Technical Textiles
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Lecture - 24
Sports Textiles

Hello everyone. Now, we will start a new topic that is sports textile. Here we will discuss different aspects related to sports textiles like materials used in sports textiles, different types of sports textiles and will try to see the present commercial sports textiles and their different characteristics. Finally, we will see different research studies and their trends that is effect of different parameters material related parameters or process related parameters on different characteristics of sports textiles. Now, we will start with the classification.

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Broadly if we see sports textiles can be classified in two broad areas, one is leisure sports this type of sports textiles, we normally wear for longer duration. Maybe throughout the day or maybe several hours it is for leisure activities, and as we have to wear this leisure sportswear for longer duration that means this particular sports textile should take care of varying climatic conditions within a day due to climatic condition changes.

So this particular sports textile should take all these things into account, on the other hand active sportswear these are basically worn for very short duration maximum physical performance should be achieved and this particular sports textile should assist in getting the physical performance and as this type of textiles are worn for short duration, we must know that these are designed for the constant climatic condition may be few seconds or may be few minutes.

So within that condition the climatic condition may not change. So that is why this type of sports textiles active sports textile we should take care of enhancing the physical performance.

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So we can define sportswear because these are clothing, so including footwear these are worn for sports or physical exercise.

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So we can further classify the sports textiles are performance sports textiles. These are basically to enhance the performance of the athletes. Basic sports textiles, sports related leisure wear and sports related fashion clothing. So, let us see how these types of sportswear we can define?

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So performance sports textiles are, these are the sportswear which are highly technical clothing and this enhance the performance with special functionality. So these are basically highly technical one so and here the basic idea is to enhance the performance. For example swimsuit, compression athletic wear, there are different types of performance sportswear. The swimsuit's main function is to enhance the performance of the swimmer.

So these details we will discuss and we will also discuss the different studies on compression athletic wear which is in short called CAW.

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Basic sportswear typically we wear for little longer duration, so these are this is relatively cheaper. Cheaper than performance sportswear and more stylish while retaining as many the material attributes as possible. For example soccer shirt, track suit, jogging suit, so here also its performance is required and this type of sportswear should have very good thermo physiological comfort and also the skin sensorial comfort should be there.

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Third one is that leisure sportswear it is basically replica of performance portion and these are normally worn in home like Sweatshirt, Golf sweater, cotton jackets these are the leisure sportswear.

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And sports related fashion clothing these are sportswear replica used in fashion. Here performance is not that important where but the design and aesthetics are important the t-shirt, baseball cap, shorts these are used as fashion sportswear.

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Now coming to the functional requirements of high active sportswear, so high active sportswear requires all these functions like it should absorb sweat very fast, transmit the sweat very fast, in active sportswear as the sports person is highly active so moisture is majorly transmitted in terms of liquid that is sweat, so this sweat generated. So whatever sweat is generated this sweat has to be absorbed and transmitted through the sportswear.

So basic requirement here is the wicking characteristics of the fabric so while designing high active sportswear one must first take into consideration of wickability of the material and as this type of sportswear they are getting wet frequently, the fast drying is very important. Cooling of the sports person is required by proper absorption of sweat and transmission of sweat and also the heat transmissions should be very fast.

And during high activity the body movement will be very high and this sportswear should not hinder all this body movement that should be very easy or smooth body movement should be there, that is why another important characteristics of high active sportswear is this should be highly stretchable and should have high elastic recovery. So while designing the high active sportswear this high stress ability and high elastic recovery is extremely important.

Also we require smoothness in the sportswear otherwise there will be scratchy sensation, it should be soft, it should be UV resistant because most of the sports are high active sportswear particularly. They are played outside so this sportswear should be UV resistant, they should be light weight because for high active sportswear we need light weight and it should be easy care. So these are the requirements of high active sportswear. So while designing or selection of material we must take all this requirements into consideration.

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Functional requirement of main sportswear

Sportswear	Required function
Shirts for tennis, volleyball, football, tracksuits	Sweat absorbing, fast drying, cooling
Skiwear, wind breakers, Rain wear	Vapour permeability, water proofing
Skiwear, windbreakers, track suits	Sunlight absorbing ,thermal retention
Swimming, skating, skiing suit	Low fluid resistance
Swimwear, skating	Strechability, opacity
Skiwear, baseball	High tenacity and abrasion resistance

Now, let us see for different types of sportswear, what are the functional requirements, like tennis, volley ball, football, tracksuits this high active sportswear. Basic requirement is that that sweat absorption, sweat transmission, fast drying and cooling. So all these high active sportswear, where high amount of sweat is generated and heat is also generated, that is why sweat absorption and transmission is most important.

Another sportswear like this group of sportswear; skiwear, wind breaker, rain wear, where typically these are played little bit in longer duration also and here instead of that sweat generation here moisture is transmitted in terms of vapour. So vapour permeability is also important along with sweat absorption also and wind water proofing because rainwear, skiwear so here waterproofing is required.

So this type of sportswear where both vapour permeability and waterproofing is required, so we must use a coating water proof of breathable coating is required. Skiwear, windbreaker, track suits where sunlight absorbing finish or material should be used like UV absorber should be there and thermal retention if it is required. So, here if it is used in extreme cold climate so there are thermal insulation should be there.

For the swimming, skating, low fluid resistance clothing should be there, in swimming the drag against the liquid should be low. So while designing the, swimming suit one should take this characteristics this requirement into consideration because this will enhance if we reduce the fluid resistance this will enhance the performance of the swimmer. In swimming and skating another important characteristic is stretchability because in swimming or skating the athletes the player they move their body part.

They stress their body part very frequently, so here stretchability is extremely important and baseball, skiwear, high tenacity, abrasion resistance is important. Depending on the type of sportswear or type of functional requirements, we will design our clothing we have to select our raw materials.

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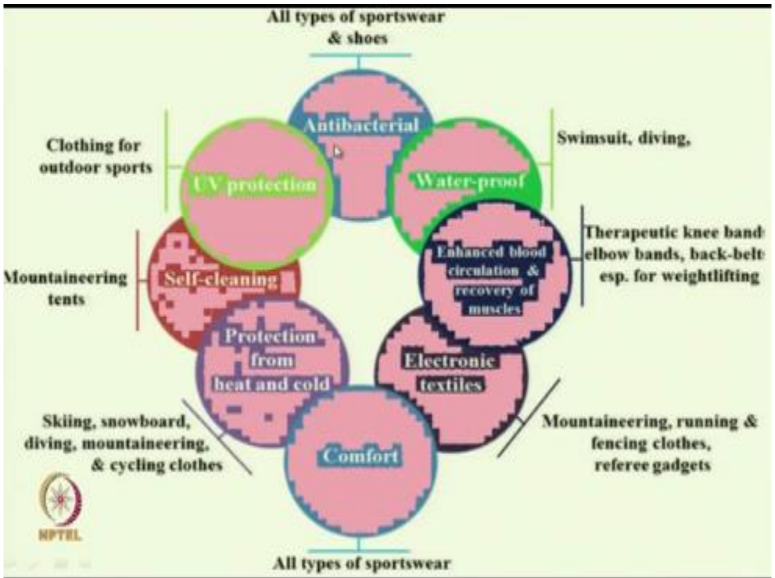

Here it also shows different functional requirements for different types of clothing, where the functional requirements are extremely important for particular application. Like antibacterial finish, this antibacterial finish is required for all sportswear and shoes, because in all the sportswear the chances of bacterial growth is there, so we should select material which are antibacterial like swimsuit, diving, waterproofing is extremely important.

