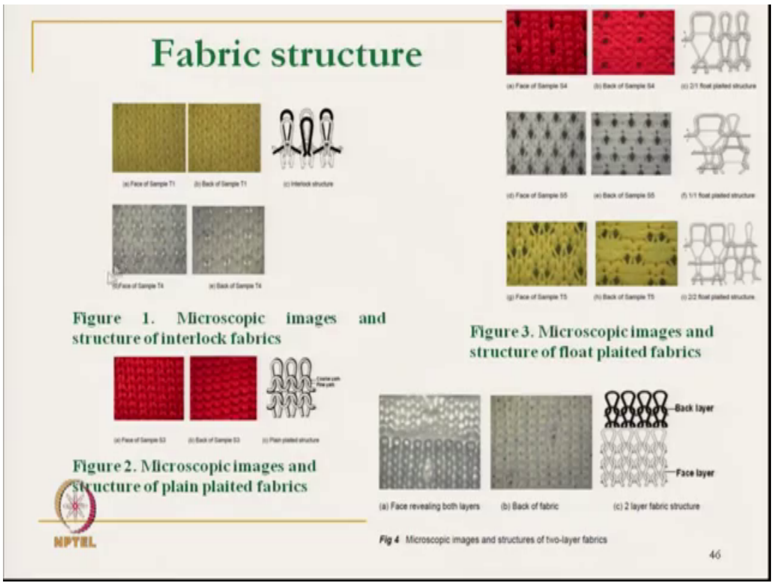

And if we see the fabric structure, these are the different fabric structures. So, this structure it is a interlock structure, its microscopic picture interlock structure. This is the plane plaited structure with the two different types of yarns are used. This is the float plaited structure. And these are the fabric with the two layer structure; this is the inner layer and outer layer structure. So, then we will discuss the fibre structure different types of fibre structure we will discuss.

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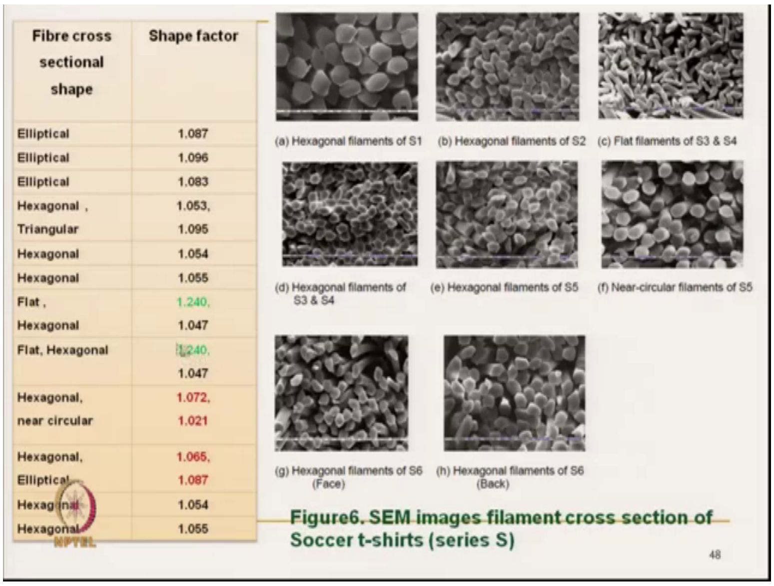

And with this so this fibre structure, if you see the cross section these are the different fibre cross section as we have mentioned. And these are the different types of cross section. This is elliptical cross section. And here this is triangular cross section here, hexagonal cross section ok, this is hexagonal cross section. So, different cross section of fibres are being used with different shape factor because cross section is changed just to change the shape factor.

They are these are the other series. This series this fibres are used for tennis t-shirt, soccer t-shirt, earlier we have seen these are those are for tennis, tennis series T, and these are soccer series S. So, with this will end here. We will continue with these findings with this study, and we will see the different findings from this study ok.

Thank you.