Technical Textiles
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Lecture - 25
Sports Textiles (contd…)

Hello everyone, we are discussing the sports textile.

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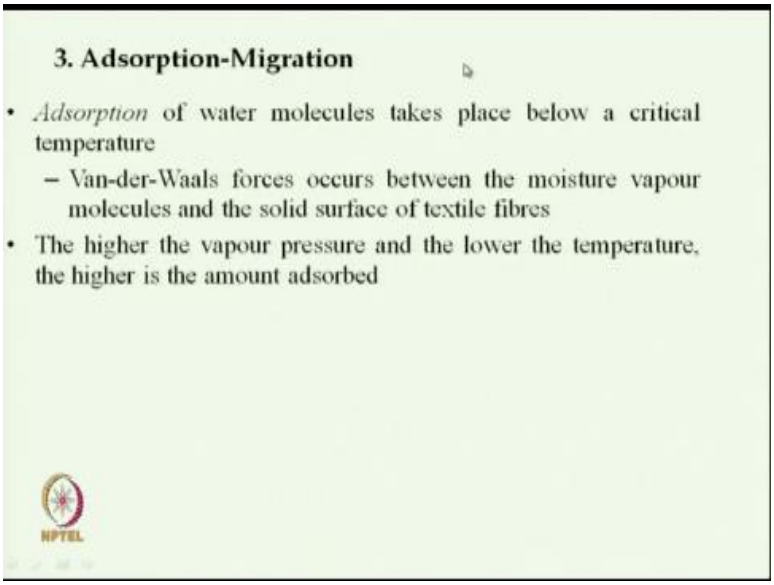

In last class we have discussed the diffusion mechanism, adsorption, transmission, desorption mechanism and the third mechanism of moisture vapor transmission is that adsorption and migration. So adsorption and migration normally takes place for hydrophobic fiber and this phenomena takes place below certain critical temperature and Van der Waals forces occur between the moisture vapor molecule and fiber surface.

And they get attached with the fiber surface but not absorbed, so at a higher vapor pressure and at lower temperature this adsorption takes place. So if the vapor pressure is high that means moisture present in the air is very high and at the low temperature this type of phenomena takes place, so where the moisture vapour gets deposited on the fiber surface.

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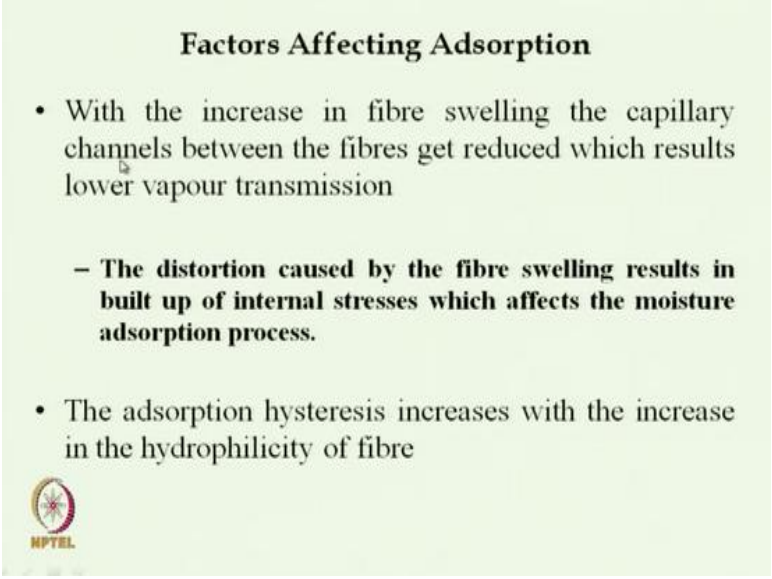

And there are various factors which affect the adsorption in case of the fibers with high swelling capability like;

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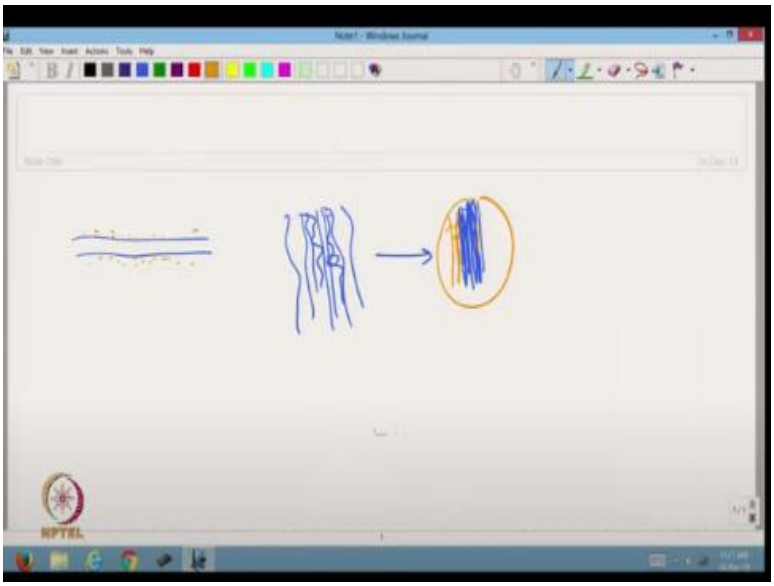

These are the fibers so if the fibers swelling capability is very high then they will get swelled and in between fibers the space will not be there. This space will get covered by swelling these fibers. So fibers adsorption, that adsorption of water molecule takes place on the surface. So if the surface gets trapped that air pocket gets trapped, so there will be lesser area on which this adsorption will take place. So this phenomenon reduces with the increase in swelling capability.

So with the increase in the swelling the capillary channel between the fiber get reduced which results lower vapor transmission through the adsorption process. The distortion caused by the fiber swelling results in buildup of internal stress between the fiber which affects the moisture adsorption process. So this internal stress development between the fibers will affect the free development of moisture on the surface.

And the adsorption hysteresis increases with the increase in hydrophilicity of fibre. So higher hydrophilicity of the fiber is there so higher swelling will take place, so this hysteresis will increase.

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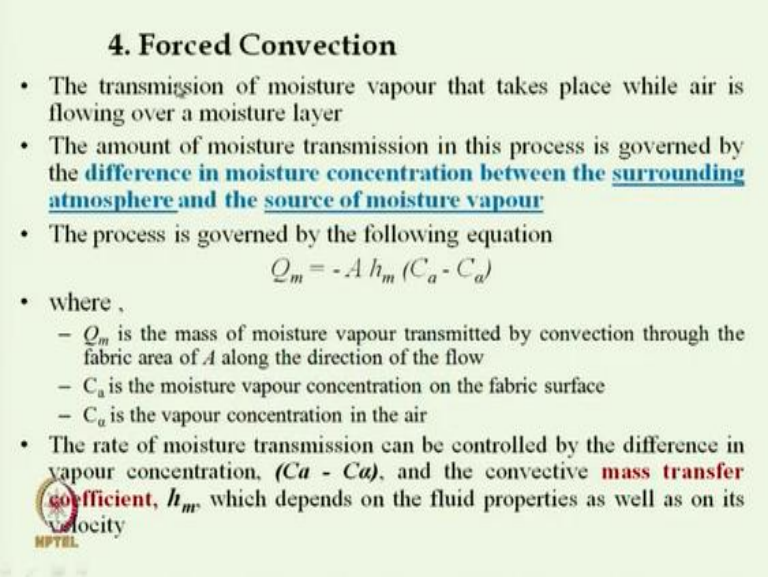

Next mechanism is that forced convection, as I have already mentioned the forced convection of moisture vapor takes place in presence of the air. So as air velocity increases the mass transfer coefficient hm it increases. So this increases with the air velocity and the convective moisture vapor transmission is a function of area and the vapor pressure also. But major effect is on that mass transfer coefficient that is the forced convection through the material is by air velocity.

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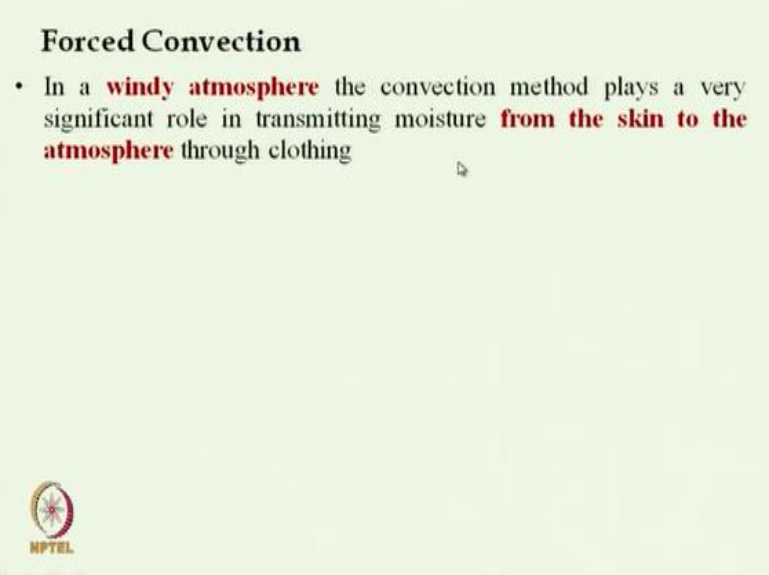

So in windy atmosphere the convection method plays a very significant role that is hm increases the coefficient increases in transmitting the moisture from the skin to the atmosphere through the clothing, so higher the wind velocity higher will be the forced conviction.

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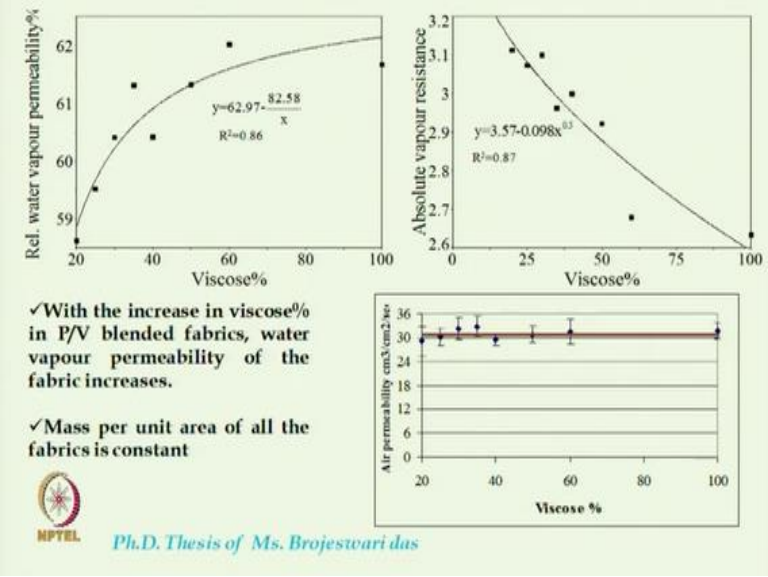

So after understanding all these if we developed the sports clothing and then we can understand the impact of the structures and the material on the moisture vapor permeability. Now in this experiment what has been done here, we have tried to reduce the moisture diffusion or to maintain the moisture diffusivity constant and we have tried to see the effect of other phenomena. Here in x-axis it shows the viscose proportion in polyester viscose blended fabric.

