Technical Textiles
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Lecture No- 26
Sports Textiles (contd…)

Hello everyone, we will continue with the sports textiles. So what we were discussing in last class, different innovative sports textile products. Now we will start with;

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Compression athletic wear or in short CAW, the compression athletic wear like tights, elastic are used among power based sports where we need high-energy, heavy power for better fit enhancing performance and recovery in the muscle fatigue. So in power sports we need free movement of our body and this type of athletic wear should be able to enhance our performance and most importantly the recovery from muscle fatigue, it should enhance, so that muscle fatigue ness is not there.

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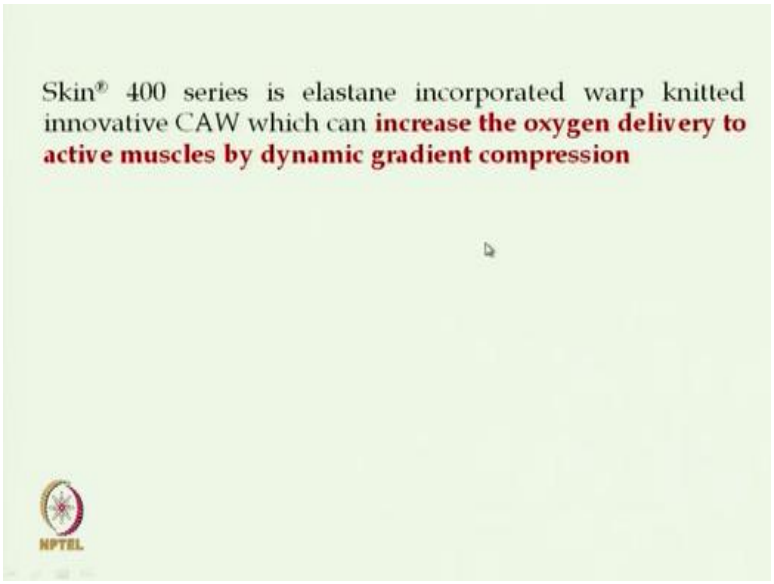

The skin 400, it is such a product which is elastane incorporated warp knitted product and here the increase in oxygen delivery to the active muscles are there by dynamic gradient compression. So due to dynamic gradient compression the active oxygen delivery is there at different muscles, the muscles which are active so there will be higher oxygen delivery.

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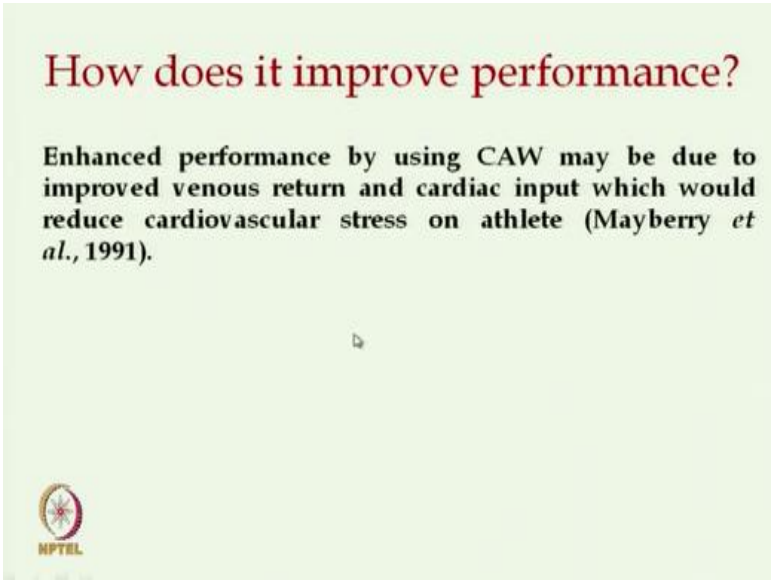

So as reported that, enhanced performance by using compression athletic wear may be due to improved venous return and cardiac input which would reduce cardiovascular stress on athletes. So this was reported in 1991. Now we will discuss another area of specialty sportswear which is swimwear.

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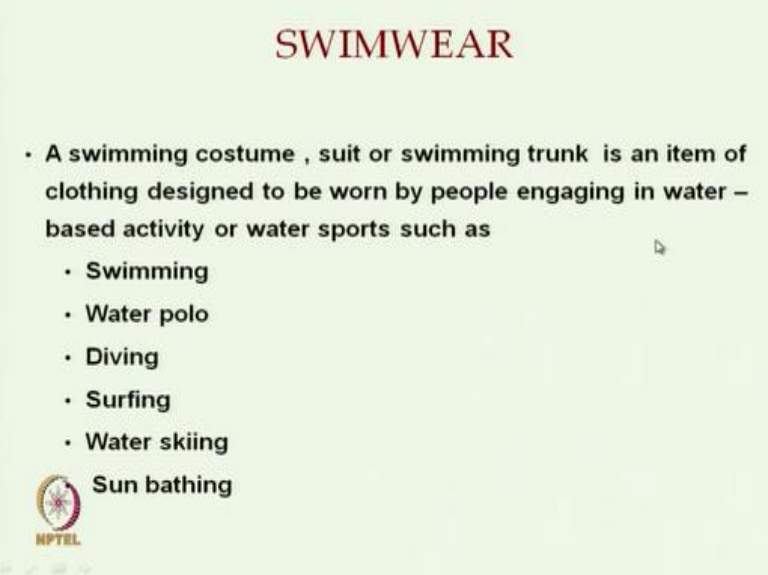

A swimming costume is an item of clothing designed to be worn by people engaging in any sorts of water sports, water-based activities, we can use this swimwear. These water sports are; swimming, water polo, diving, surfing, and water skiing or sunbathing.

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There in swimming wear, psycho-physiological comfort that is both psychological comfort and physiological comforts are required like fit, it should fit well with the swimmer, it should not be loose it should fit with the body. Design is also important, colour is important, coverage of the body depending on the requirement or maybe gender, thermal properties are important and performance factors.

The swimmer should get assistance from swimwear for better performance, so there are developments, I will just discuss where proper designing or proper selection of fiber proper designing of the fabric structure enhances the performance of swimmers.

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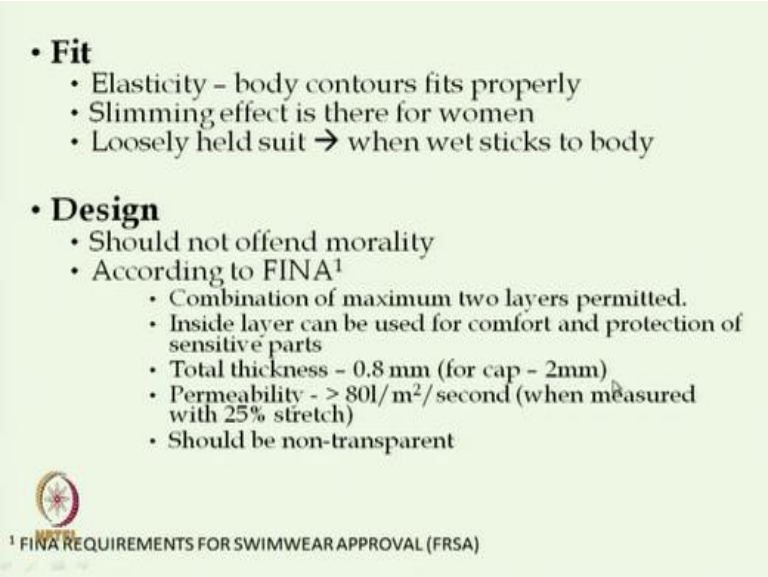

As far as, fit is concerned the elasticity of the fabric is very important, it should fit well with the body contour, it should not be loose or tight, so properly it should follow the body contour and it gives slimming effect of the swimmer particularly women, loose held fit swimming when it wets it will stick to the body. So a loosely held suit is not that important required for swimming design, as far as design is concerned it should not offend morality.

So designing should be such according to the international standard FINA, which actually gives or which directs different guidelines for swimwear, combination of maximum two layers are permitted for designing swimwear. We must take this into account, inside layer can be used for comfort and protection of sensitive parts, the total thickness is proposed 0.8 millimetre, and total permeability should be more than 80 liter per square meter per second, when stretch is 25%.

So this should be the permeability should not be less than this and the cloth should not be transparent, these are the guidelines of swimwear.

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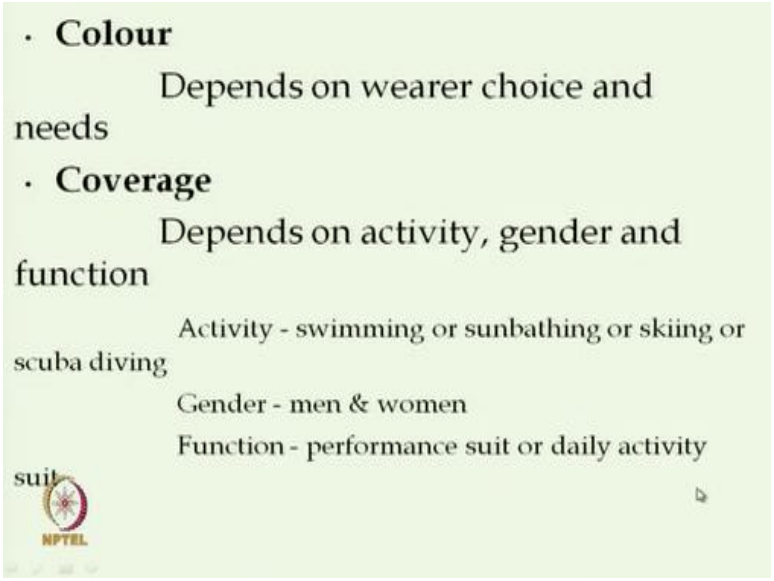

The colour it depends on the wearer, the coverage depends on the activity, gender and function, so activity as per as swimming or sunbathing or skiing or scuba diving depending on the activity, the coverage of the swimmer is that, they change as per as gender, men or women there are standard coverage specified and for function that performance suit or daily activity suit, so we have to change the coverage.