That for weight lifting or for back-belt therapeutic, knee bands, this here the blood circulation and recovery of muscles are extremely important. So this sportswear requires to enhance the blood circulation and muscle recovery, like for weight lifting we use back-belt here it is required to enhance the blood circulation and it is required to recovery the muscles. Electronic textiles are also used for different applications.

Comfort is required for all type of that sportswear, so every sportswear requires the comfort and protection from the heat and cold is also required when we use this sportswear for extreme environment like mountaineering, cycling, ok, self-cleaning requirement is there for some of the sports related clothing like mountaineering tents. We need to clean this type of tents easily and UV protective clothing or UV protective sportswear is required.

Where we use the clothing for outdoor sports, as I mentioned so for soccer, tennis for any outdoor sports we require UV protection.

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Now basic challenges in sportswear, there are two challenges mainly for active sportswear. The sportswear has to manage high rate of sweating, so it should absorb and transmit high rate of sweating. So typically the rate of sweating is 1.5 to 2 liters per hour. So this much sweat the sportswear should manage without enhancing the weeight, the mass of the clothing if increases then there will be discomfort.

And also the metabolic heat generation is very high during high activity, typically it is ranging from 800 to 1400 watt, so this heat should be transmitted through the sportswear, so these are the challenging requirements.

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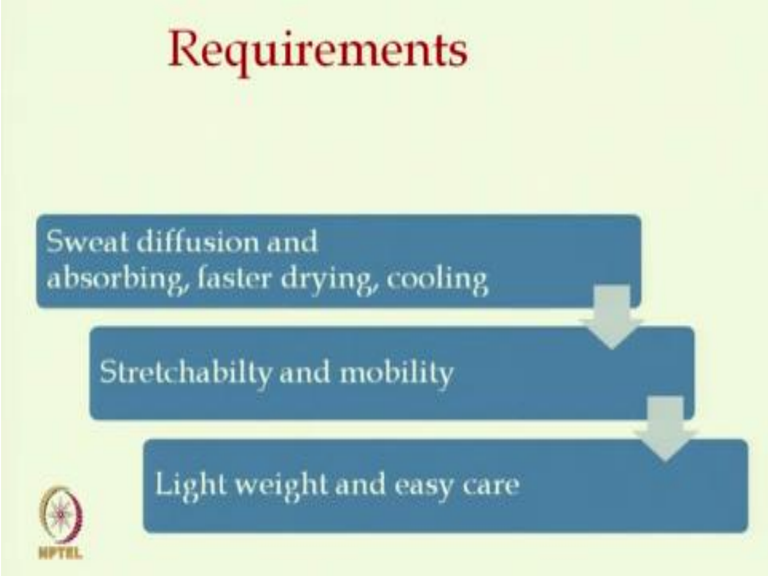

So basic requirements are the sweat should diffuse through the sportswear, it should be absorbing, fast drying and then it should be cooling. Stretchability and mobility; mobility are requirement of high active sportswear, it should be lightweight and easy care. So keeping all these in mind we should design the sportswear, so stretchability if we want to enhance we have to use some material like stretchable material.

So that it is during stretching the load required is not that high and it should be recoverable. Light weight we should use the material typically with the low density material we should use.

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So to enhance the comfort characteristics of sportswear, we must target different types of requirements then we can select our clothing. Like, first requirement is that for any sportswear: thermo physiological comfort this talks about the heat transmission and mass transmission. Mass transmission in terms of the moisture vapour and moisture in liquid form, and if it is high active sportswear then moisture in liquid form is important and if it is low active sportswear where the moisture vapour transmission is dominant.

Then skin sensorial comfort, it should not be scratchy, it should be smooth and it should not cling, to the clinging sensation should not be there. So designing of the clothing such that, during extreme sweating the sportswear should not cling with our skin. Psychological comfort is also important the designing or color should be such that the sportsperson should be psychologically comfortable.

And also the color of the sportswear sometime enhance the performance of the sports person and mobility like stretchability is also important. So that it should not hinder the free movement of the sports person.

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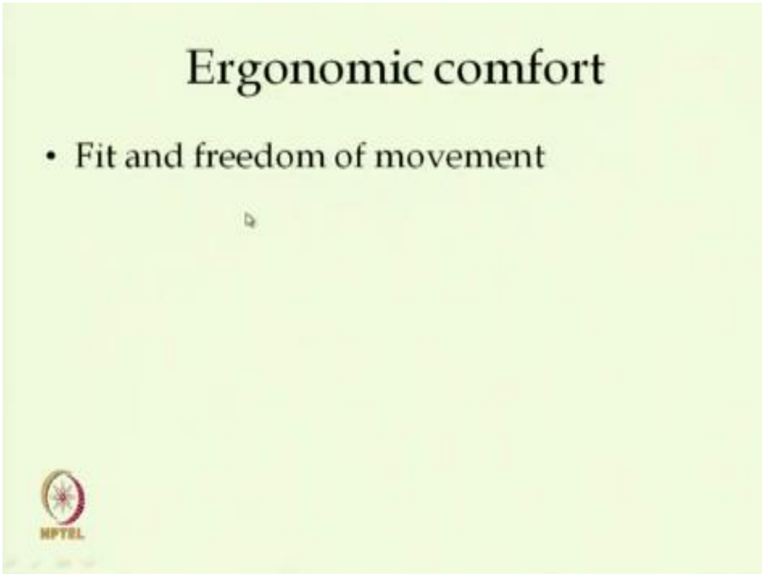

And mobility is related to the Ergonomic comfort, related to fit and freedom of movement, so body movement should be free there should not be any restriction in body movement. And at the same time the clothing should be actually fit with the body it should not be too loose.

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Skin sensorial comfort is that it is a mechanical sensation when the cloth comes directly into our into contact with our skin. So during rubbing that some sensation rubbing sensation sometime it creates uncomfortability among the sports person that sometimes affect the performance and as far as psychological comfort;

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It depends on the fashion and personal preferences, sometimes color of sportswear can also influence the performance of a player. So there are studies one of the studies it shows that it has been reported that red color enhances the performance by stimuli of the testosterone dependent signal. So that stimuli sometimes enhance the performance of a player.