So, viscose proportion is increased from 20% to 100%, so that means 20% viscose 80% polyester here, 60% polyester, 40% polyester, 20% polyester and 0%. So gradually the hydrophilicity increases so with the increase in hydrophilicity we have tried to study the impact of the moisture vapor permeability. Here the fabric structure has been kept in such a fashion that air permeability is constant.

That means porosity of the fabric, the pore structure or opening of the fabric was maintained at constant level. So air permeability was constant, so that means here the diffusion the Fickian diffusion was kept constant but with the increasing viscous content what has been observed the vapor permeability moisture vapor permeability increases and the absolute moisture vapor resistance reduces.

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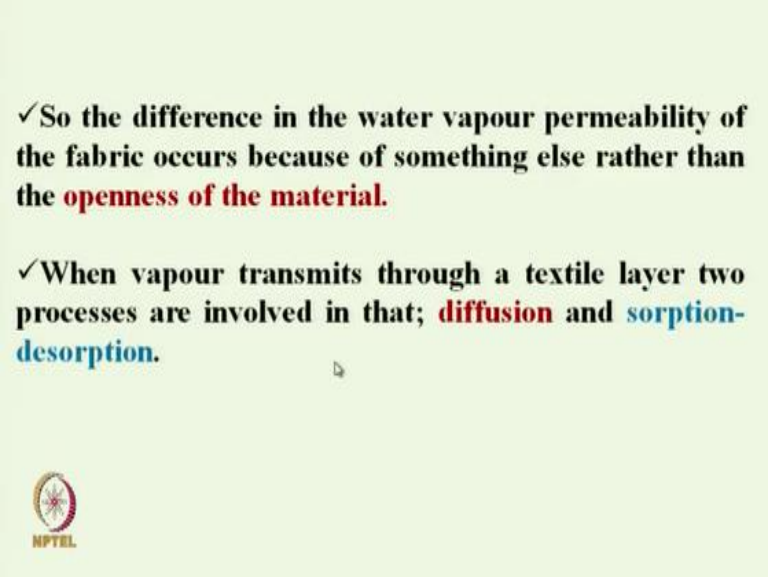

The basic reason is that here it actually the moisture vapor transmitted through the adsorption and desorption principle, so the difference in the water vapor permeability of the fabric occurs because of something else rather than the openness of the material. Because openness we have kept constant, so that the air permeability was constant. When vapor transmits through the textile layer two processes are involved diffusion and sorption-desorption.

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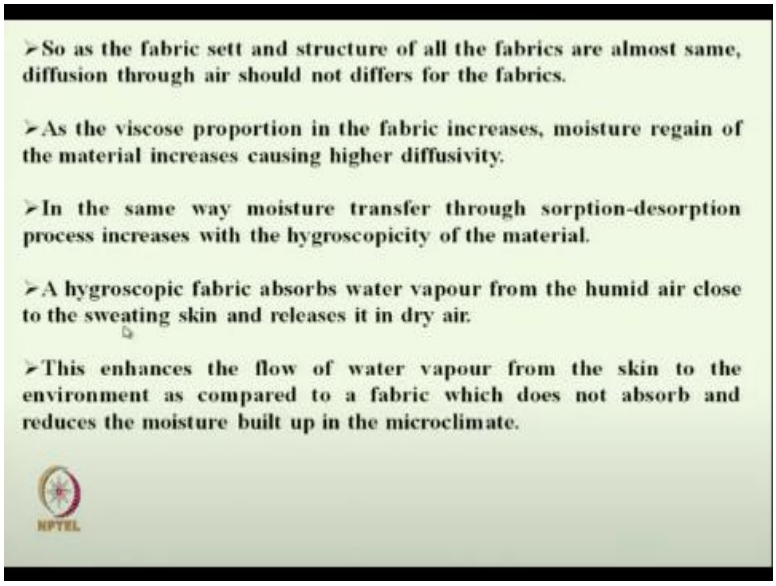

So as the fabric structure was kept constant the diffusion was also constant as viscous proportion in the fabric increases, the moisture regain of the material increases causing higher diffusivity. So this is again that non Fickian diffusion will also be there here in the same way moisture transfer through the sorption-desorption process increases with hygroscopicity of the material.

So both non Fickian diffusion and sorption-desorption method of moisture transmission takes place here. So as hygroscopicity of the fabric increases it will absorb the water vapor from the humid air which is close to the skin and releases to the outer environment. In this way so for these two mechanisms with the increase in moisture that hydrophilic fiber content the moisture permeability increases.

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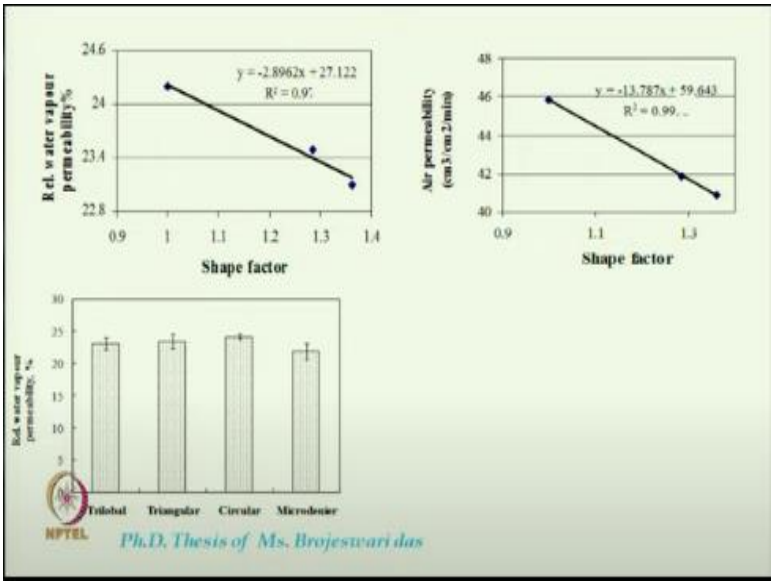

Another study was that the polyester shape factor was increased so we have used 3 different shape factors of polyester, 1 which is circular, 1.3 which is triangular it is around 1.3 and 1.35 which was trilobal. So these three materials were used and what has been observed that with the increase in shape factor, relative water vapor permeability reduces like air permeability also reduces.

So this is basically due to the air drag, so that means to design sportswear for enhancing the moisture vapor permeability we must select the clothing with higher hydrophilic fiber content and if we have to select the hydrophobic fiber we should select the circular cross section not the shaped cross section and these are for very low active sportswear where moisture is mainly transmitted through the vapor form not by the liquid form or sweat form.

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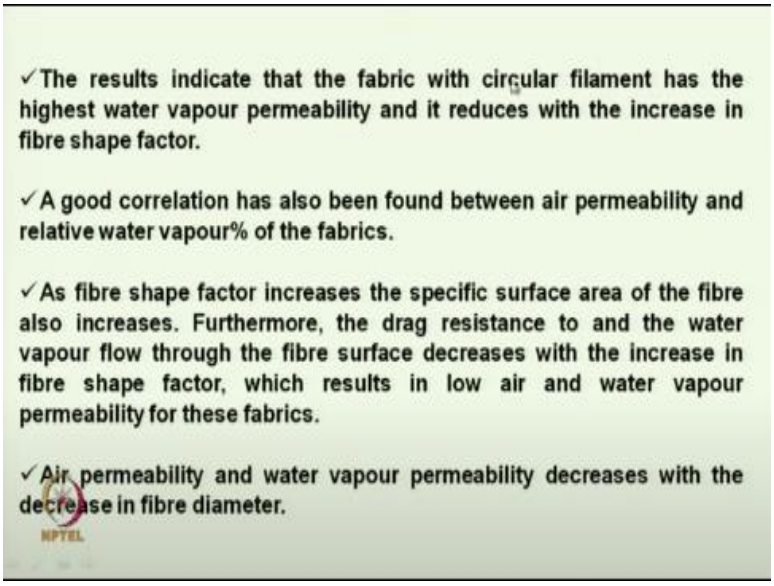

That means the result indicates that the fabric with circular filament has the highest water vapor permeability and it reduces with the increase in fiber shape factor. So that is why we have to select the fiber with circular cross section.

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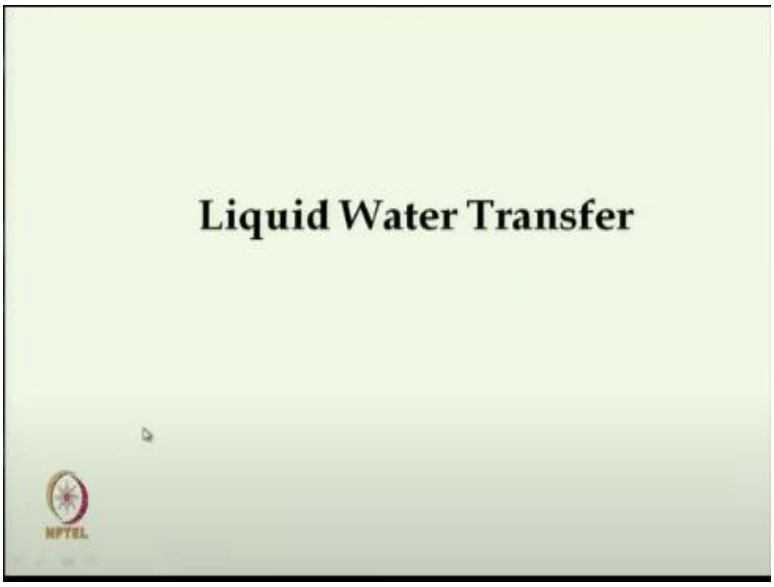

Now coming to the liquid water transmission, liquid water transmission as I have mentioned it is extremely important for high active sportswear. So to manage the liquid water in the sportswear we must understand the basic phenomena, basic mechanism of liquid transmission for designing the sportswear.

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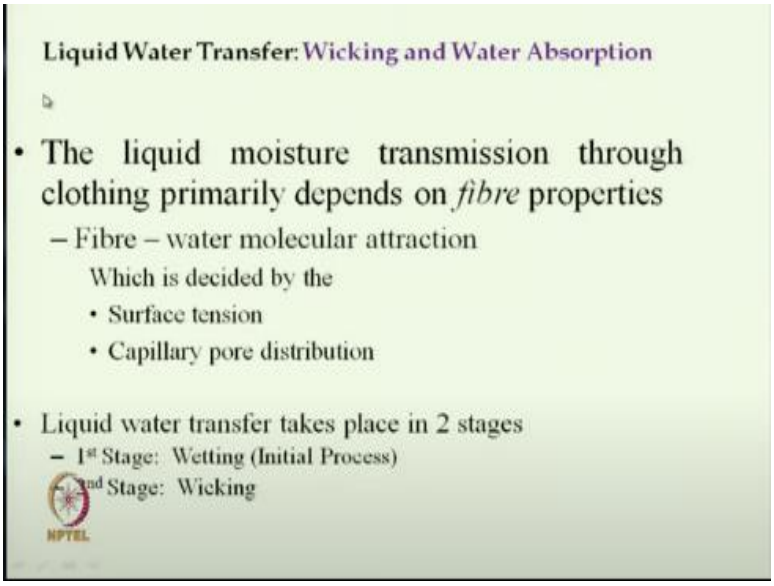

So liquid water gets transmitted by two stages, one is wetting stage and then wicking. So two principles are there it is wicking and water absorption. By the term wicking we mean that the water from one place will get transmitted to other place without the water logging in those pores. So water will not remain in the pores between the fiber, but water will get transmitted from one place to another place that is called wicking and water absorption means which will retain water within the structure.