Whether we are using for performance purpose or daily activity depending on this we can change the coverage.

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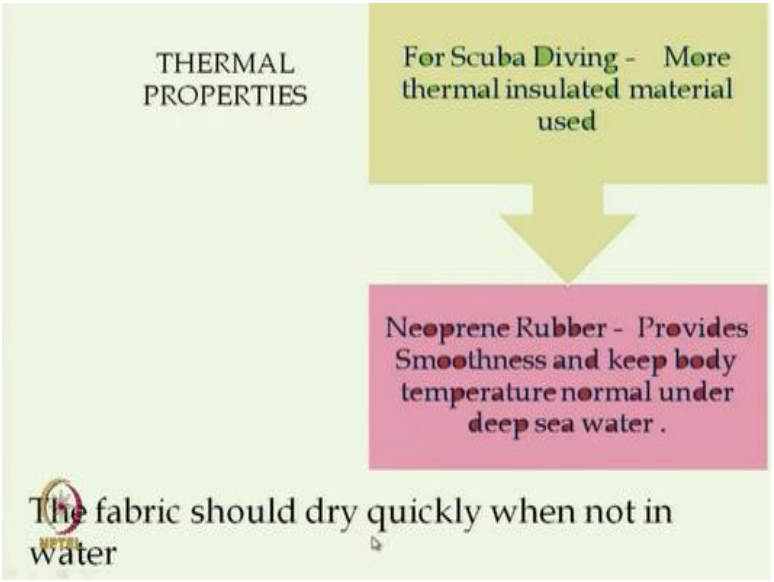

As far as thermal properties are concerned for scuba diving more thermal insulated materials are required, neoprene rubber coated clothings are used which provides smoothness and keep body temperature normal under deep sea water. So proper thermal properties are important and the fabric should dry quickly because they have to be used repeatedly.

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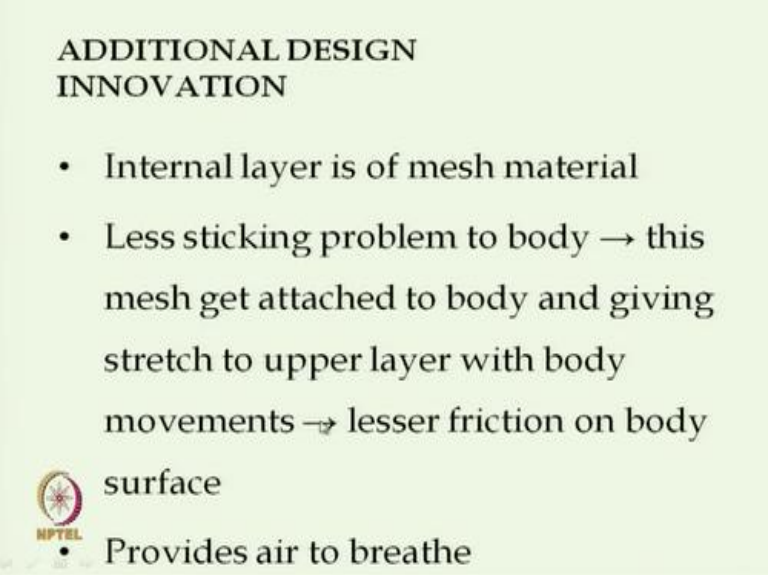

So additional design innovations are, the inner layer is of mesh material, so the basic requirement of swimwear is that it should not stick or cling with our body. So if we use mesh material, less sticking problems will be there. This mesh gets attached to the body and gives stretch to the upper layer with body movement, so less friction on the body surface, so this mesh will stick to the body, they will not move against the skin.

So rubbing action will not be there but at the same time the upper layer will get stretched and which will change with our body contour movement contour change during the movement and this will provide air breathability.

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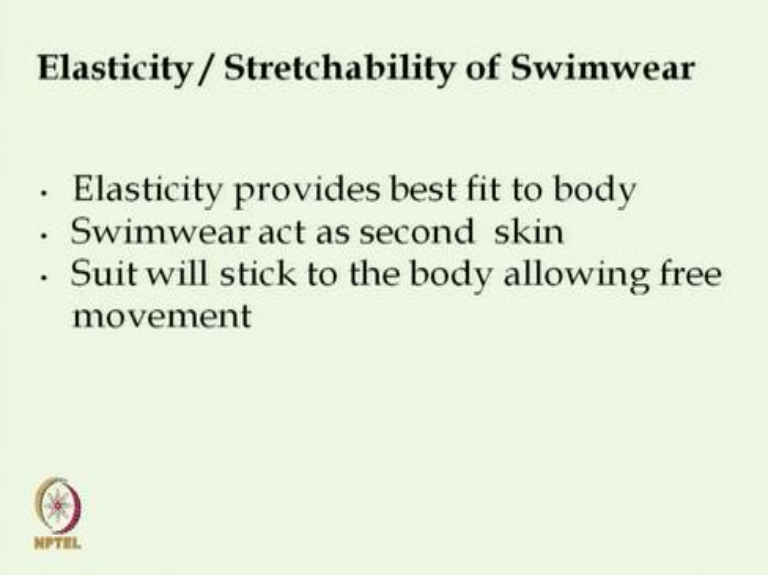

Elasticity and stretchability of swimwear is extremely important because it provides best fit to the body, here swimmer acts as a second skin, so our free body movements should be there during the swimming and this swimwear should stick to the body it should not move against the body like other clothing material, also the swimwear should be designed to reduce the drag.

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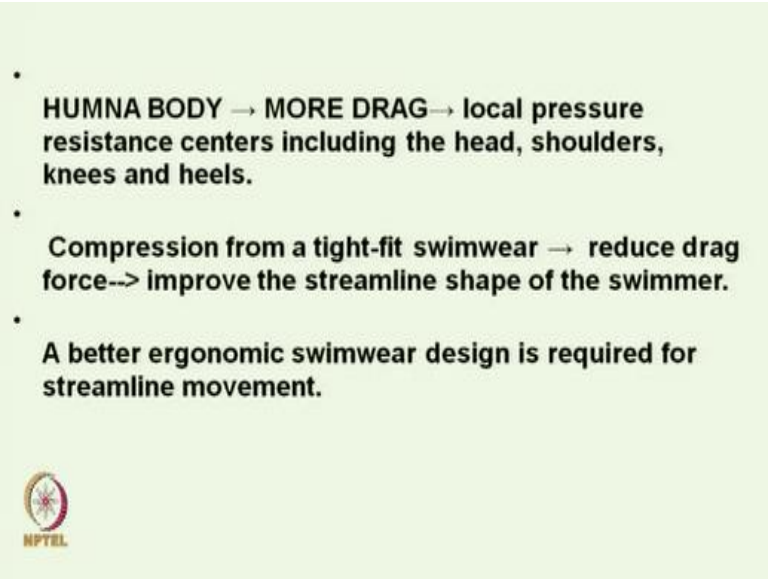

So the human body more drag local pressure resistance centers including the head, shoulders, knees and heels. In these areas including other areas also, the higher drags are there so compression from the tight fit swimwear, as the swimwear applies excess pressure and compresses the body it reduces the drag force and it improves the streamline shape of the swimmer.

So the tight fit swimwear due to its compression, so drag force during the swimming operation reduces and a better ergonomics swimwear design is required for streamline movement, so that one can design the swimmer for better streamline movement.

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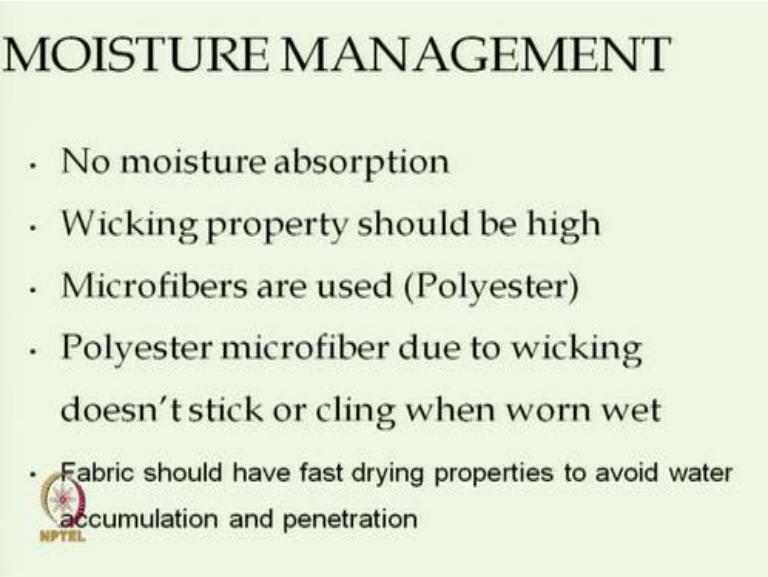

As far as moisture management characteristics of swimwear is concerned, it should not absorb moisture otherwise it will have extra drag force, wicking properties should be high whatever water is there it should get wicked out, microfibers are used; polyester microfibers, these are used due to higher wicking and they do not stick or cling when it is worn in wet condition. So swimwear is normally in wet condition, so this should not cling to our body and this fabric should be fast trying to avoid the water accumulation and penetration, this would dry fast.