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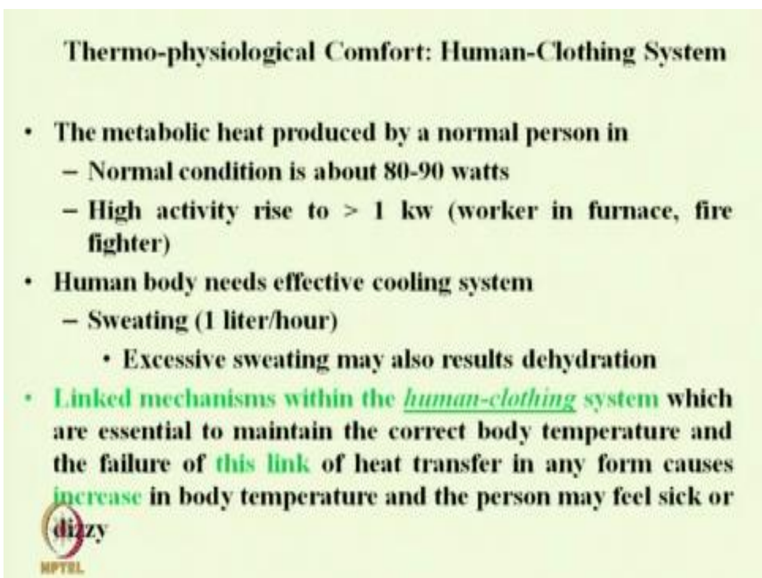

As far as thermo physiological comfort of sportswear, so here we must understand that human clothing system. When we wear any clothing we the clothing or sportswear should interact with our body and to enhance the thermo physiological comfort. So in thermo physiological we must see both the heat transmission and the mass transmission. As far as heat transmission is concerned that for normal activity, we release heat of around say 80 to 90 watts.

And for high activity as I have already mentioned for it can range between 800 to 1400, so it can go beyond 1 kilowatt, so this type of heat we must release actually we must that clothing sportswear should be able to release this rate of heat generation from our body and also it should be capable to manage the sweating. So in high activity, the sweating rate is very high, it can go up to 2 liters per hour.

So this linked mechanism has to be there. So when we require that moisture or liquid to be absorbed that absorption should be there and that sportswear should be able to absorb that level of moisture, that amount of this sweat otherwise there will be uncomfortable sensation. Even as far as heat is concerned when we require to release it the sportswear should be able to release the heat.

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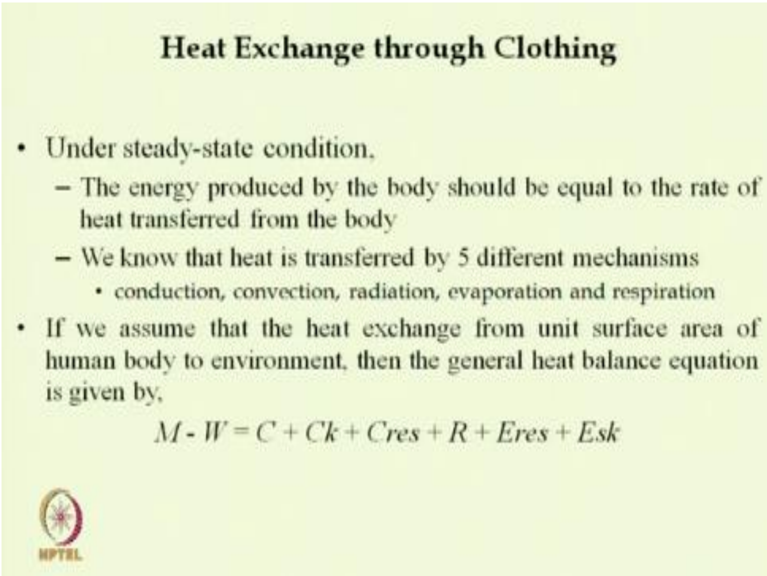

So this heat exchange in steady state condition is governed by this formula, although in during sports we never reach any steady state condition but the heat should be able to get transmitted whatever heat we generate this would be transmitted and they are transmitted through five different mechanisms and these mechanisms are conduction, convection, radiation, evaporation and respiration.

Respiration is during the heat is generally released during respiration. So nothing to do with the sportswear, so we must maintains the balance of this general heat equation.

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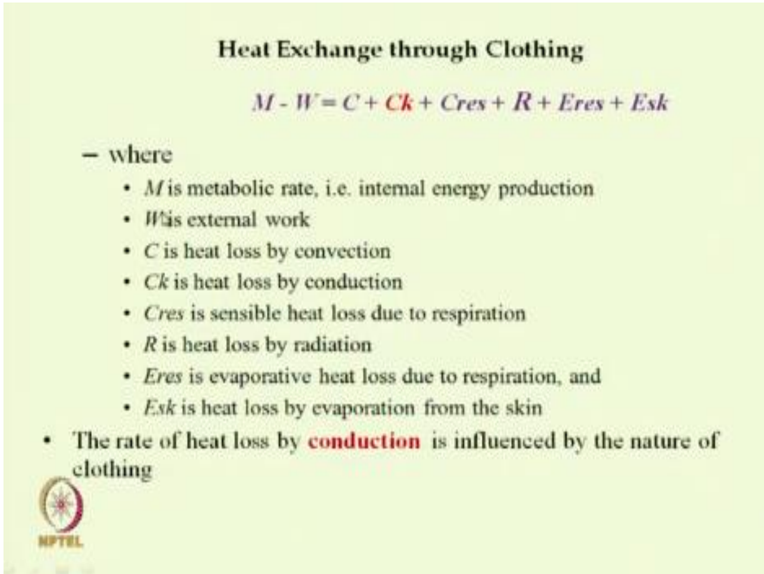

Where M is the metabolic heat generated that is internal energy produced during the activity, W is the external work done by sports person, C is the heat loss by convection, Ck is the heat loss by conduction, Cres this is heat loss by respiration, R is the heat loss by the radiation which is very important because the majority of heat is transmitted through radiation, here if we see that heat Ck it is by conduction.

The rate of heat loss by conduction is influenced by the nature of the clothing. So here we can play with the clothing that is if we insulate the clothing by incorporating the extra air pockets, so we can enhance the conduction.

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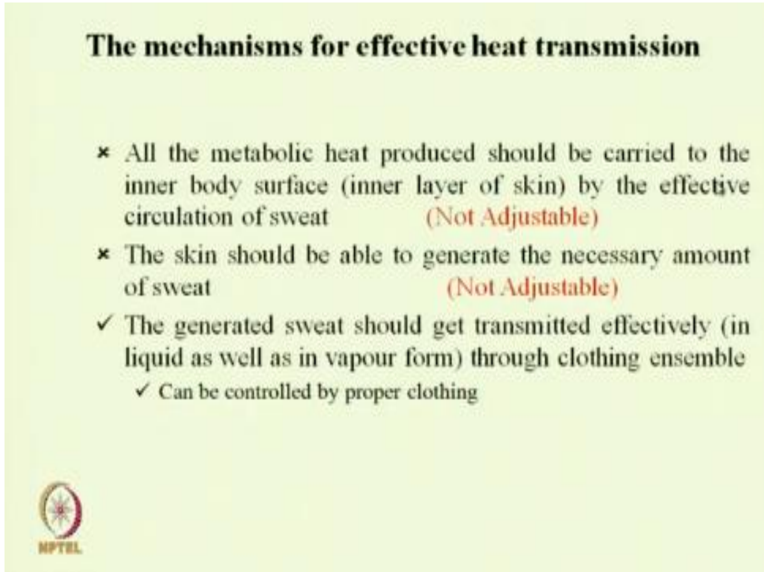

So all the metabolic heat produced should be carried away from the inner body to the skin. So which is not adjustable, we cannot adjust our body physiology, and this is done by proper circulation of sweat and also through enhanced blood circulation and the skin should be able to generate necessary amount of sweat. So this two it is not adjustable these are actually physiological performance but which we can do to manage this generated heat and sweat.