The liquid moisture transfer through the clothing primarily depends on fiber properties that is fiber water attraction and that is a surface tension is there and capillary pore distribution. So depending on the capillary pore size the transmission of water will vary, as I have mentioned it takes place in two stages, first is wetting which is extremely important and then second place is wicking.

So for wicking to take place first wetting has to be there because due to wetting phenomena, the liquid that the sweat or water enters into the pores and by wicking it gets transmitted from one place to another place by capillary pressure.

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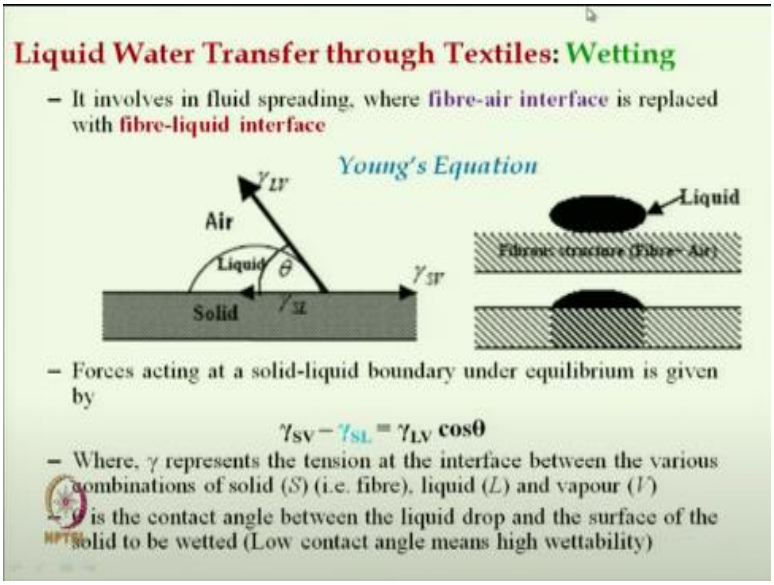

Now first let us discuss the wetting. The wetting of fibrous material means the space between the fibre-air interface is getting replaced by fiber-liquid interface. So here in dry clothing, dry sportswear the fiber is actually surrounded by the airspace but when it is wetting, this fiber air space is being replaced by fiber liquid and this is followed by the Young's equation where this gamma is SV here as per this picture here this theta is the contact angle lower the contact angle higher is the wettability of the material.

So we can control the contact angle by proper selection of the material that is polymer or by proper selection of the structure of the fiber. Cross section of fiber also enhance the wettability so this equation is balanced by that is gamma SV means between solid and air the surface tension between solid and air. Surface tension between solid and liquid that is gamma SL and gamma LV it is a liquid and so this are the three equations, so it is balanced

Now here we must have the reduced gamma SL the solid fiber and the liquid the surface tension should be as slow as possible so that the theta this contact angle reduces lower this value gamma SL means this left hand side will be high and to have higher left hand side we must reduce theta for a constant gamma LV so we should have lower surface tension and lower contact angle to have better wetting.

So during wetting this liquid penetrates immediately inside the structure and after that another phenomena will be there that is called wicking which will transmit this liquid from this place to other place maybe in the cross plane or maybe along the plane.

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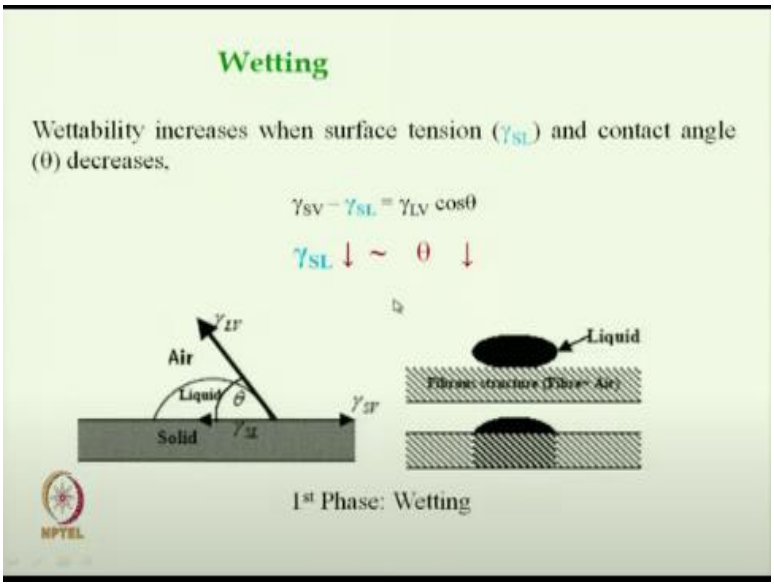

So you must reduce the surface tension between fiber and liquid that we can do in various ways by proper selection of fiber polymer, proper selection of liquid and also we can do by reducing the contact angle.

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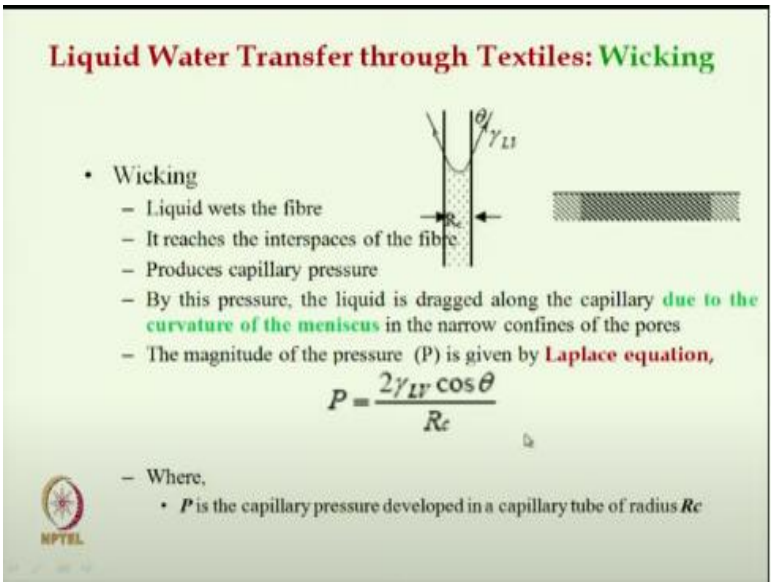

After wetting next is wicking and wicking is followed by this Laplace equation. So this Laplace equation here P is the capillary pressure generated within the capillary between the space within

the structure of material where theta there is a higher theta. So if we can reduce the theta cos theta, so we will be able to have higher capillary pressure. So reduction in cos theta that means if we use the fiber with lower contact angle then we can have very high capillary pressure.

At the same time if we reduce this capillary radius that way we can enhance the capillary pressure and also liquid and vapour this liquid vapour surface tension if we increase then also we can increase the capillary pressure. So by controlling the capillary pressure so here we can do by proper arrangement of fiber that is by reducing the capillary pressure we can enhance the wicking characteristics or proper selection of material we can control the theta that is contact angle.

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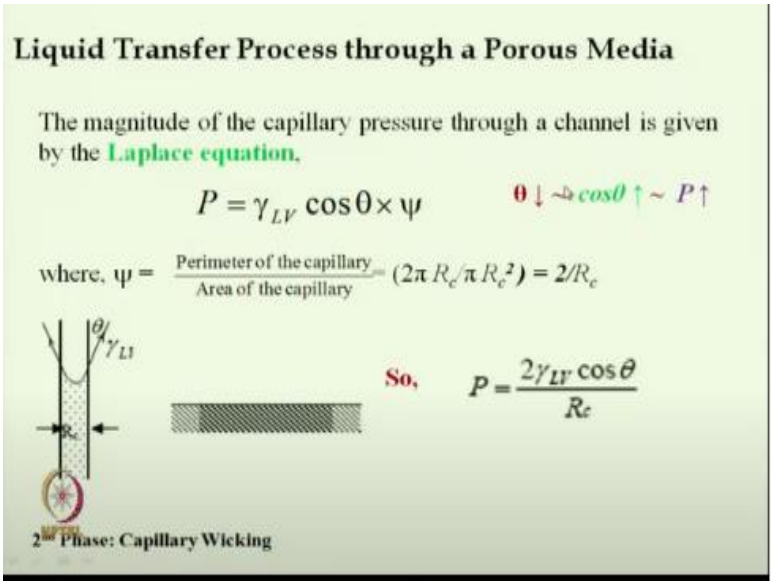

So lower contact angle is higher cos theta, higher capillary pressure that we can do and the Rc is the capillary radius that we can also control.

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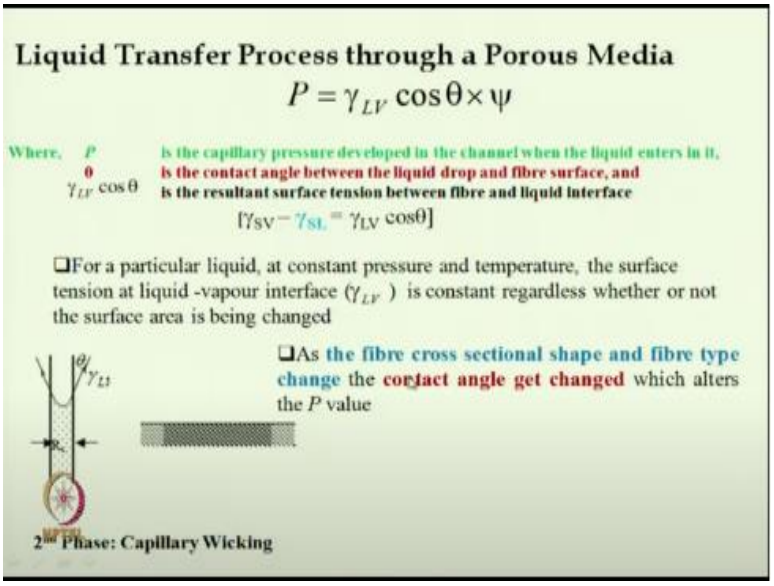

The picture shows here as the fiber cross sectional shape and fiber type changes the contact angle gets changed which actually affect the pressure. So to control the capillary pressure we can select proper fiber and proper fiber cross-sectional shape.