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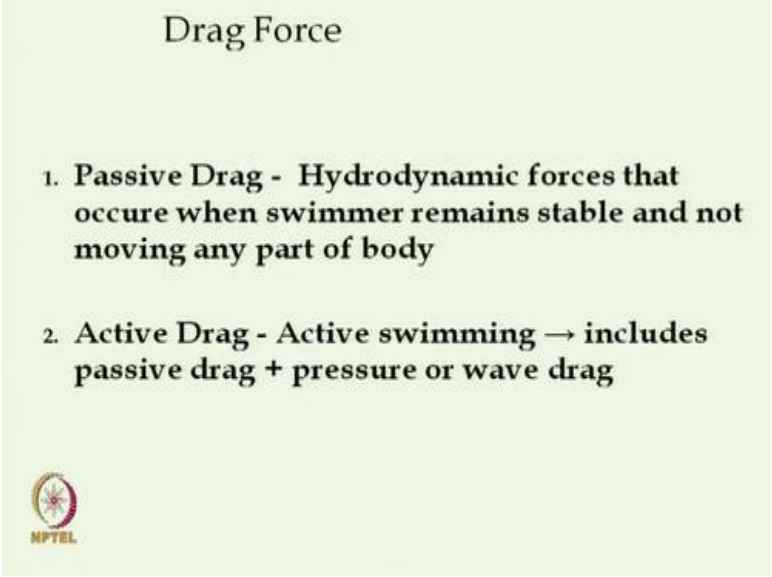

Drag force is concerned, there are two types of drag force one is called passive drag force, when a swimmer is stationary, that he is not moving due to the hydrodynamic force that occurred when the swimmer remains stable and not moving any part of the body. So in case of hydrodynamic force, this is called passive drag and active drag is when the swimmer is actually moving. So active swimming, this includes passive drag and pressure or wave drag so there are two drags, the pressure and wave drags are due to the movement of the swimmer.

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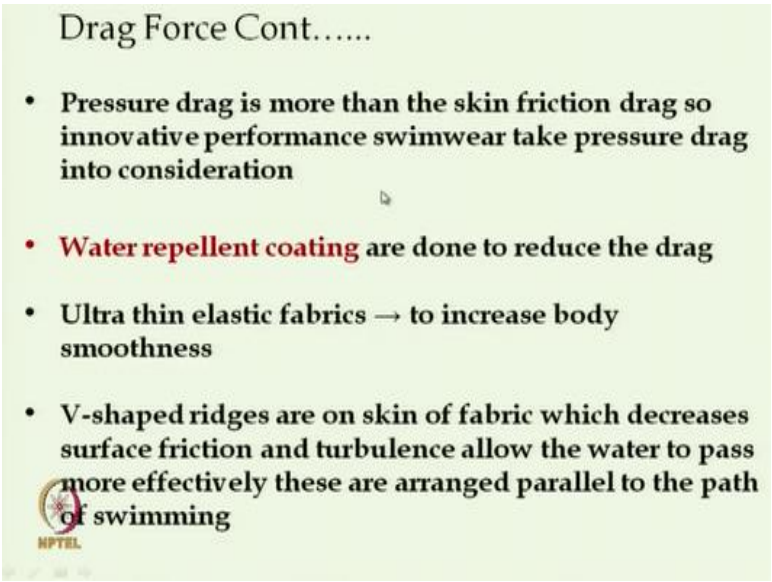

The pressure drag is more than the skin friction drag so innovative performance swimmers takes pressure drag into consideration. For designing the innovative swimwear this pressure drag one has to take into consideration, first thing is that it should not be absorbent so water repellent

coating is required to reduce the drag, ultra thin elastic fabric to increase the body smoothness and also there are swimwear with v-shaped ridges are there on the skin of the fabric outer surface which decrease the surface friction and turbulence. So during the movement its surface friction reduces, so the drag force reduces.

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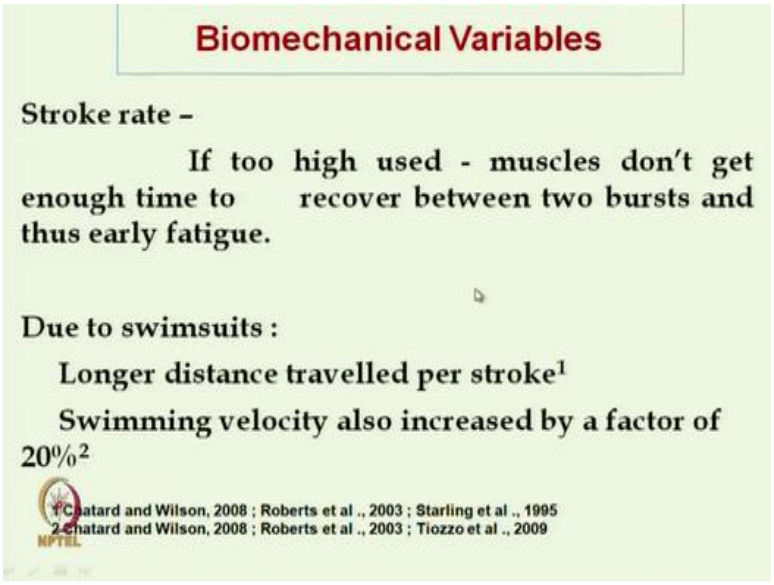

Biomechanical variables are also there, these are one of them is stroke rate; if too high stroke rates are used, in that case if the swimmer is trying to use very high rate of stroke, the problem would be that muscle does not get enough time to recover between two bursts and thus early fatigue will be there. So muscle should come back immediately to enhance the time for fatigue. This is done by the proper designing of the swimmer.

And proper elastic material is used due to swimsuit longer distance travel to per stroke, swimming velocity also increases by a factor of 20%. So, longer distance per stroke is important to reduce the stroke rate, now coming to the fabric materials for swimwear.

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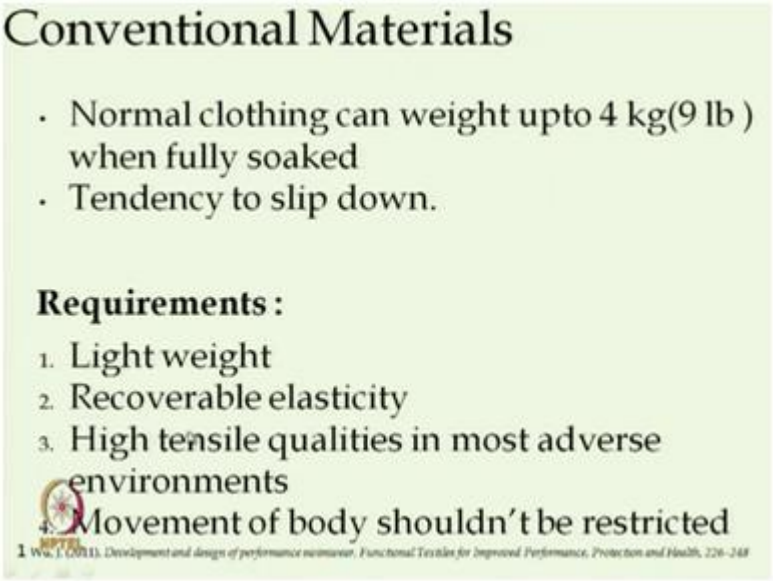

The conventional clothing can weigh up to 4 kg when it is fully soaked and their tendency is to slip down, so lower friction between the skin and fabric will enhance the slipping tendency and they absorb liquid. So the basic requirement of the materials used for swimwear is that it should be lightweight, it should be recoverable; the elastic recovery should be high, high tensile qualities in most adverse environments and the movement of the body should not get restricted, so there should be elasticity.

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The materials used in swimwear are typically polyester and nylon, so polyester due to their various characteristics strong resilient fibers, soft and comfortable in fit which is required for

swimmer, durable, abrasion resistant, quick drying, chlorine resistant, UV protection, so these are the characteristics of polyester. As per nylon is concerned, their main characteristics are abrasion resistant.

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SOME EXAMPLES

S.NO.	BRAND	COMPOSITION
1	Speedo LZR	70% Nylon (Polyamide) &30% Elastane (Lycra)
2	Speedo FSII	81% Nylon (Polyamide) &19% Elastane (Lycra)
3	Diana submarine	66% Nylon (Polyamide) & 34% Elastane (Lycra)
4	Spalding full length	82% Nylon (Polyamide) & 18% Elastane (Lycra)
5	TYR Sayonara	55.5% PU-Chloroprene, 40.5% Nylon (Polyamide)

Some commercially available brands are, where we can see that nylons are generally used along with the elastane, so polyamide and elastane and their blends are used typically around 70 to 80% nylons are used and 20 to 30 % elastane are used for this type of swimwear brands. Another type of swimwear which is used with a polyurethane coating, so polyurethane chloroprene coating which is 50% and 55% and around 40 % nylons are used, so it is polyurethane coated which is used for some speciality sports textile.

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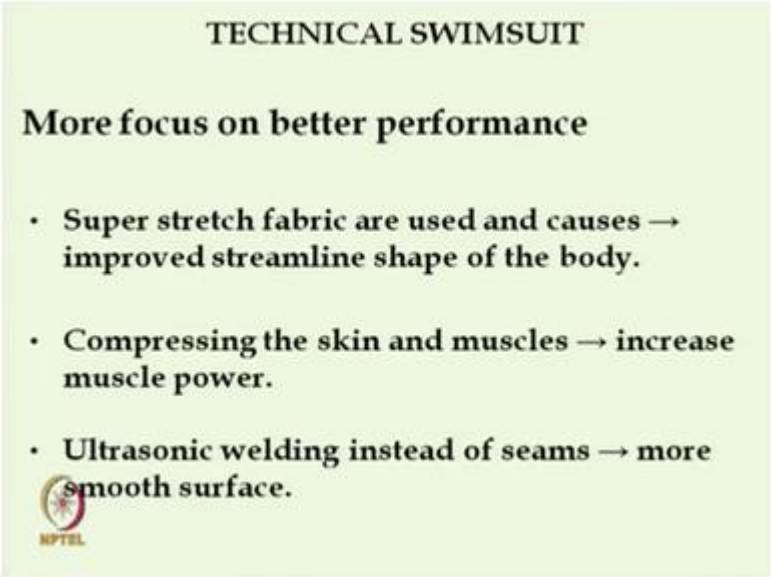

So, technical swimsuits and their main focus in better performance. Super stretch fabrics are used which improves the streamline shape of the body to reduce the drag, compressing the skin and muscle increases the muscle power, so the swimwear should be able to compress the skin, another important feature of the technical swimsuit is that ultrasonic welding instead of seaming. So here to have lower surface drag, so more smoothness.