By proper designing the sportswear, by proper selection of material, proper selection of the design, proper selection of weave structure or knitted structure, we can and proper selection of fibre materials so yarn we can control this thermo physiological activities.

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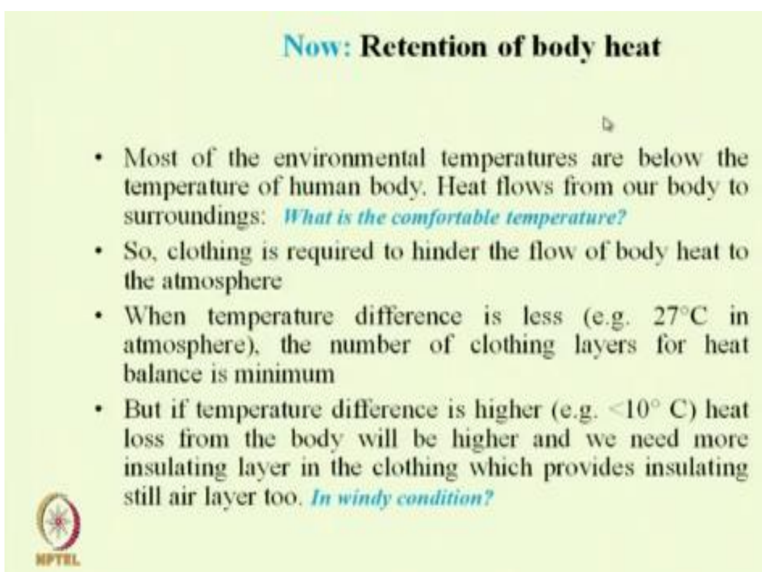

So sometime we require to retaining the body heat, this is mainly required for the lower activity clothing when we use this sportswear at cold environment. So low activity and cold environment means during low activity, we generate lower level of metabolic heat and that is why the level of heat transfer from our body to the environment is very high. So we have to retain the body heat by proper selection of clothing.

And this type of heat transmission from the, body from our body, it is enhanced during windy condition. That is convective heat transmission is very high in windy condition. So we must design our sportswear accordingly.

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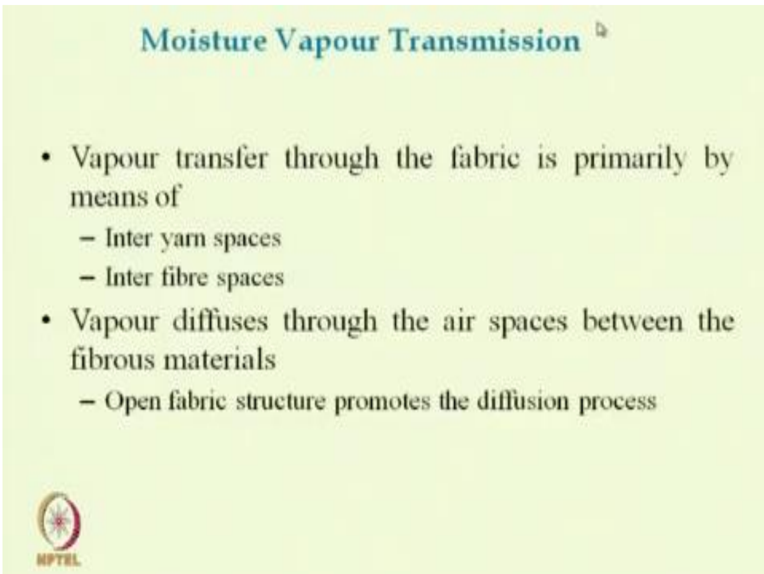

As far as vapour transmission is concerned; so moisture vapour transfer through the fabric is primarily by means of: inter yarn space and inter fibre space. So this space we have to manage accordingly depending on the requirement. So the vapour diffuses through the air space between the fibrous material, so the open structure enhances the diffusion process. So apart from diffusion, there are many other mechanisms of the moisture transmission those I will discuss.

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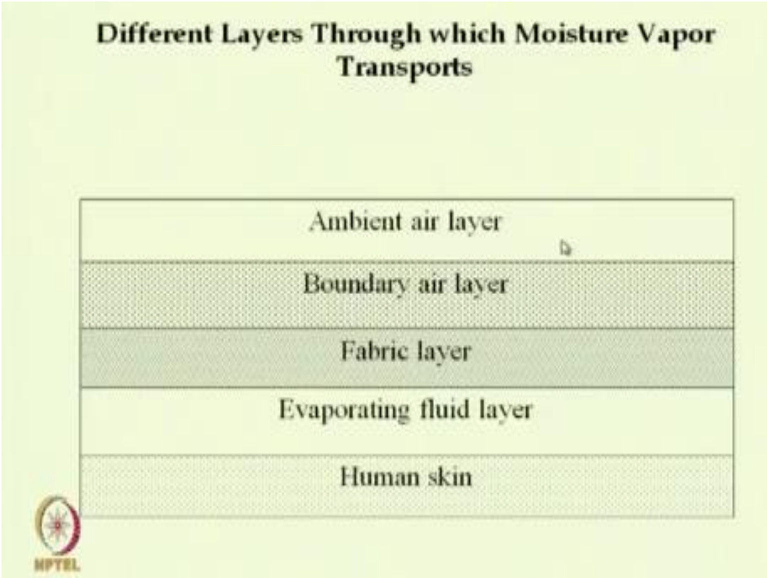

So there are different layers required for moisture vapour transmission that is human skin which generates the moisture vapour. So that is evaporating fluid layer, so moisture can transmit through the in the form of vapour directly from the skin or sometime when we sweat that fluid gets evaporating, this evaporating sweat fluid layer evaporating moisture should get transmitted through the fabric layer.

So there must be certain openings or air pockets should be there and then after that it forms boundary layer and then, ambient air layer. So this boundary layer formation is hardly there during the sports because in sports the player is normally in the moving condition he is always in dynamic condition. So that is why boundary layer formation is not there. This boundary layer, air layer formation is there only in the case where the person is stationary and there is no air movement.