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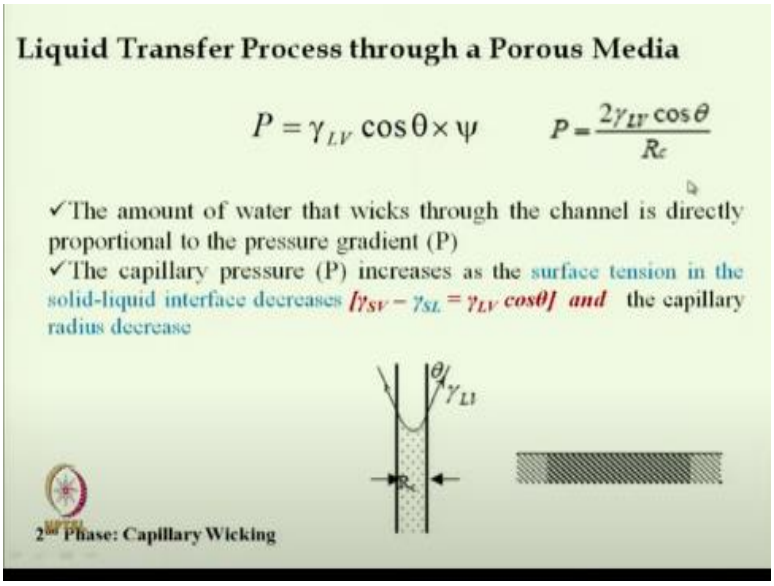

Here it is showing same equation the amount of water that wicks through the channel is directly proportional to the pressure gradient. So that is the pressure here this capillary pressure the capillary pressure increases as the surface tension in the solid-liquid interface decreases and the capillary radius decreases that I have already mentioned so we must engineer our clothing accordingly, sportswear accordingly.

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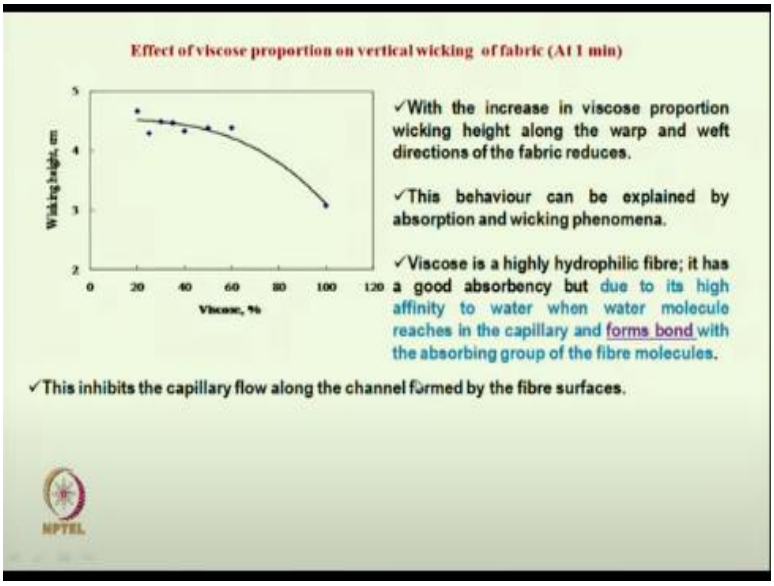

Now here if we see if we take the fabric which we have used we have which we have seen in case of moisture vapor transmission the same set of fabrics we are taking polyester viscose, the viscose proportion is increased from 20% to 100% but here what we have observed here with the increase in viscose content the wicking height, the wickability reduces. The reason behind here the viscous it is a hydrophilic fiber.

So it absorbs moisture but due to the formation of bond between the viscose fiber and water it does not allow the water to flow through the structure easily. It tries to retain the moisture vapor inside moisture liquid moisture inside that is why wicking height reduces. So with the increase in viscous proportion the wicking height along the warp and weft direction of fabric reduces, here we have used woven fabric.

This behavior can be explained by the absorption and wicking phenomena. Viscous is highly hydrophilic fiber it has good absorbency but due to high affinity of water when water molecule reaches the capillary it forms a bond with the absorbing group of Viscose. So that is why it actually retards the wick ability, reduces the wick ability.

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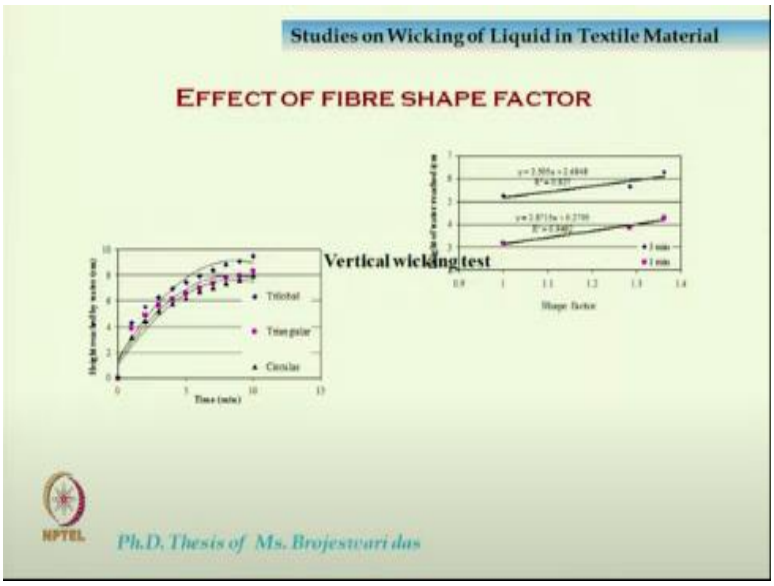

Similarly if we see the effect of fiber cross sectional shape with the increase in shape factor from circular to trilobal the wickability increases. This is the trilobal. Circular is showing lowest wicking height and this picture shows the effect of shape factor. It is a similar but here the effect of shape factor is shown so as the shape factor of the polyester filament increases the wicking capacity wick ability also increases wicking height increases.

This is mainly due to the enhanced wetting and reduction in theta so higher the capillary pressure, so capillary pressure increases with the increase in shape factor.

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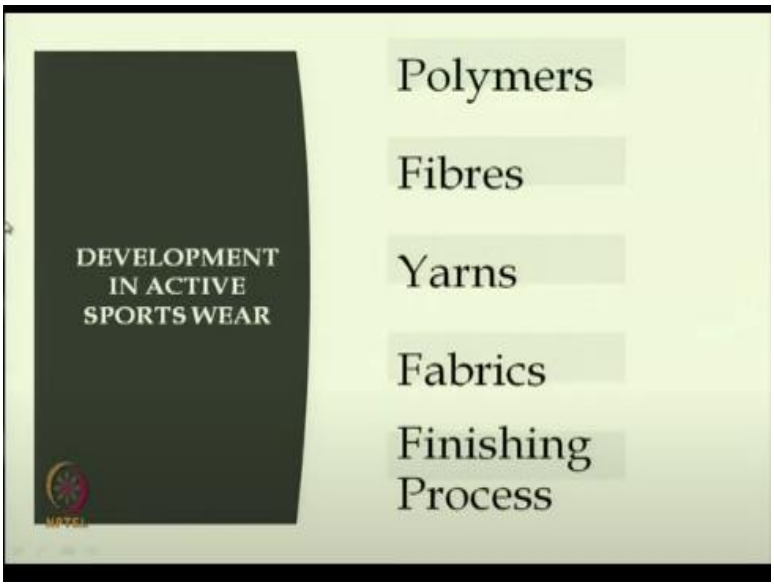

Now we will discuss some innovative sportswear for active sports, these are commercially available technologies. So I will just mention few of them just to get idea about the direction of development. So developments took place in various areas like polymers, fibers, yarns were made with the different structures for enhancement of performance of sportswear sportsperson, fabrics different types of innovative fabrics were developed and different finishing process. Here we will mention some of them;

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Like polymers, if we see the polymer phase change polymer materials are used, PCM. Phase change materials are used in some speciality sports textile where after reaching some specific temperature the phase change takes place and during phase change it absorbs heat from the sports person and the sportsperson feels cool. So this phase change materials are in use in some specific high active sportswear where heat generation is high

And the heat release sometime does not take place in that rate. So to enhance the heat release this phase change materials are used.

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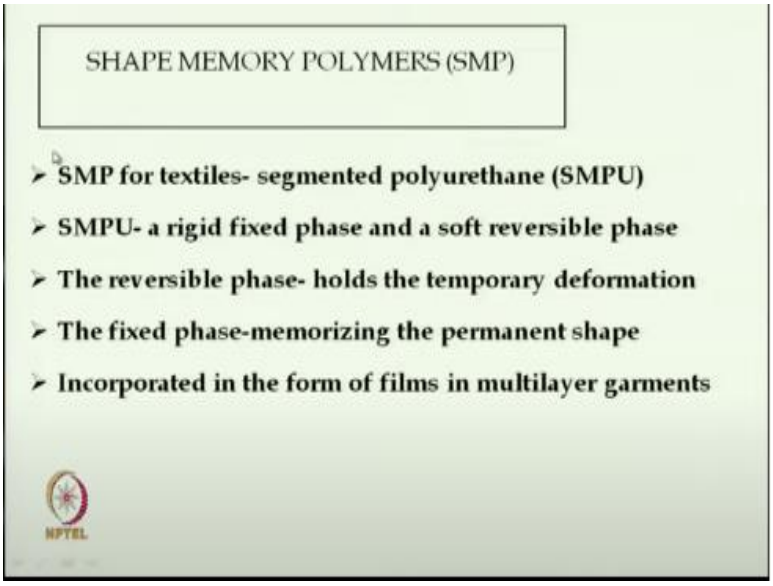

Next is that shape memory polymer, SMP. These are used for some high active sportswear mainly some multi-layer garments are produced, this shape memory polymers are applied on the textile material in the form of coating. The shape memory textiles are segmented polyurethanes are used. The segmented polyurethanes have two phases, one is rigid phase another soft reversible phase. The rigid phase is fixed phase and soft reversible phase holds the temporary deformation.

So this reversible phase the soft which actually deformed and they hold the temporary deformation and the fixed phase which memorize the permanent shape. So then after deformation due to this fixed phase the material comes back to the original shape. These are incorporated in the form of film in the multi-layer garment, so these shape memory polymers are used in some speciality sportswear.