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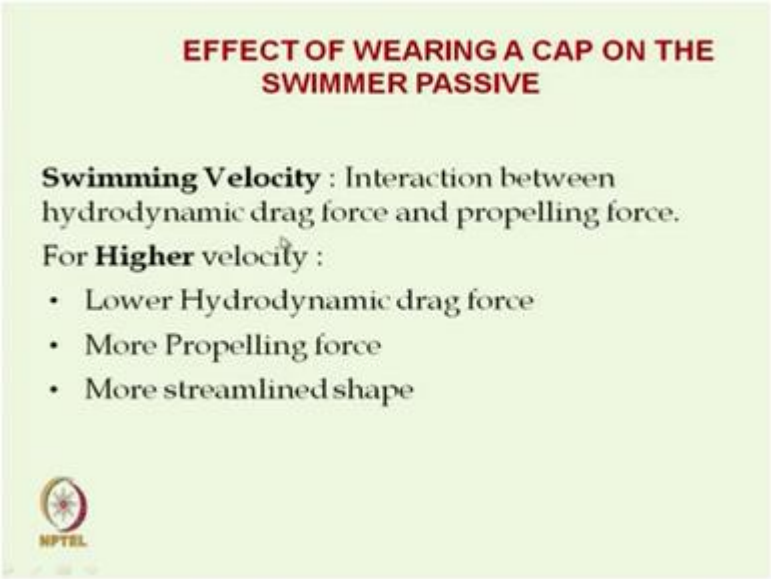

Instead of stitching, the ultrasonic welding is used. Swimming cap is also important, the effect on swimming velocity interaction between hydrodynamic drag force and propelling force, for higher velocity; lower hydrodynamic drag forces are there when we use swimming cap, more propelling

force, more streamlined shape. So the swimmer is along with the swimming cap will enhance the performance.

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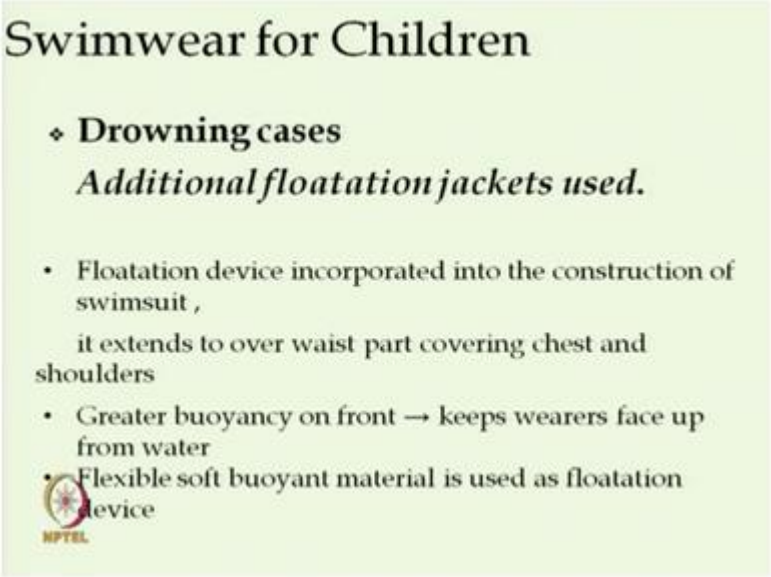

For children's swimwear there are some specific requirements, to reduce the drowning case, additional floating jackets are used, so this floatation device enhances the floating characteristics and this greater buoyancy on front keeps the wearer face up from water.

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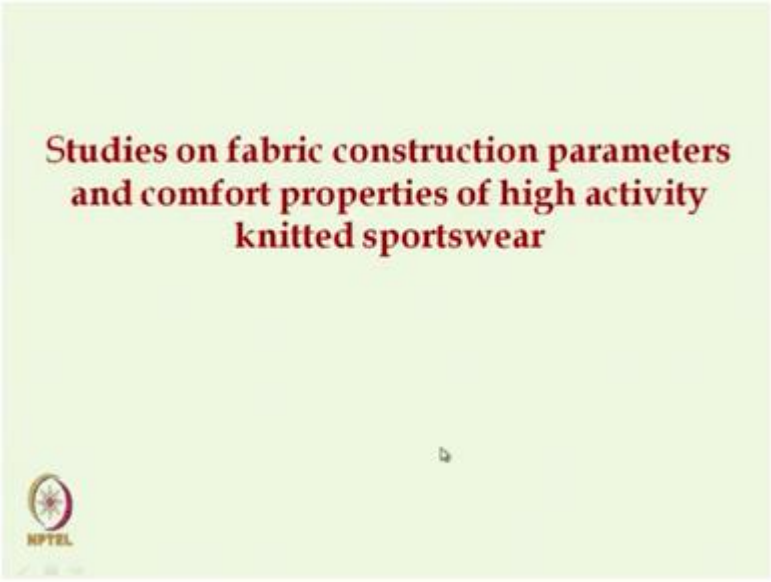

Now we have discussed these commercially available products, in the next section we will discuss the effect of different construction parameters on the comfort characteristics of

swimwear. So here we will use the only knitted swimmer because knitted swimmers are mainly used due to their stretchability characteristics, the fabrics used are here. These are basically not only for swimming, for any high active sportswear.

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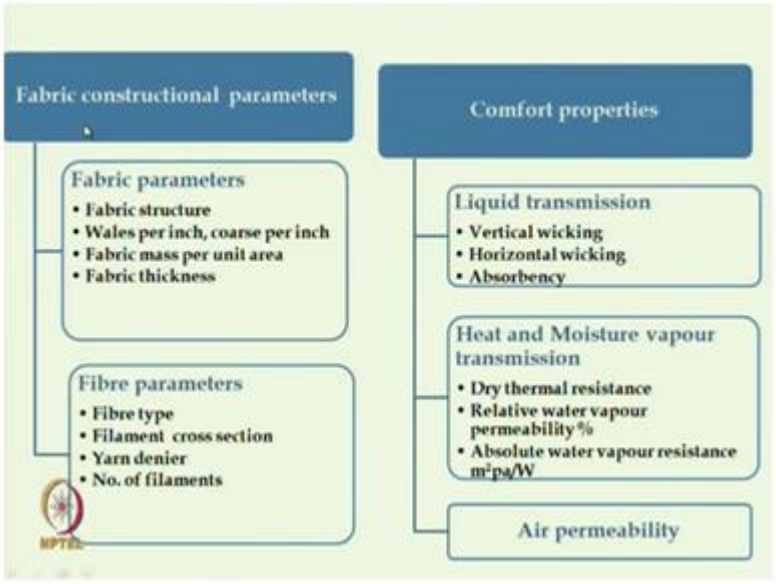

In the fabric constructional parameter, the fabric structure was changed fiber characteristics, what we have used is fiber diameters, the different fiber diameters were used filament cross sections were changed in high active sportswear only the filaments are used because of the high rate of sweat generation we require wicking. So for a higher wicking rate we need filaments not the staple yarns. The comfort properties were measured that is liquid transmission, heat and moisture transmission, so different transmission characteristics are measured.

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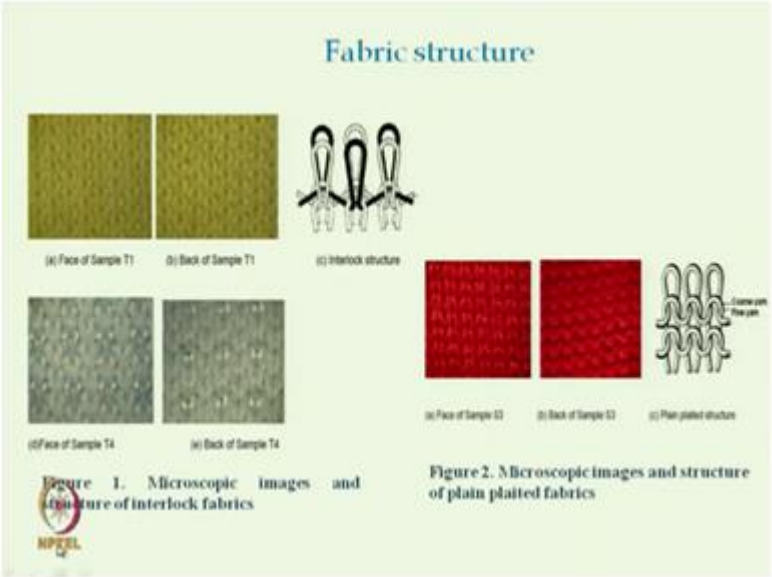

Figure 1. Microscopic images and structure of interlock fabrics

Figure 2. Microscopic images and structure of plain plaited fabrics

There are different types of fabric structures there, interlocked structure, plated structure.