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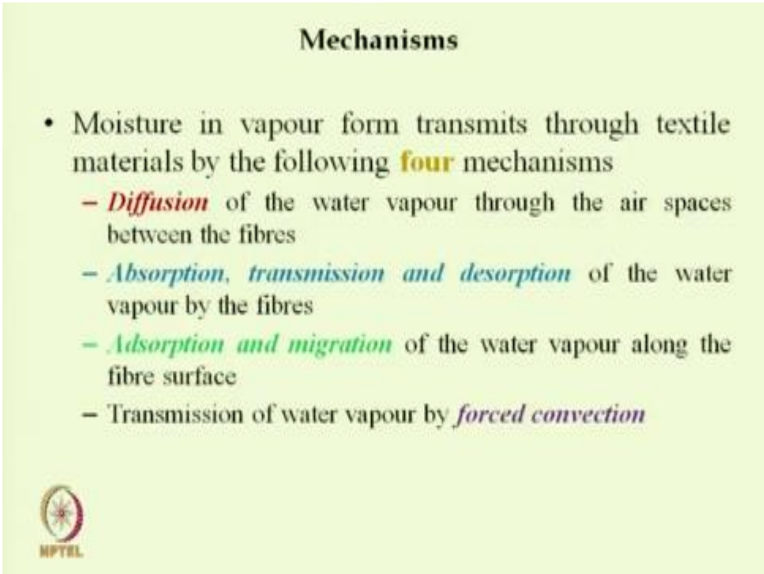

As I mentioned the moisture vapour transmission takes place mainly by four different mechanisms, it follows four different mechanisms, these are diffusion, next is absorption, transmission and desorption, third one is adsorption and migration and fourth one is forced convection. So diffusion means where the moisture vapour gets diffused through the fabric where the air space is there. So between the airspace between the fibres there are air spaces.

So through these air spaces the moisture vapour gets diffused then absorption, transmission and desorption the water vapour takes place through the fibre itself. So the fibres absorb the moisture that is hydrophilic fibres absorb moisture and transmit the moisture from one surface to other surface, the surface where the moisture vapour gradient or vapour pressure is high from that surface to the other surface it transmits.

Like when we are wearing cloth in dry air dry atmosphere, so inside the microclimate that is between our skin and the fabric, cloth. If the moisture the concentration is high, that is vapour pressure is high, higher than the atmosphere. So that will that moisture will get transmitted from our body to the atmosphere. On the other hand if the outside humidity is saturated atmosphere is saturated with the humidity.

So in that case this transmission due to diffusion or absorption transmission, desorption will not take place in that from the skin to the atmosphere. Next is that adsorption and migration. So this adsorption and migration takes place in the form of water vapour along the fibre surface. So fibre, they do not absorb but the moisture is adsorbed at the surface this phenomena takes place mainly for hydrophobic fibres.

And in case of windy conditions, so moisture vapour gets transmitted through the forced convection. So these are the four mechanisms depending on the atmospheric condition and the structure of sports textile, the moisture gets transmitted through these mechanisms, it may happen that all the mechanisms are also taking place together or some of these mechanisms are taking place together. So we must design clothing after understanding these mechanisms like:

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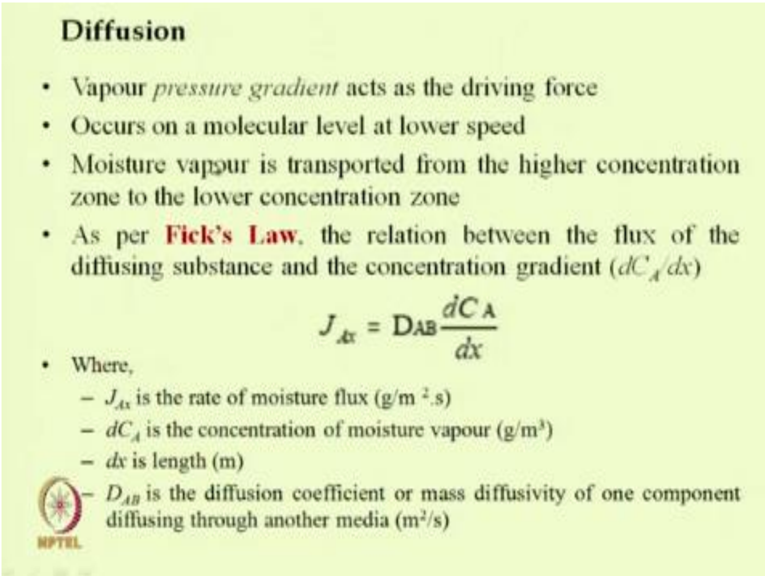

Diffusion its vapour pressure gradients that is the actual driving force and diffusion takes place by Fick's law and this diffusion it occurs on the on a molecular level at low speed. So always this diffusion takes place in lower speed if then any turbulence air turbulence is there then there will be forced convection and as I have mentioned moisture vapour is transported from higher concentration to a lower concentration zone.

And here this the concentration gradient dCA this is the driving force and dx is the length transmitted in this case the thickness of the material and DAB is the diffusion coefficient. So the Fickian diffusion means here the diffusion takes place through the air pockets.

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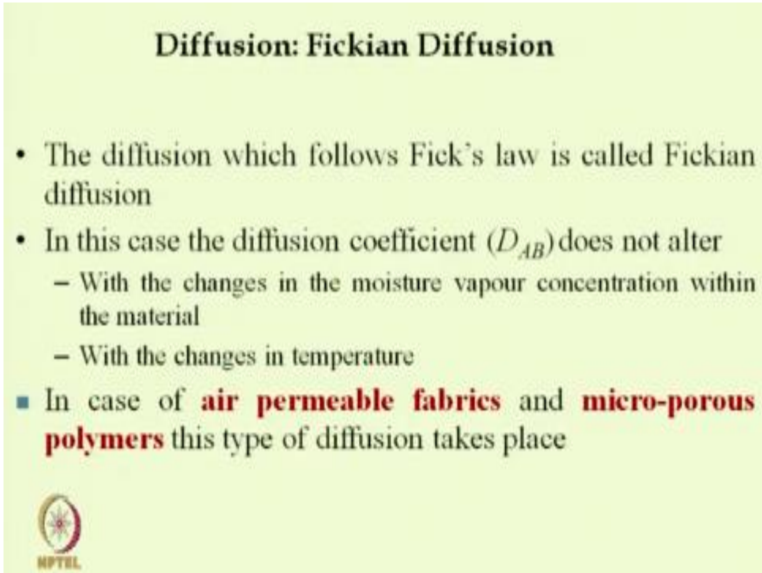

And this type of diffusion is called Fickian diffusion. So in this case the diffusion coefficient DAB does not alter with the change in moisture vapour concentration within the material with the change in the temperature. So diffusion coefficient is a constant parameter. So in case of air permeable fabric and micro porous polymer these types of diffusion take place. So if air permeability is there so that means the pocket air pockets are present.

So Fickian diffusion takes place through this where the polymer does not absorb the moisture only between the fibre there will be air pockets and micro pores and through this micro pores the water vapour gets transmitted.