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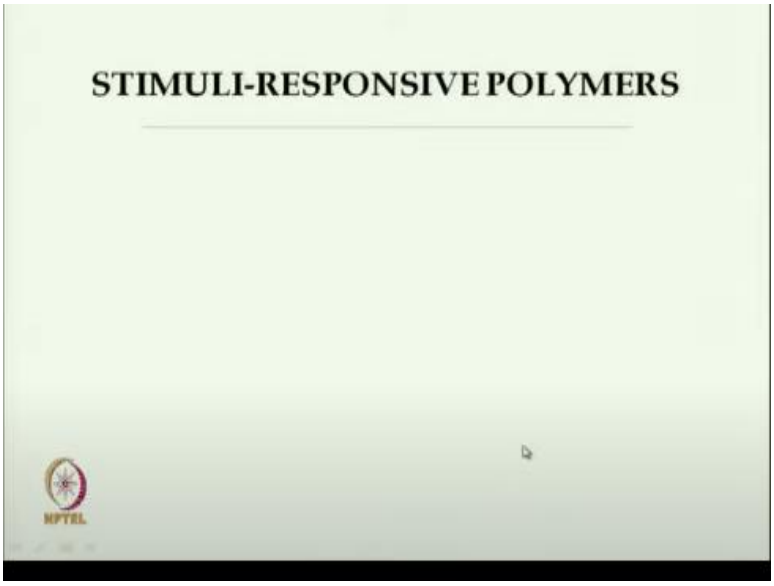

Stimuli responsive polymers are also used one example is that with the increase in the temperature material the fiber gets swelled or with the increase in moisture fiber gets swelled. So as the temperature increases if it swells so it will block or on the other end with the increase in temperature the shrinkage may take place or sometime it may get extended. So depending on the diameter change or length change the structure of the sportswear, change accordingly.

And we can use this structural change to control the heat and moisture transmission during the activity because during activity the heat and moisture in the body changes so that changes in heat and heat release or heat generation should work along with the structural change of the sportswear where we use stimuli responsive polymers.

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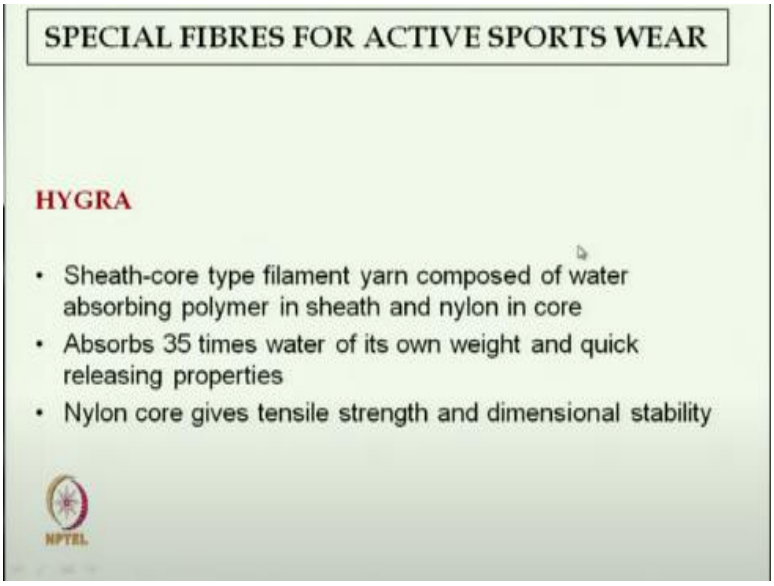

Now coming to the fibers, there are different speciality fibers used in active sportswear the commercial names I will use here, Hygra is one such fiber where it is a core sheath type filament. It is composed of water absorbing polymer in the sheath and nylon in the core. So nylon in the core helps in keeping the dimensional stability and strength and when we use the absorbing polymer in the sheath it will have higher quick release of moisture or water from or sweat from the body of the sports person. So it absorbs about 35 times of water of its own weight.

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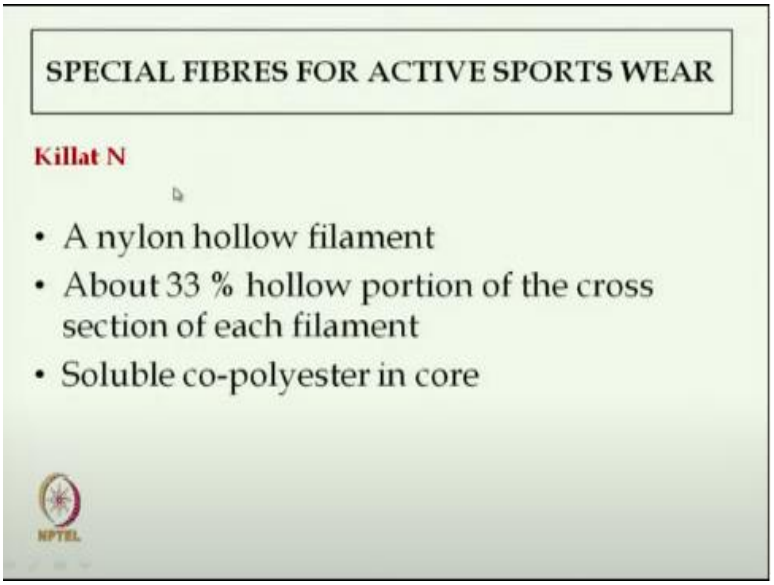

So it can absorb high amount of water keeping the strength and dimensional stability intact. Next is Killat N, this fiber it is a nylon hollow filament about 33% of hollow portion which is produced by soluble co-polyester in the core. So that those cores will get dissolved it is soluble

and then it will form the hollow filament and this fiber is used for the insulating type of sportswear.

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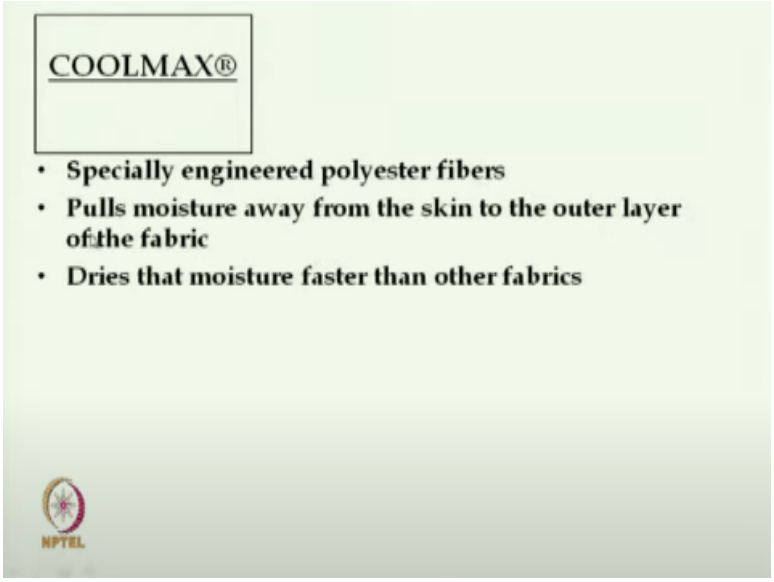

Coolmax is another commercial product specially designed polyester fiber here. It is made of polyester. It pulls moisture away from the skin to the outer layer dries the moisture faster than other fabrics as per their literature.

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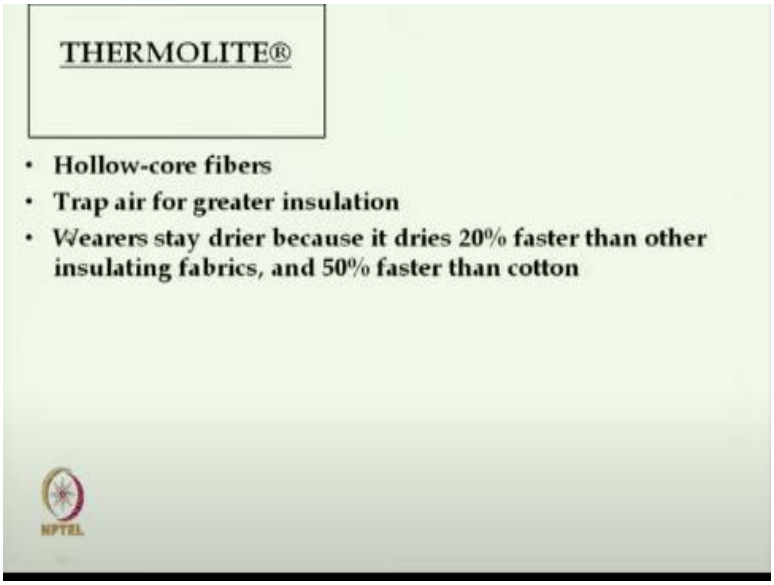

Thermolite is another hollow core fiber. It traps air in the core whereas it is giving insulation. The sports person remains dry because it dries 20% faster than other insulating fabrics. That is the manufacturers claim.

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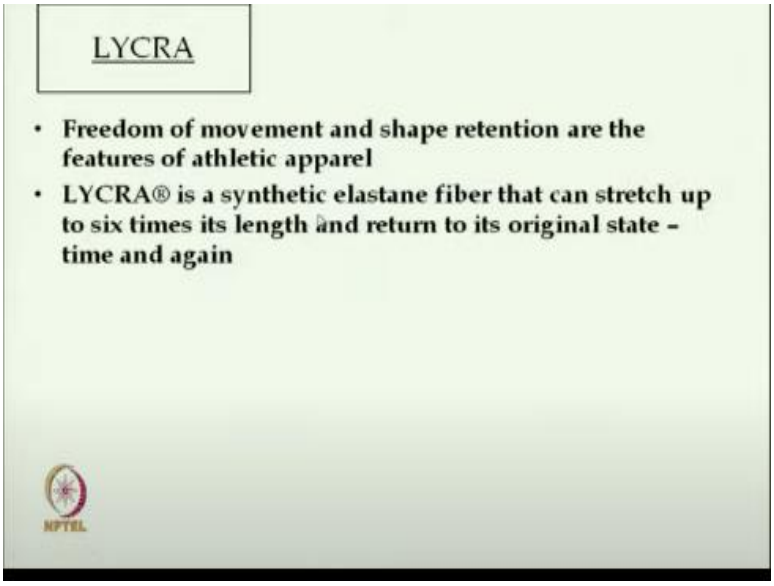

Lycra is another fiber which is basically a well-known fiber. It is an elastane fiber where the high stretchability is there. Freedom of movement, shape retention are the main features of this athletic apparel, so this sportswear the shape in proper form by proper relaxation and due to high elasticity, it adds to free movement of the body. This is a less synthetic elastane fiber and can be stretched up to 600% of its length.

And it can return to their original stage with a short time and it they return repeatedly. It is not that it is basically their elastic recovery is very high. So for this type of sportswear for repeated stretching and the relaxation is required which is provided by Lycra.