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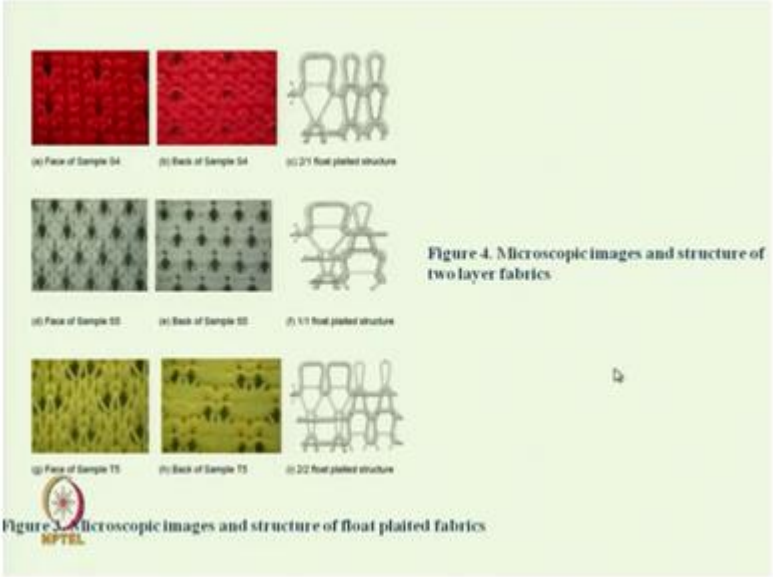

Figure 4. Microscopic images and structure of two layer fabrics

Figure 3. Microscopic images and structure of float plaited fabrics

Float plated structure and double layer fabric structure, these are the different structures which are used for active sportswear.

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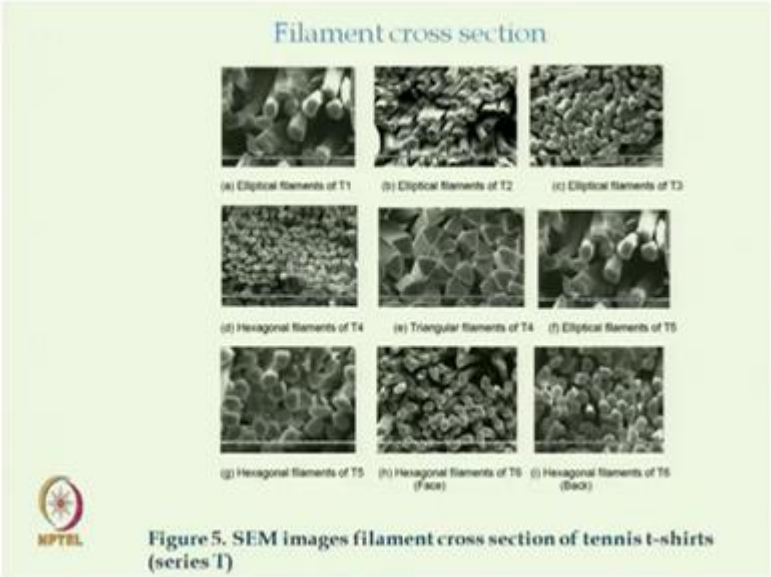

Figure 5. SEM images filament cross section of tennis t-shirts (series T)

And these are the different filament cross sections, in the study we have taken two series of standard sportswear, series T is used for high active tennis sportswear of international brand, large number of sportswear were taken and what has been observed in all the sportswear for tennis and soccer so tennis series T, soccer series S, what we have observed the almost all the sports where the filaments are used and the filament cross-sections are not circular there are deviation from circularity to enhance the shape factor for enhancing the wicking characteristics.

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Figure6. SEM images filament cross section of Soccer t-shirts (Series S)

This is for soccer what we have observed again in case of the filaments used in soccer, also there are different shapes deviating from circularity.

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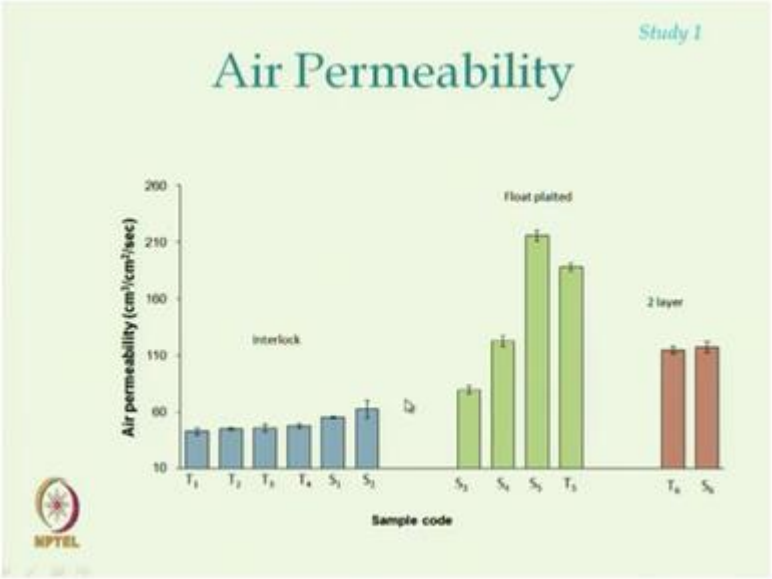

When we come to what we have observed the different types of structures are used both for tennis sportswear and for soccer and in interlock what has been observed is the air permeability is least and where float plated structure, air permeability is higher followed by the two layer structure, so where we need higher air permeability we must use the float plated structure.

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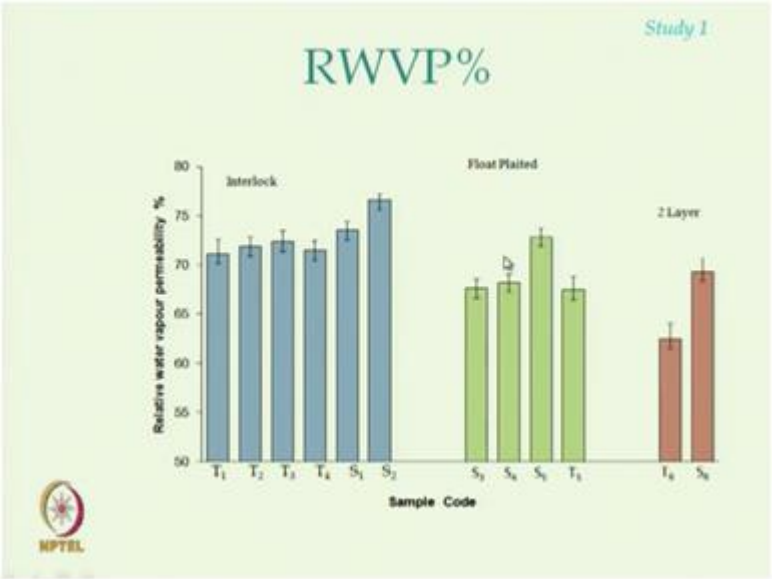

Now coming to the relative water vapour permeability, the interlock structure is giving highest relative water vapour permeability here and this is basically due to the fact that although there

are lower pores but number of pores were very high here which enhance the diffusion of moisture vapour.

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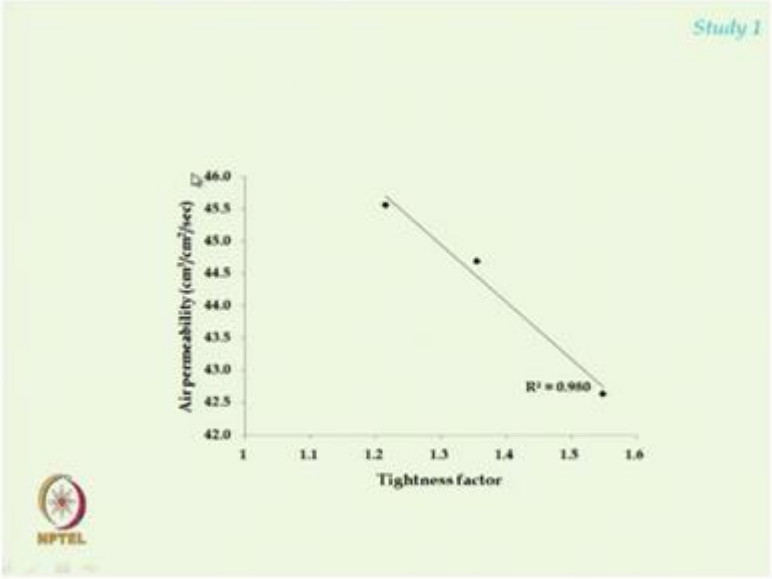

With the increase in shape factor what has been observed the reduction in the air permeability that we have already observed earlier also, this is mainly due to higher specific surface area which provides extra drag.

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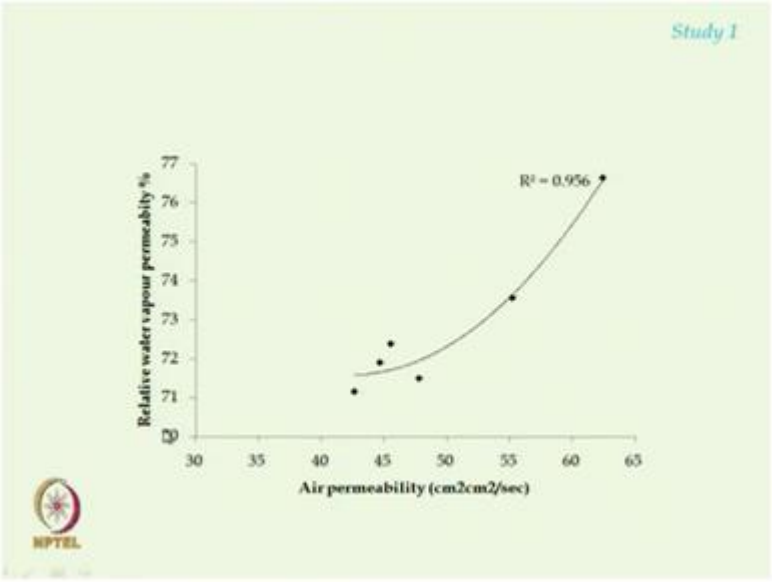

Air permeability and relative permeability if we take the large number of fabrics together, they are following almost similar trend except for few structure like interlocked structure where air

permeability was found lowest but moisture vapor permeability was very high, otherwise the air permeability follows the relative moisture vapor permeability trend.