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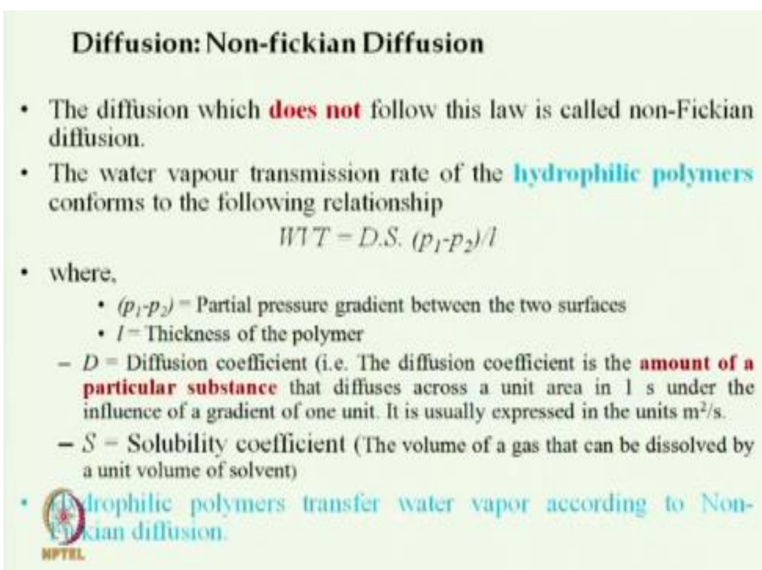

Another important diffusion phenomenon is the non-Fickian diffusion, where the diffusion does not actually follow the Fickian diffusion and mainly takes place in hydrophilic polymer like cotton where the material absorbs the moisture. So, water vapour transmission is equal to D that is diffusion coefficient, S is the solubility coefficient and p1-p2, there partial pressure gradient between two surfaces of the fabric and l is the thickness of the fabric.

Here we will see this is the solubility coefficient. In case of textile material it depends on the absorption capacity of the moisture vapour, so hydrophilic polymer transfers water vapour according to non-Fickian diffusion. Now, let us see let us draw.

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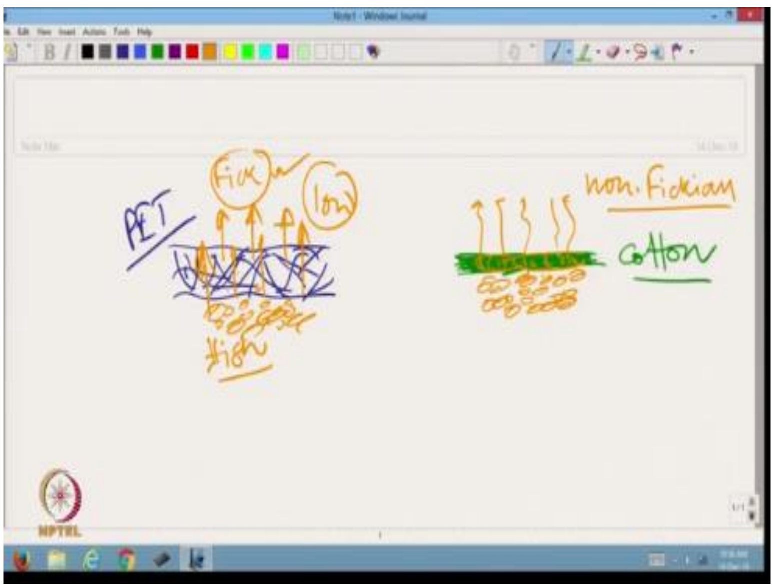

Suppose this is one cloth, this cloth is made of hydrophobic fibre, maybe say polyester and moisture vapour gets transmitted through the pores using the technique that is the diffusion mechanism. So here moisture vapour concentration is high, here it is low concentration. So this will get moisture vapour are getting transmitted through diffusion, which is Fickian diffusion. Here it follows the Fick's law.

But if we consider clothing, so it is a say cotton, hydrophilic material, cotton or any hydrophilic material. Suppose ideally we have produced a clothing with zero it is totally blocked, zero pores and in this case, what will happen? Moisture is there high concentration of moisture. What will happen? Due to the hydrophilicity of this material this moisture will get absorbed by the material itself by cotton here.

And through the material this moisture will get transmitted to other surface when moisture vapour pressure is low and finally it will get transmitted through this and diffusion is taking place through the material itself through the polymer not through the air pocket. So this diffusion is known as non-Fickian diffusion. So both are diffusions. But the Fickian diffusion is through the pores air pockets and non-Fickian diffusions are through the materials.

Now for as far as textile materials are concerned say sports textiles are concerned both the Fickian and non-Fickian diffusion takes place. So basically if we use a polymer like hydrophobic polymer in those polymers the Fickian diffusion mainly take place.

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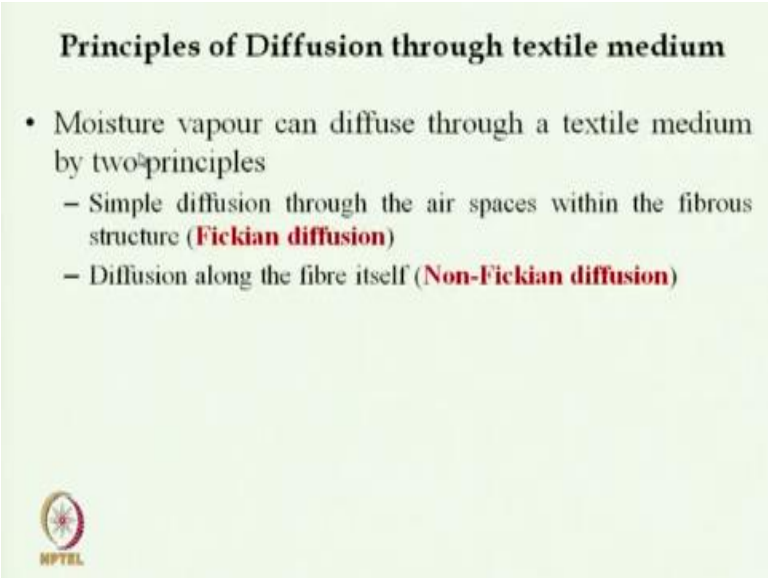

So if we see the principle of diffusion. So moisture vapour transmitted through Fickian diffusion and non-Fickian diffusion, so they are normally they take place together depending on the structure and Fickian diffusion is almost instantaneous because the diffusion through air is very fast. As compared to diffusion through a fibrous material.

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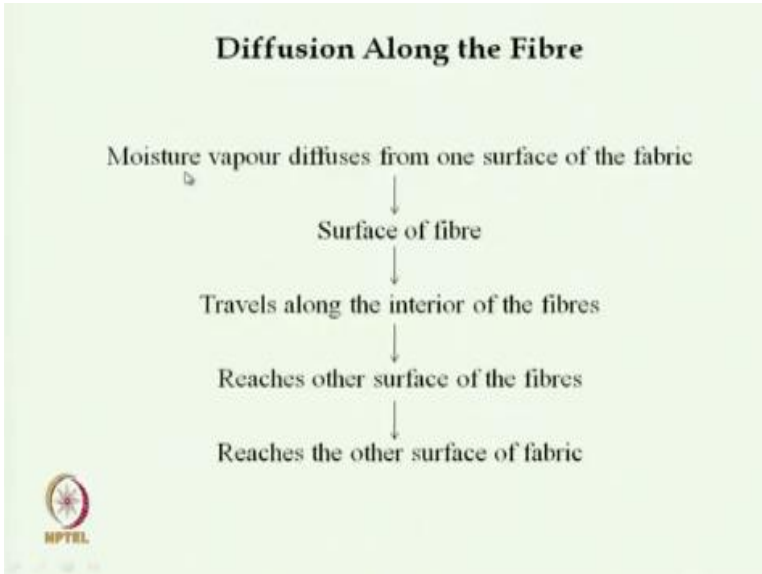

So the stages are the diffusion along the fibre it takes place, the moisture fibre, moisture vapour, diffuses from the skin to the first fabric surface then the surface of fibre and travels along the interior of the fibres. I am talking about here non-Fickian diffusion then reaches to the other surface of the fibre then gradually reaches to the other surface of fabric as I have shown already. So during the travel these are the stages it covers.