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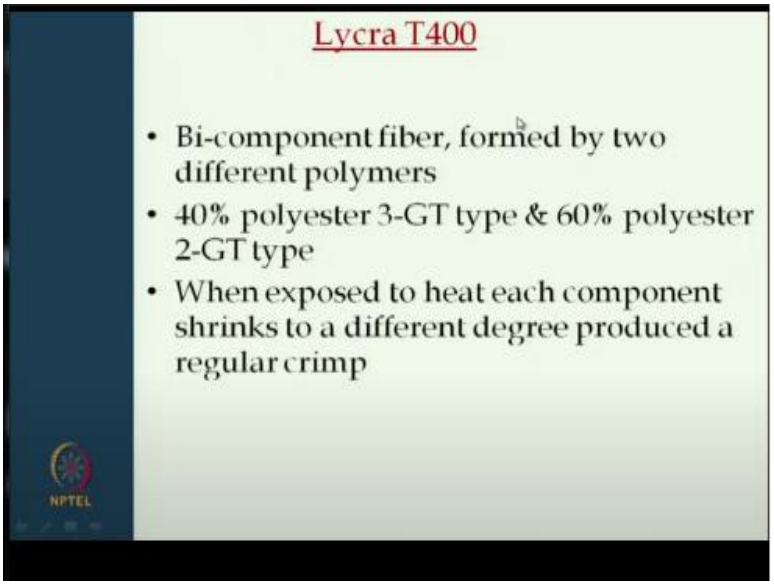

Another special product which is called Lycra T400, it is a bi-component polyester where it is a bi-component fiber from two different types of polymers 40% polyester 3-GT type and 60% polyester 2-GT type. When exposed to heat each component shrink at different degree and which produce the crimp. So the here the phenomena is that;

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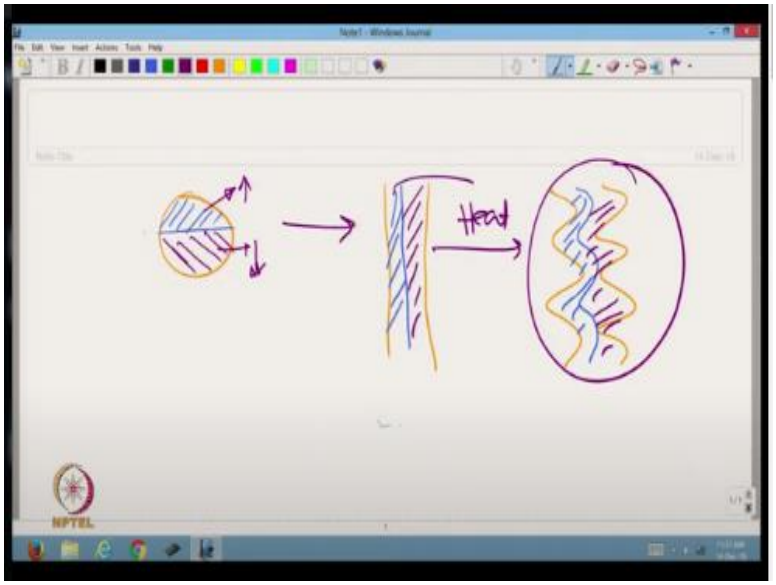

Suppose this is fibre it is bi-component, suppose this is one component, here is another component. If this is at high temperature shrinks at higher shrink and here the shrinkage is lower. Now after shrinking when it is coming to the warm condition this fiber, due to their differential shrinkage due to heat. This fiber will form crimp due to their differential shrinkage individual fiber and this crimp will result air pockets.

So initially the air pocket was less with a straight fiber but with the heat the air pocket has will increase. This air pocket will help in; it will increase the pores also. This air pocket will enhance the heat transmission, so there this crimp will enhance the heat transmission.

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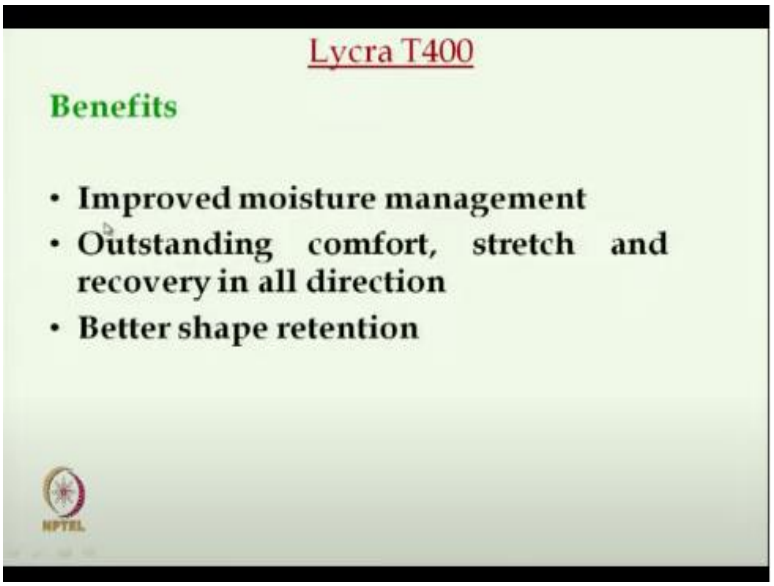

The benefits here is that the improved moisture management so at higher temperature when we need to release moisture at higher rate so due to the crimp formation they will help this pores will help the extra pores help in releasing moisture so enhance comfort, stretch and recovery at all directions and they have better safe retention.

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Now coming to the effects of cross sectional shape of fiber the profiled polyester with modified cross section like trilobal and hexachanel improve wicking characteristics. This actually it has been observed that this type of fiber if we change the profile cross section of the polyester from circular to trilobal or hexachanel, it has been observed they are improving the wicking and drying ability.

Combinations of polyester with thermo-regulating viscose gives better wicking ability and poor drying capability. So if we combine this the drying capability will reduce.

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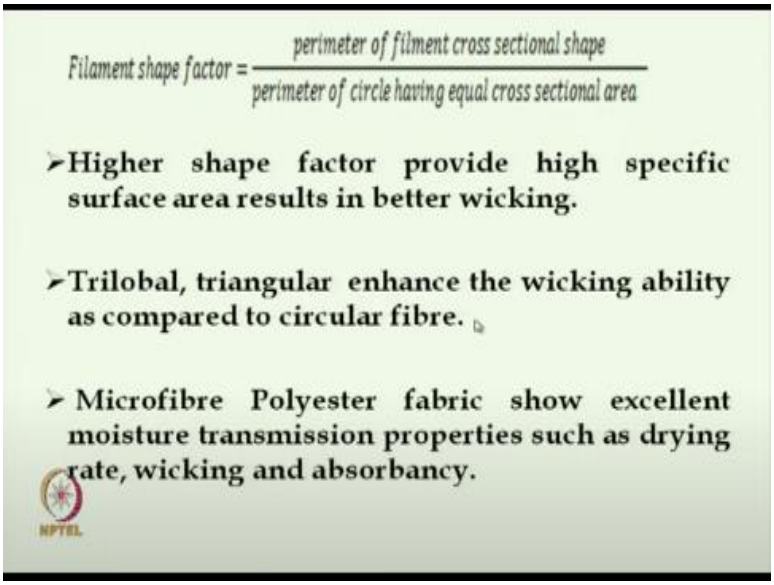

If you see the fiber shape factor, so as we have mentioned increase shape factor will enhance the weak ability. So fiber shape factor it is defined by the perimeter of filament cross-section as per their present cross-sectional shape and the perimeter of circle having equal cross-sectional segment. For same cross-sectional shape the perimeter of filament and perimeter of circle if we take the ratio that is actually shape factor filament shape factor.

So higher shape factor provides higher specific surface area which results better wicking, trilobal triangular enhance the wicking ability as compared to circular so due to the higher shape factor. Microfiber polyester fabric shows excellent moisture transmission properties such as drying rate wicking and absorbency. So this the fabrics polyester fabrics with a microfiber the wickability

increases, so if we want to engineer clothing or sports clothing with better wick ability we must use the filament with high shape factor or we can use the microfiber fabric.

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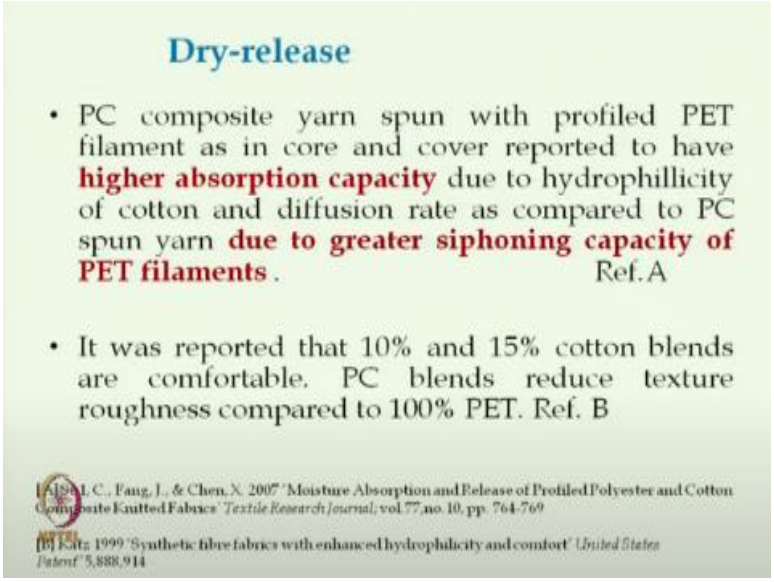

Another product is that it is a dry release fiber. The polyester cotton composite yarn so if we talk about the yarn so here in dry release it is a polyester cotton composite yarn and it is not blended. Now if we see here;

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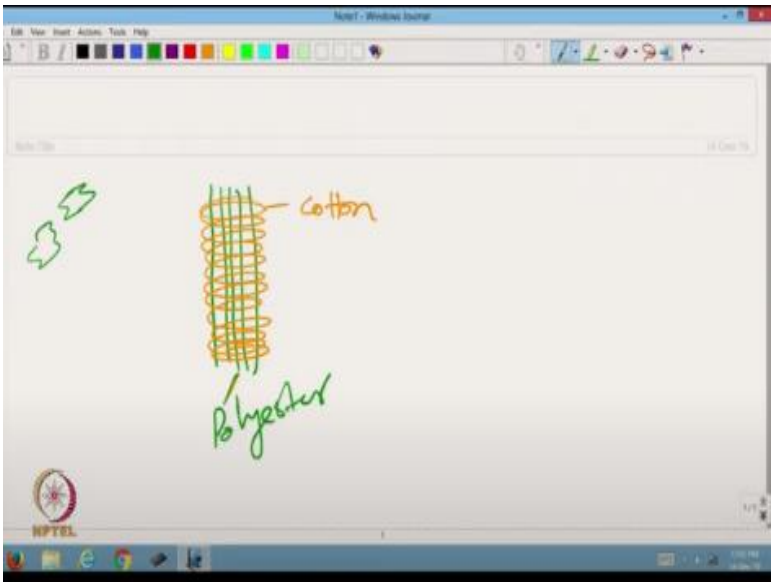

It is a polyester cotton composite fibers are used. These are the polyester filaments, continuous filaments sometimes we can use shaped cross-section. It is not the circular and it is covered by cotton, coarse type structure, this is cotton, this is polyester filament. So cotton absorbs moisture

and the polyester helps in wicking. So that is the type of yarn which has been proposed here, so this is the composite yarn spun with profiled polyester filament in the core.

Why profile? Because profile polyester will have higher wickability and which is this filament are covered with a higher absorption capacity of hydrophilic fiber like cotton, so it was reported that 10% and 15% blend of cotton are comfortable because here majority of the yarn content it is a filament and the cotton content will be only just to cover.