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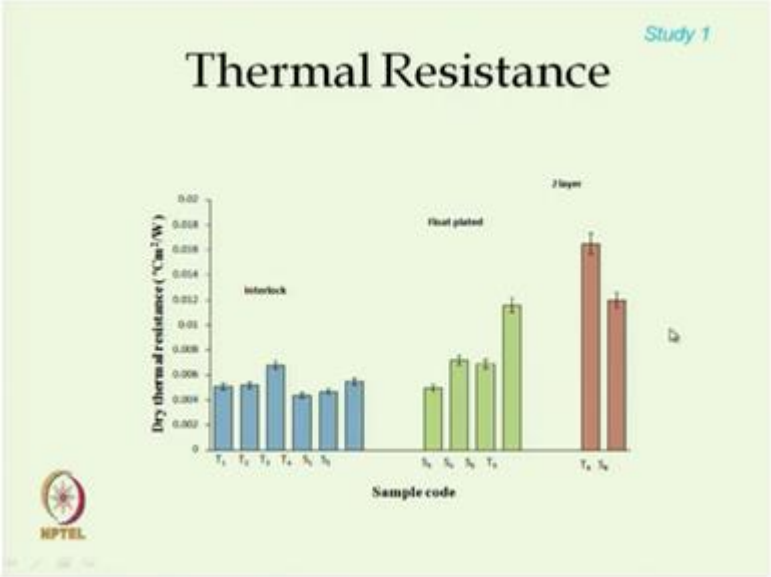

As per as thermal resistance is concerned we can see here interlocked structure gives lowest thermal resistance, where two layer structure gives maximum thermal resistance, this low thermal resistance is due to the compact structure where the amount of air pockets are less although the number of air pockets were high but the size of air pockets were less, that is why the thermal resistance is low. Here between the two layers the air entrapment was there, that is why it was giving higher thermal resistance.

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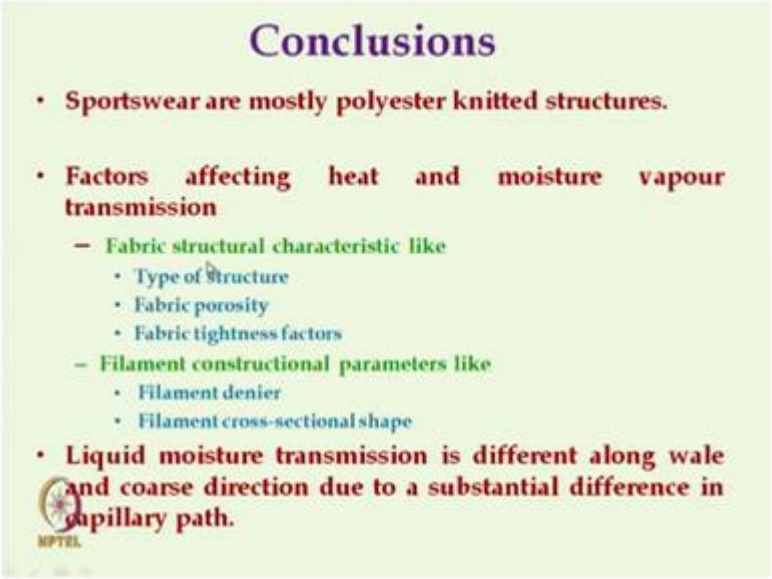

Now what is the findings in this study, what we have observed the sportswear's are mostly polyester knitted structure made of filaments, the knitted structure is basically due to the stretchability requirement and polyester is hydrophobic, so it does not absorb moisture but it wicks quickly. The factors affecting heat and moisture vapor transmissions are the fabric structure, the fabric porosity, type of structure, we have observed, fabric tightness.

Because interlocked structure is tighter in nature that is why the thermal transmission is better. Filament cross-sectional shape and also filament diameter.

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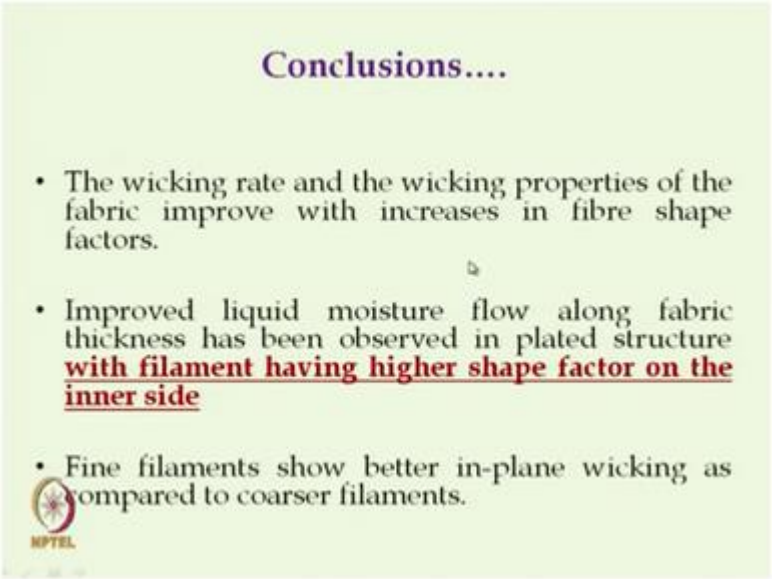

It has also been observed that the wicking rate and wicking properties of the fabric improve with the increase in fiber shape factor as I have already mentioned.

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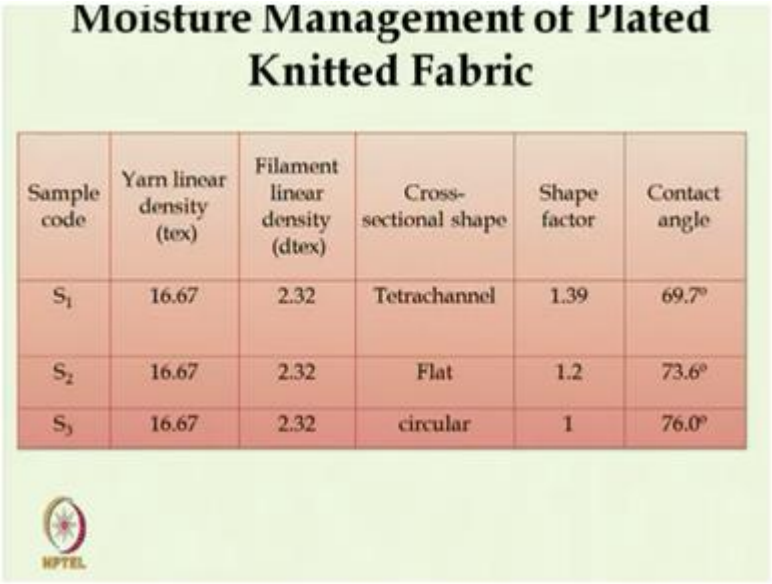

Another study what has been carried out where we have developed plated knitted structure using two different types of filaments of different cross sections. Here three different cross sections were taken circular, flat and tetra channel with different shape factors 1, 1.2, 1.39 and contact angle reduced with the increase in shape factor from 76 to 69.7 and filament denier was kept constant.

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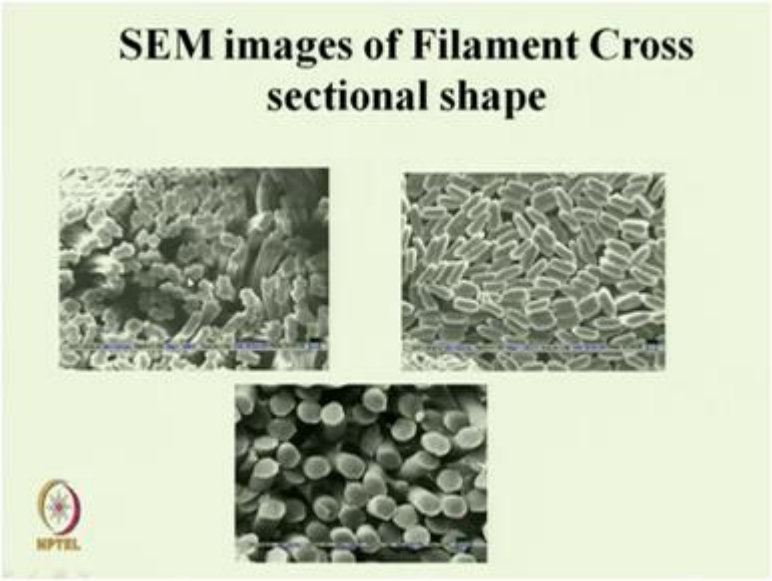

These are the three different filaments flat, circular and tetra channels.

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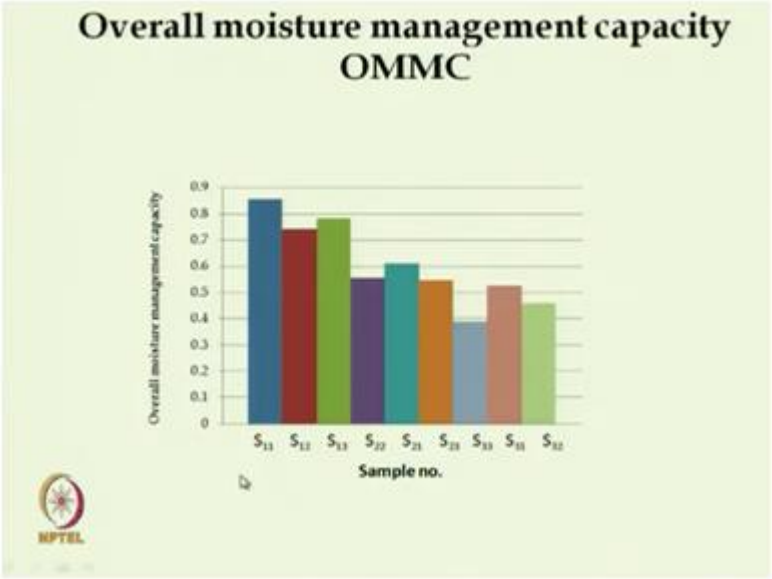

And in plated fabrics as I have mentioned that two different filaments were used in a fabric S11 means the filament with higher shape factor, this is S1 the tetra channel S3 is the circular S11 sample, 11 means both the inner and outer layer fabrics were made from the tetra channel. So S11 where both the inner and outer layer was made of tetra channel is giving the highest water overall moisture management capability whereas the fabric which is made of circular both inner and outer it is giving least moisture management capability. So we have to select the filament cross-section accordingly.