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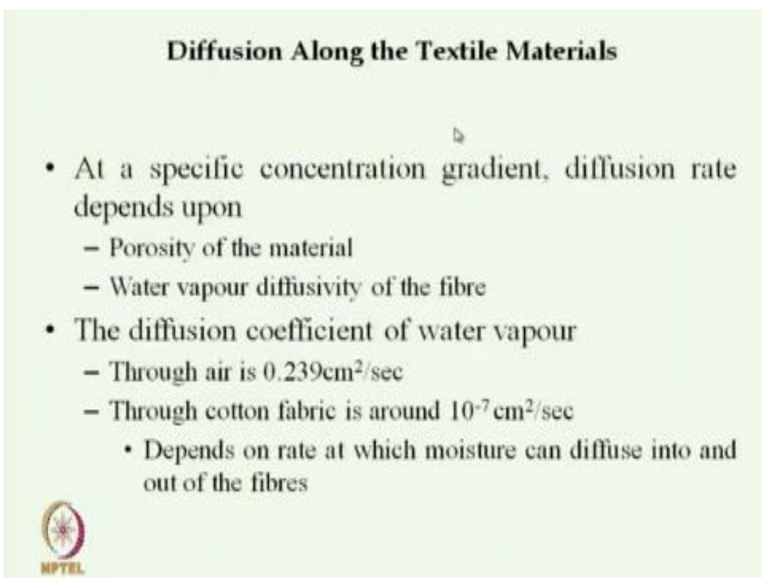

So diffusion as far as the non-Fickian diffusion and Fickian diffusion, the diffusion through the air it is the diffusion coefficient here it is 0.239 square centimeter per second, it is through air and if we see through cotton it is very very slow, it is of the order of 10 to the power -7 square centimeter per second this is very slow. So that is why for fast diffusion for faster release of moisture vapour we must create pores in the sports textile. Otherwise it will be very slow.

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So moisture vapour in case of hydrophilic fibre, it does not follow the Fickian law, only in case of very compact material otherwise both Fickian and non-Fickian diffusions are there.

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So that is why we have discussed that diffusion along the fibre materials takes place in two stages in first stage it is a Fickian diffusion through air gap and second stage much slower that is non-Fickian diffusion.

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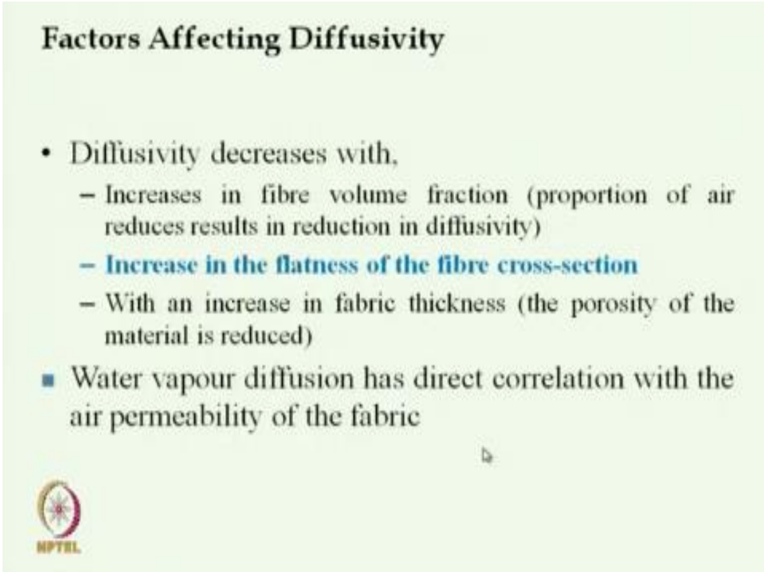

So the factors which affect the diffusivity it is these are the diffusivity decreases that is diffusion rate through the material it decreases with the increase in fibre volume fraction, now as I have already mentioned.

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Suppose this is one fibre one structure, this is one fabric, next one is much more compact and third one is very, very compact. Now, here it is 1, 2, and 3 as in this case the air pockets are there so majority of the diffusion will take place through the air pockets, which is very fast. Here the air pockets are reduced. So diffusion will take place majority of the diffusion will take place the through the material and as the air pockets are present little bit.

So this the diffusion will take place through the air pockets also but here in this case the material present is very high volume fraction has increased. So diffusion will majorly takes place through the material which is very slow, so diffusivity reduces with the increase in volume fraction of material. So, that is what it is stated here. Increase in flatness of fibre cross section reduces the diffusivity, because like air permeability the drag increases with the increase in specific surface area.

Similarly when moisture vapor gets transmitted through the textile material through the fibres structure depending on the specific surface area provided the drag will increase. So, more surface specific surface area more will be the drag with an increase in fibre fabric thickness. So higher fabric thickness means it will slow down the diffusivity because that will ultimately affect the path. So, thicker fabric will increase the path of movement of the moisture vapour.

So that will reduce the diffusivity. So water vapour deposition has direct correlation with the air permeability, the factors which affect the air permeability those factors will also affect the moisture vapour transmission. So, another factor which affects the diffusion coefficient.

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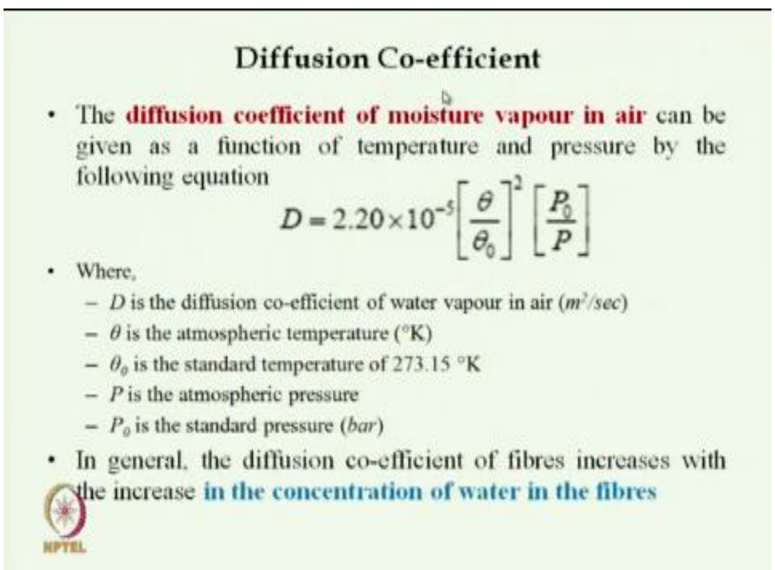

So these are the factor two factors are there one is the vapour pressure, another is the temperature. So in general; the diffusion coefficient of fibre increases with the increase in the temperature, so temperature and pressure. So with the increase in that is the vapor pressure the diffusion coefficient decreases. So at higher temperature the rate of diffusion will be high and when the moisture vapour pressure is high in the atmosphere then rate of diffusion will be reduced.