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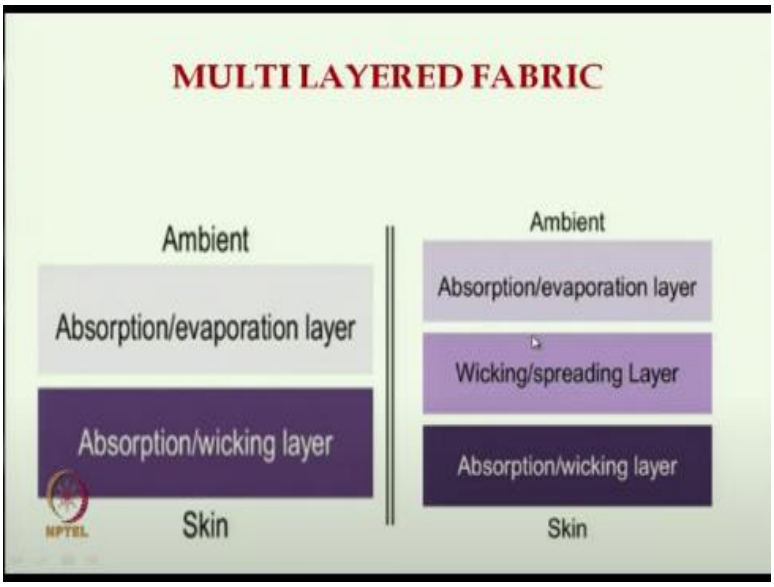

Now coming to the fabric structure innovative fabric structure, there are different layers proposed like here this type of layering is that it is absorption and wicking layer. We should have one layer which will be absorbing and wicking layer then absorption and evaporation layer. So two layer structure is there, here inner layer is absorption layer and from next layer it is evaporation layer which will absorb evaporate.

Sometime the spreading layer is also required but if we try to use only two layers, so in first layer that is absorption, wicking and spreading is also important because spreading is important due to the fact that the liquid water will get spread over the total area of the clothing which will enhance the evaporation rate. If it does not, suppose it is absorbing but spreading does not take place then what will happen? The evaporation will take place within that small area.

And that will take time but if we can spread the liquid to a larger area then the evaporation will be faster. Next commercial product that is the sports clothing fabric is that is Entrant DT.

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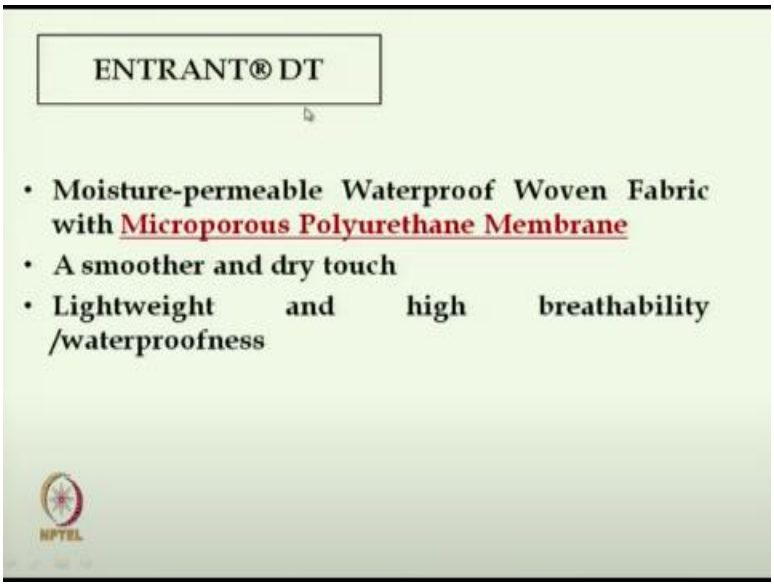

Which is actually coated polyurethane membrane coated; it is waterproof microporous breathable coating on woven fabric. These are smoother and dry touch because it is a polyurethane coating is there and lighter weight and higher breathability and waterproofness, for many application like scuba diving and this type of sports we try to use this type of clothing. Another important characteristics is the anti-static finish;

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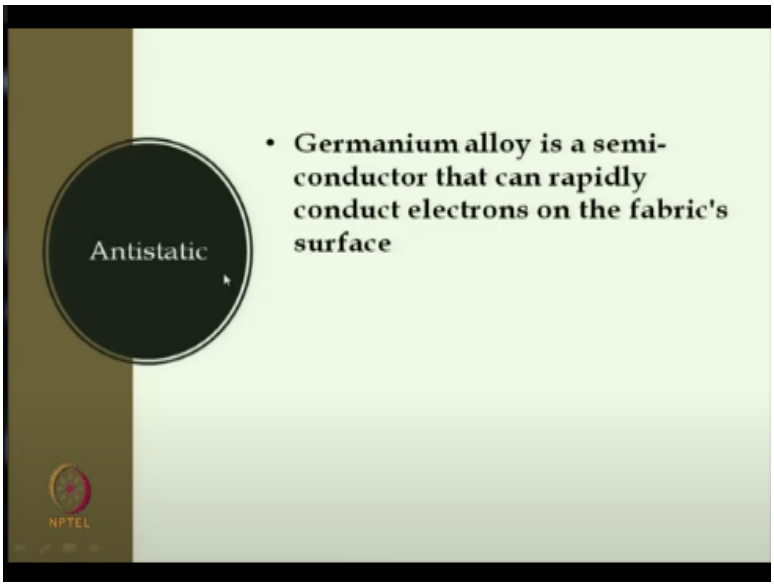

Because the textile that is sportswear always in particularly in active sportswear they are always in rubbing against the skin or they are rubbing against the other surface against the two surfaces of the clothing. So due to all these antistatic electricity generated static charge generated. So anti-static the fabric the anti-static materials are there like germanium alloy is a semiconductor that can rapidly conduct electrons on the fabric surface, so these type of finishes can we can apply.

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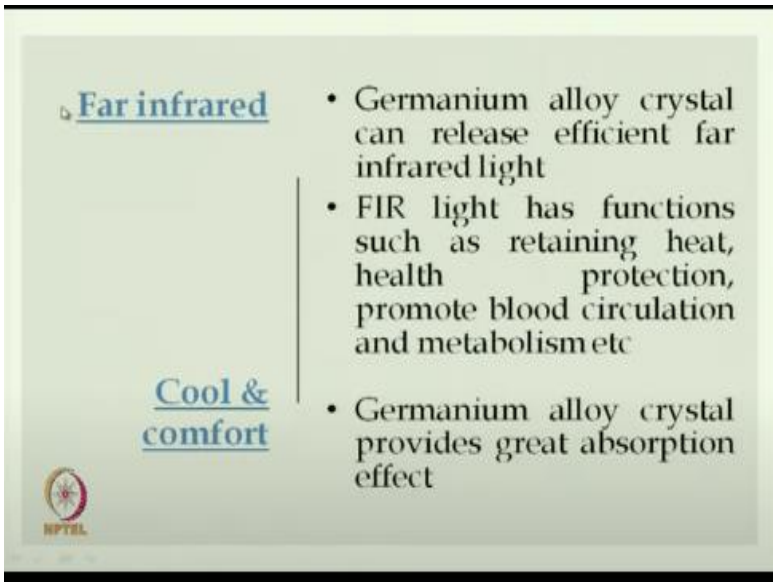

Another germanium alloy a crystal they are used to absorb the infrared light like crystal can release efficient far infrared light. The infrared light has the functions such that retaining heat health protection, promote blood circulation and metabolism. So this type of development is there another is that germanium alloy crystal provides greater absorption the absorption effect. So this higher absorption will keep us comfortable.

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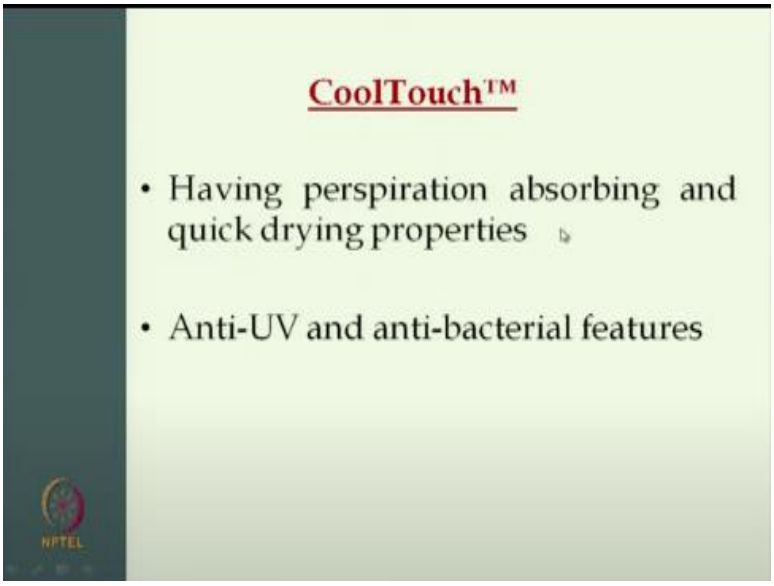

Next product is cool touch. Here having higher perspiration absorption capacity that is quicker drying its anti-UV that is the UV protective antibacterial feature. So cool touch they have incorporated many features.

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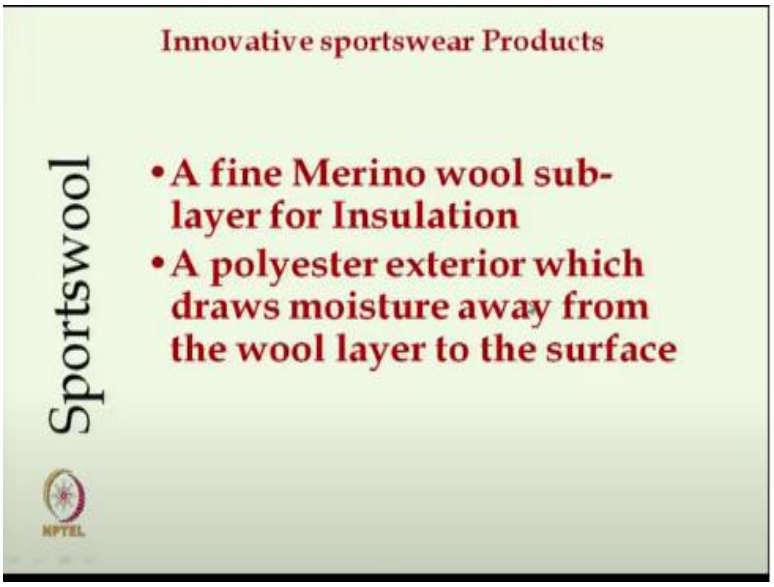

Another innovative product is the sports wool. It is here a fine merino wool sub-layer is used for insulation so inner layer is merino wool layer. Another is the polyester exterior layer which draws moisture away from the wool layer to the surface. Now here we have to see the different products but depending on our requirement we have to use.