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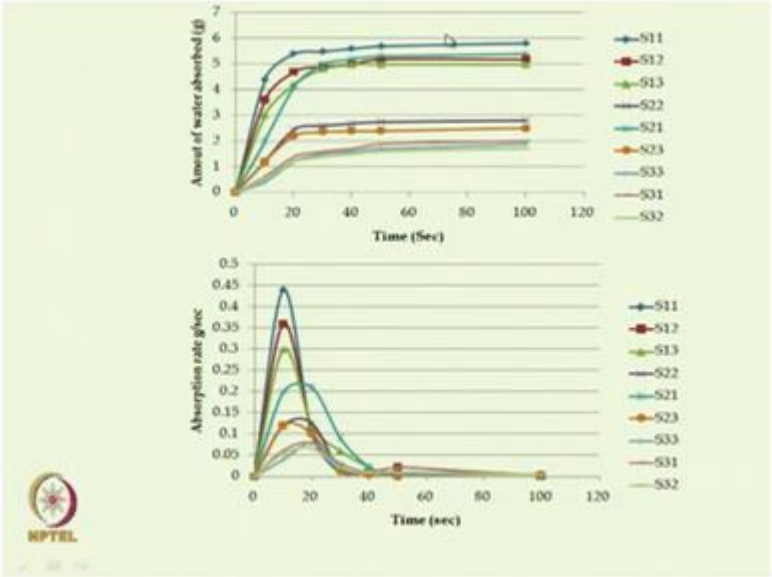

The amount of water absorbed so this is highest in S11 where both the layers are made of the tetra channel absorption is also highest.

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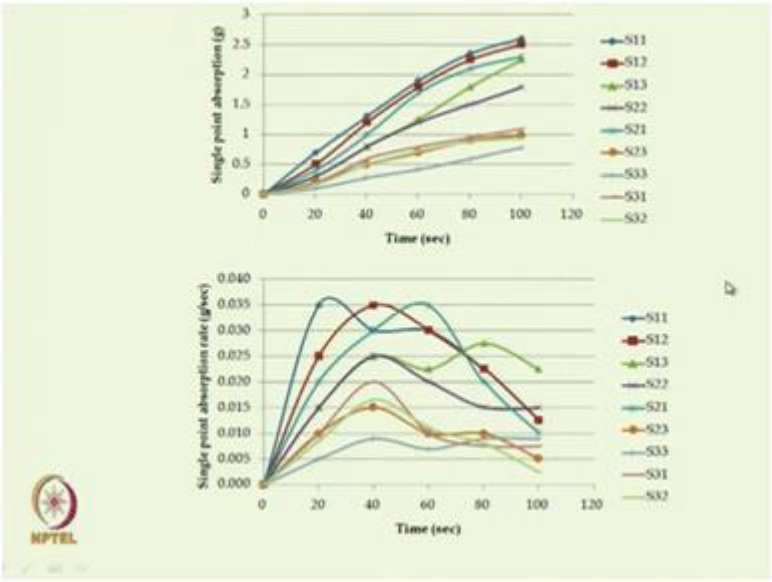

Similarly, so if we see the fabrics which are made of both layers with tetra channel filament are giving the highest moisture management capacity.

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So fabric with tetra channel on both sides showed excellent moisture management, highest bulk absorption capacity, highest in-plane wicking, but all these properties deteriorated when it is replaced by the flat or circular and circular when we use in both the layers it gives least preferred property, it is a poorest property.

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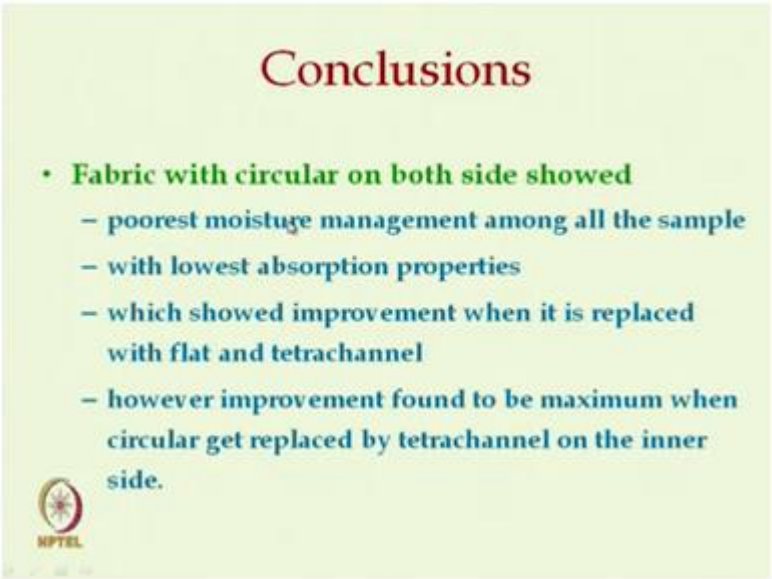

Fabric with circular on both sides shows poorest moisture management capability, lowest absorption.

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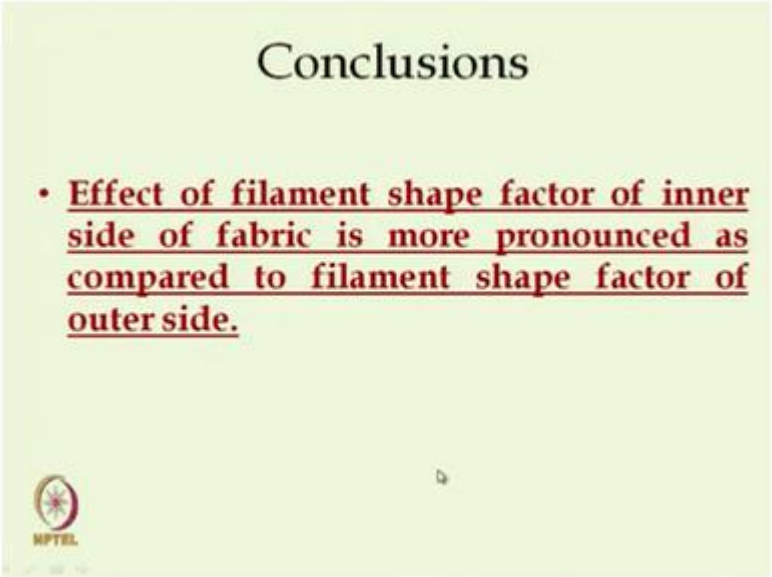

Another conclusion from this study was the effect of filament shape factor of inner side of fabric is more pronounced as compared to filament shape factor in the outer layer and our next study was that the study on the effect of various core-spun.

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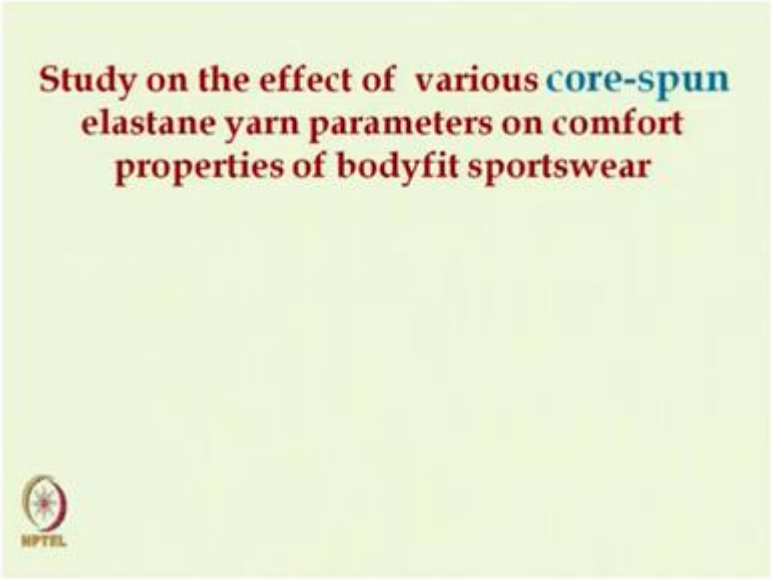

Elastane yarn their parameters on comfort properties of bodyfit sportswear. So for bodyfit sportswear it should be stretchable one so that the core-spun yarns are used where in the core elastane filaments were used.

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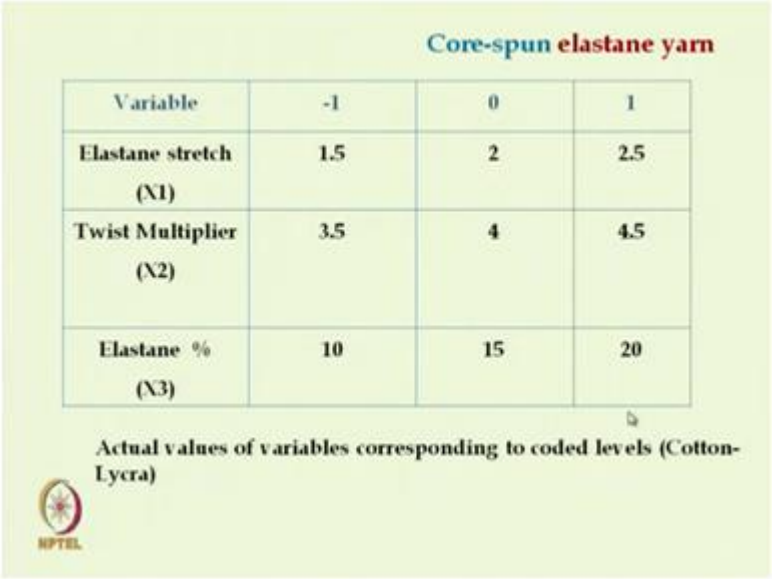

So these are the parameters for developing the sportswear, the variables were taken the elastane stretch, twist multiplier and elastane proportion. So elastane stretch was 1.5, 2 times and 2.5 times, these are the elastance stretch during the manufacture of core-spun yarn. Twist multiplier was increased from 3.5, 4 and 4.5 and elastane percent was varied from 10 %, 15 % and 20 % in core sheath structure by changing the sheath proportion.