At the same time the diffusion coefficient also affected by the concentration of moisture within the fibre structure, so if the concentration of the moisture are within the fibre structure increases, it will increase the diffusion coefficient. Next phenomena is that.

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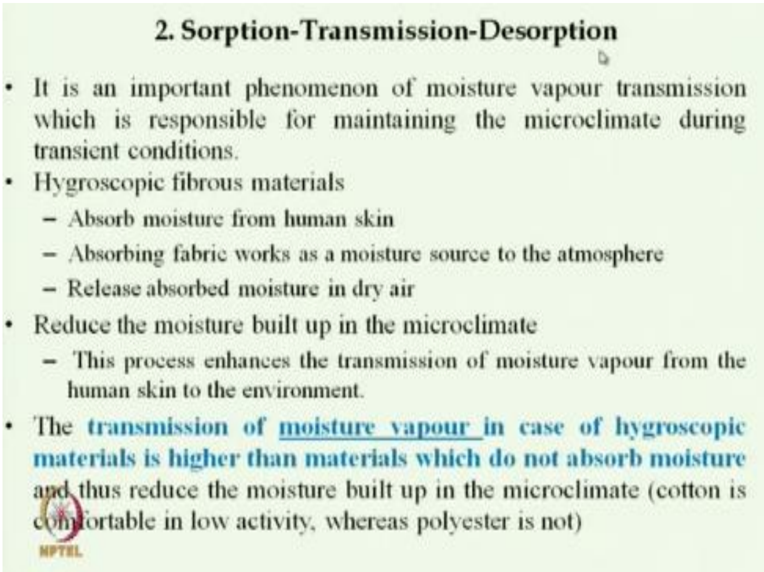

Sorption-transmission and desorption that is basically almost similar to non-Fickian diffusion here it is not actually diffusion but phenomena is similar, in non-Fickian diffusion, the moisture vapor transmitted through the structure through the fibre structure using the diffusion principle, but in this principle sorption, transmission and desorption, here diffusion does not take place but moisture vapour gets transmitted along the fibre that within the fibres through the fibres structure.

So hygroscopic fibrous material absorb moisture from the human skin, absorbing fabric works as moisture source to the atmosphere and release absorbed moisture in the dry air that is the principal. Now let us see, let us try to understand the difference between the non-Fickian diffusion and sorption-transmission and desorption.

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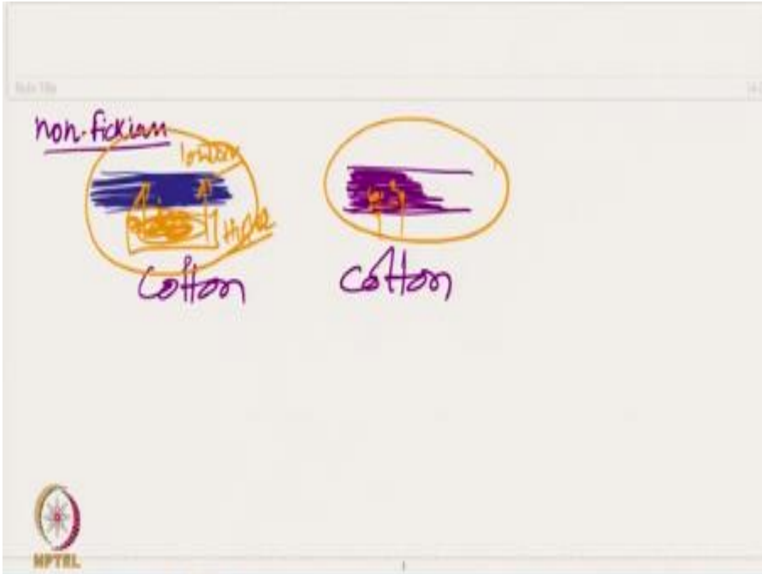

In non-Fickian diffusion, let us consider here. As we have discussed the material compact, there is no air gap, two materials: same material for example cotton, so assuming there is no pores. Now this is non-Fickian diffusion non-Fickian diffusion the moisture vapour here is getting it is not absorbed through the vapor pressure here higher concentration, moisture vapour it gets diffused through the fibre structure, but here it absorbs fibre absorbs moisture inside.

And through the fibre may be in length wise maybe in width wise they get transmitted which means here for non-Fickian diffusion, we need proper vapor pressure gradient that means it will get transmitted from higher vapour pressure to lower vapour pressure. This is higher vapour pressure to lower vapor pressure, it will get transmitted but here we do not a driving force is not the vapor pressure.

Here driving force is the absorption it will absorb and get transmitted to gradually it will get transmitted to other surface. So in this way, it will reduce the moisture built up in the microclimate. The transmission of moisture vapour in case of hygroscopic material is higher than the materials which do not absorb moisture. So hydrophobic fibres they do not follow this type of mechanism.

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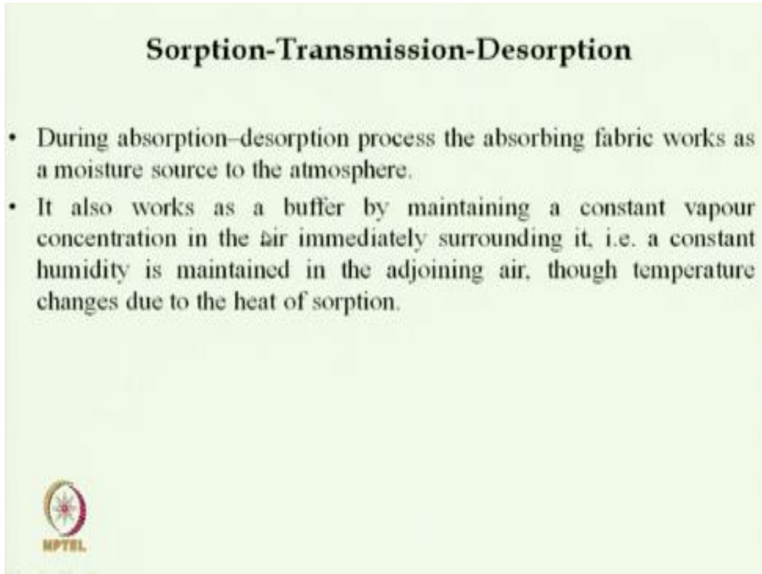

So during absorption- desorption process the absorbing fabric works as the moisture source to the atmosphere. So there is no vapour pressure gradient required, only by absorption and then this absorbing material will release the moisture gradually to the atmosphere. So we will continue with this mechanisms in the next class, till then thank you.