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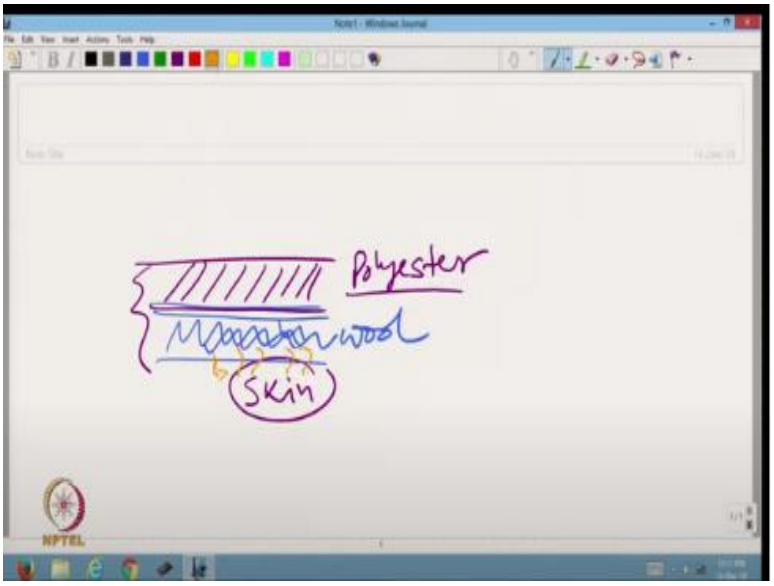

Here in the sports wool this is wool and outer layer is a polyester layer, so two layers wool and skin, our skin. Here whatever the liquid we are generating wool absorbs and from there polyester is that hygroscopic material it takes and wicks to the outer layer that is the mechanism here. It is proposed the polyester draws the moisture from wool and keeps the layer dry.

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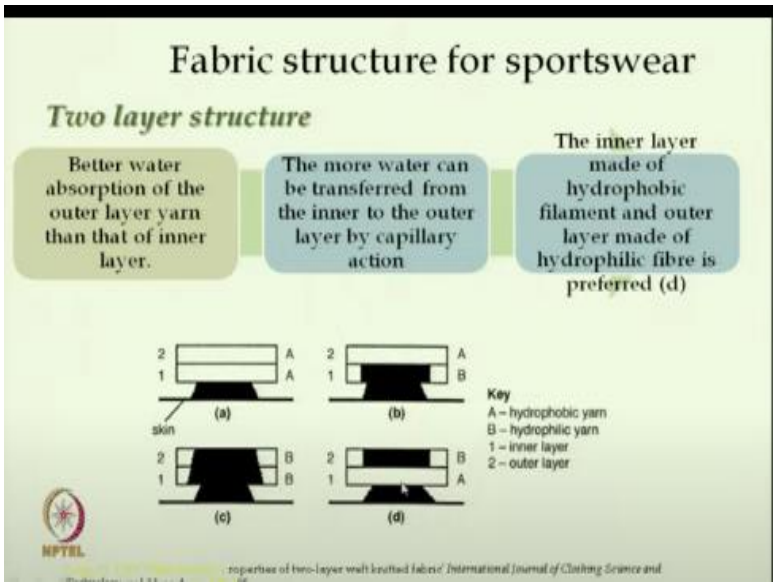

So another approach of two layers structure here entirely different approach was proposed the approach here is just entirely different. This layer, layer one this layer A is the hydrophobic layer and layer B is the hydrophilic, this is hydrophilic. Just reverse to what we have discussed here better water absorption of the outer layer yarn than the inner layer. So outer layer the D is actually preferred here that is what it has been proposed.

The more water can be transferred from the inner layer to the outer layer by capillary action. So here from the inner layer to outer layer by capillary action because the inner layer is a hydrophobic. Hydrophobic polymer is used where we need capillary flow it does not absorb but after it is being flown that through capillary flow this hydrophilic layer B which is outer layer it will absorb and from there the water will get evaporated.

The inner layer is made of hydrophobic filament and outer layer is of the hydrophilic filament. It is actually that it has been reported this is the preferable layers, combinations. Here 4 different combinations were shown both the layers were hydrophobic, inner layer hydrophilic, outer layer hydrophobic, both layers are hydrophilic and inner layer hydrophobic, outer layer hydrophilic. This is actually preferable and this will in turn keep the sportsperson dry.

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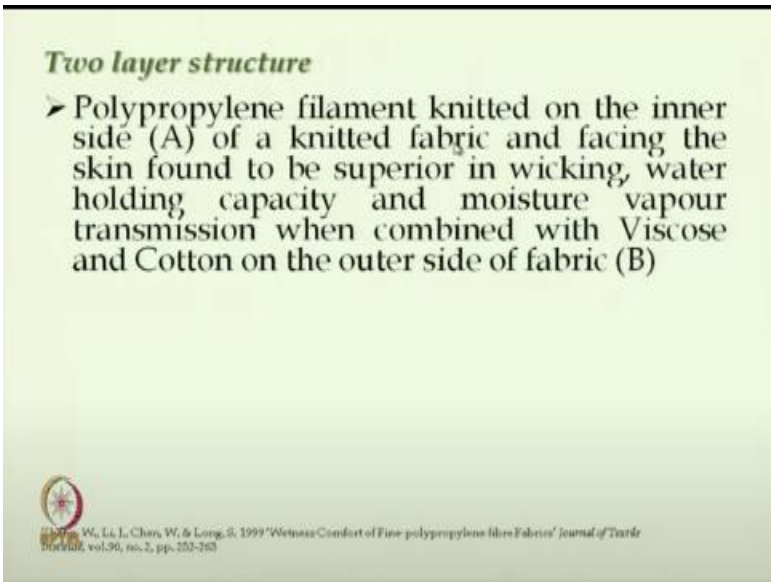

So polypropylene filament knitted fabrics on inner side that is A and the facing the skin this A layer which is made of polypropylene knitted fabric which will be in touch with the skin and it has been found to be superior in wicking because polypropylene wicking characteristics is very high. Water holding capacity and moisture vapor transmission when combination with the viscose or cotton in the outer layer.

So polypropylene along with the viscose or cotton we can use. So this is here A is polypropylene and B is either cotton or viscous we can use.

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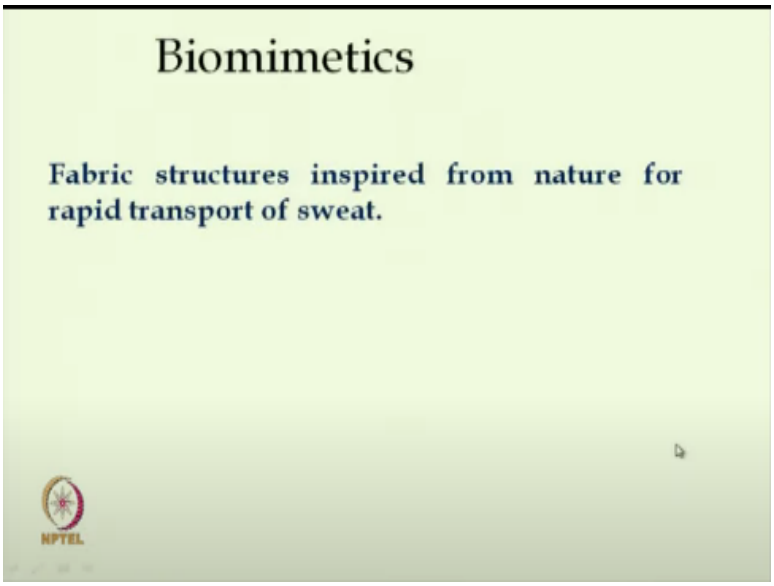

Biomimetics is also used in case of sports textile where the pore size of different layers are controlled, so fabric structure inspired from nature for rapid transmission of sweat.

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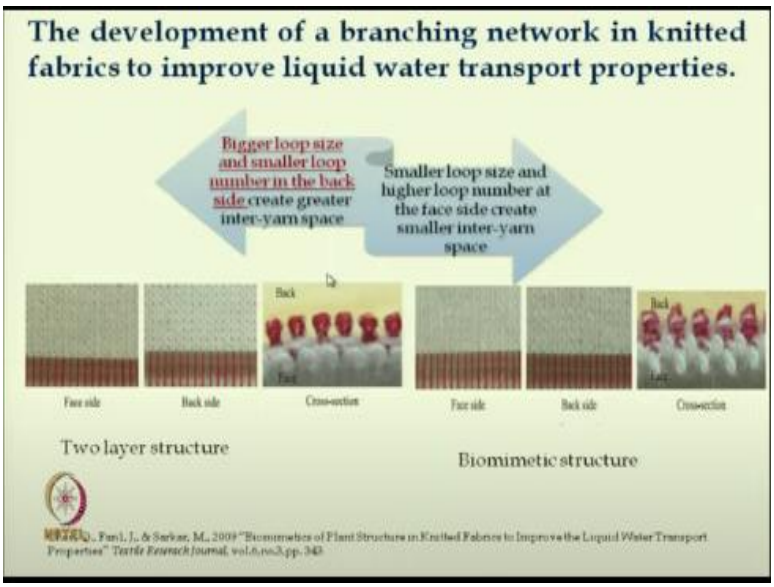

So these are the structures where the bigger loops and smaller loops are created at different layers. So smaller loop size and higher loop number at the face side created the smaller loop size in the size creates the smaller intern-yarn space. So in the face side smaller loops;

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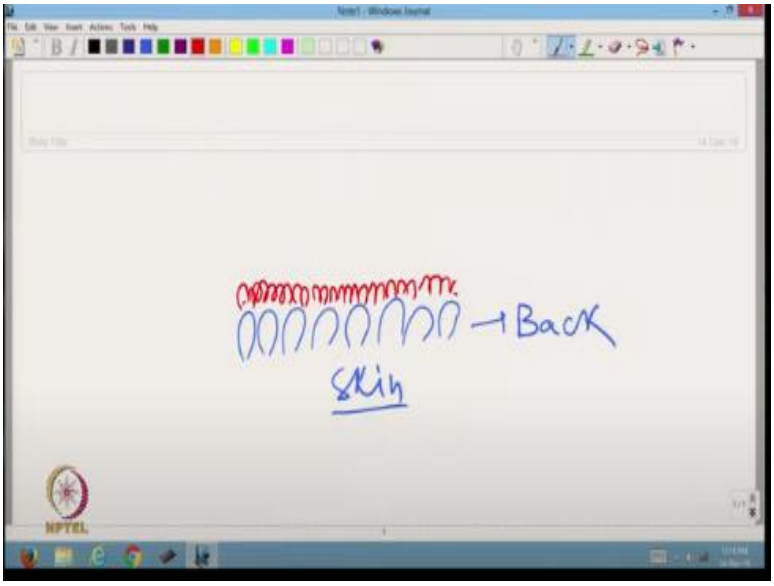

These are the bigger loops; this is the back side skin. Now face side, smaller very smaller loop and number of loops are more. So what will happen here, in this way we create multi-layer or maybe more than one layer, two layers also we can create. But here idea is that here this will create larger pore size and gradually the pore size will reduce. So moisture in the liquid form will get transmitted.

If this layer will absorb moisture here and here due to the lower pore size higher wicking rate will be there it will get transmitted fast. So different layer conditions, layer selection or of multi-layer knitted fabric are created to enhance the wickability. So in next class we will discuss other aspects of sports textile. Till then thank you.