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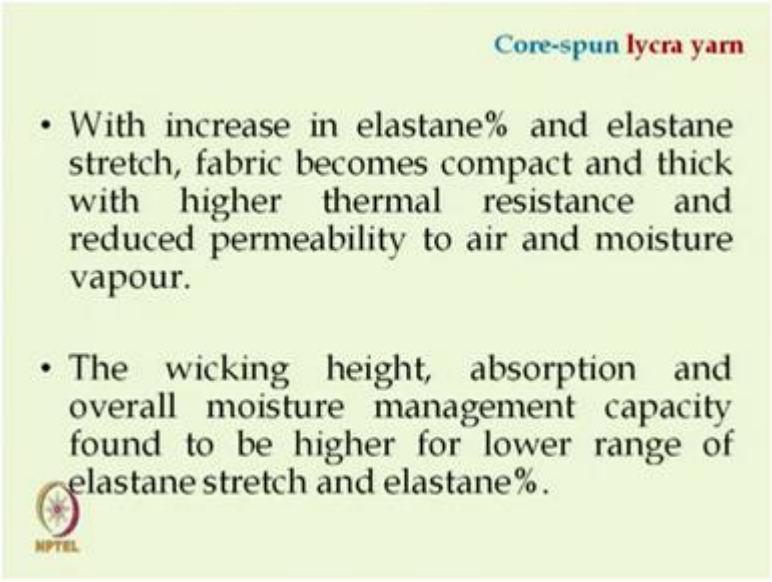

What has been observed is that with the increase in elastane percent and elastane stretch, fabric becomes compact because during the production the elastane stretch was applied and that is why during relaxation fabric becomes compact and thick and this will give higher thermal resistance

and the reduced air permeability. So, if we want to produce sports clothing with higher breathability or higher air permeability we must use the lower elastane stretch and lower elastane percent.

The wicking height, absorption and overall moisture management capacity found to be higher for lower range of elastane stretch. If the fabric becomes compact, that means the wicking height reduces and absorption will also reduce, there must be some open space for absorption. And wicking height reduction is due to the sheath portion that is cotton, the sheath portion when it is contracted the crimps in the sheath portion is increased, that is why the wicking height is reduced. The twist has got significant role in heat and moisture transmission.

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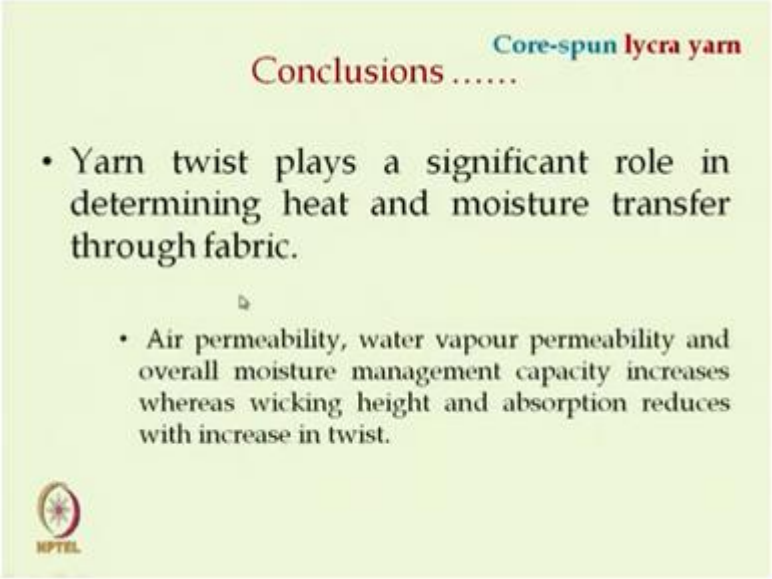

With the increase in twist yarn diameter reduces, so air permeability, water vapor permeability and overall moisture management capacity increases with the twist because of the diameter increase in yarn but the wicking height and absorption reduces due to increase in twist. As the twist increases, the obliquity effect of fiber increases so the liquid in the channel will have to travel higher distance, thus the wicking height reduces and absorption reduces because of the compact structure of yarn.

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And next characteristics is that the thermo physiological comfort characteristics of polyester elastane plated knitted fabrics. Here it is not like earlier study where we have studied the core-spun yarn with the polyester with the elastane in the core and staple fiber in the sheath, but here what we have produced the elastane and polyester, both filaments were taken and plated structures were developed both polyester and elastane filaments were taken in parallel manner.

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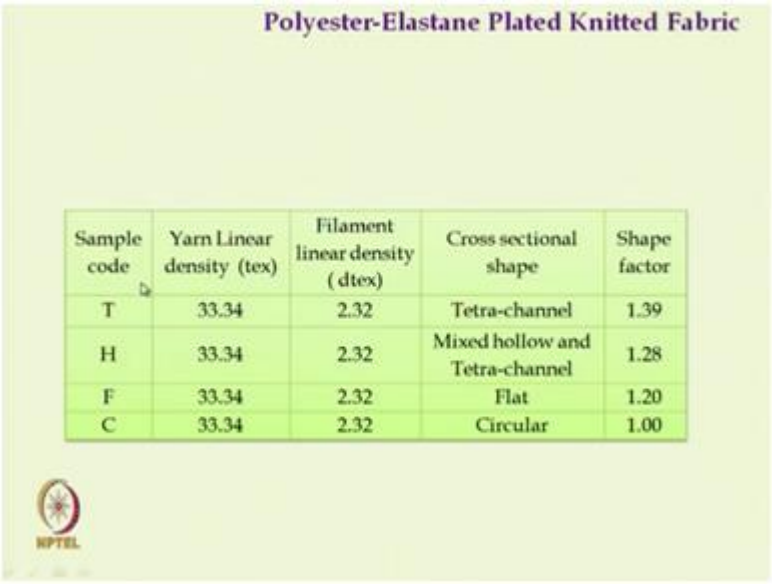

The sample codes were T for tetra channel, H for hollow, so mixed hollow and tetra channel hollow filament, F for flat and C for circular with different shape factors and yarn linear densities were the same.

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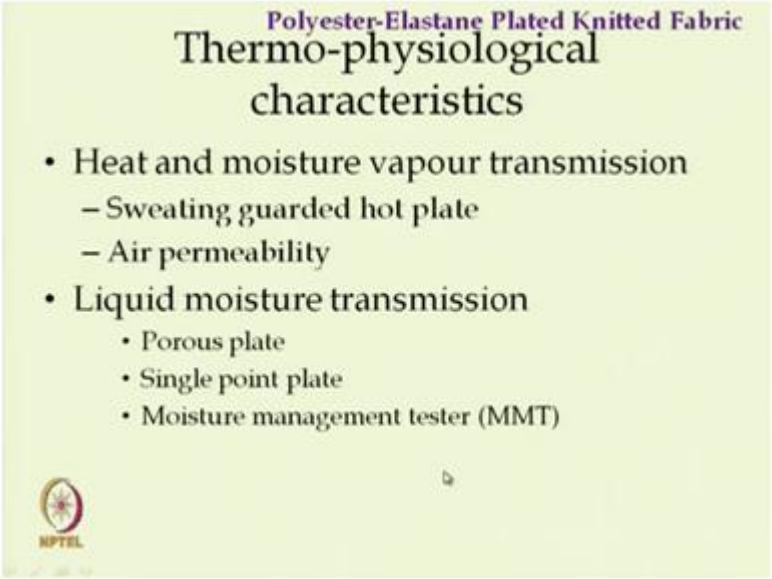

And same elastance were used, the thermo-physiological characteristics where heat and moisture vapor transmissions were measured, liquid moisture transmissions were also measured by using a porous plate, single point plate and moisture management tester.

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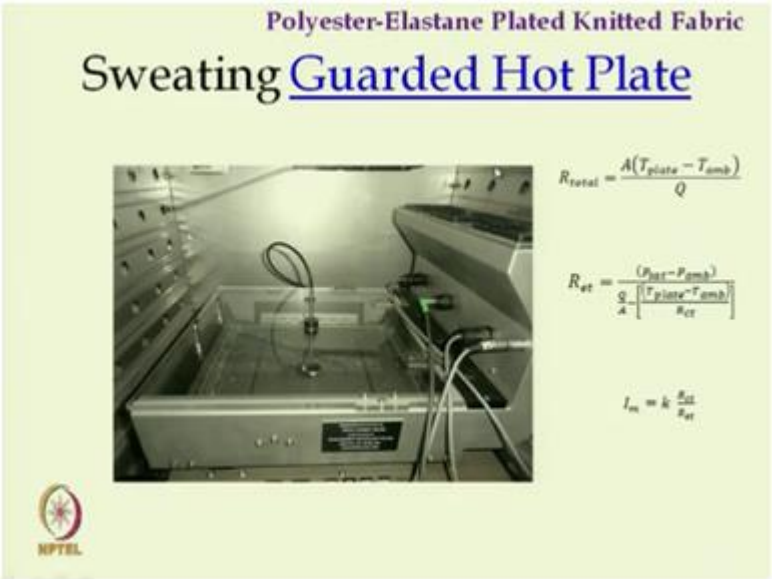

This is the guarded hot plate.

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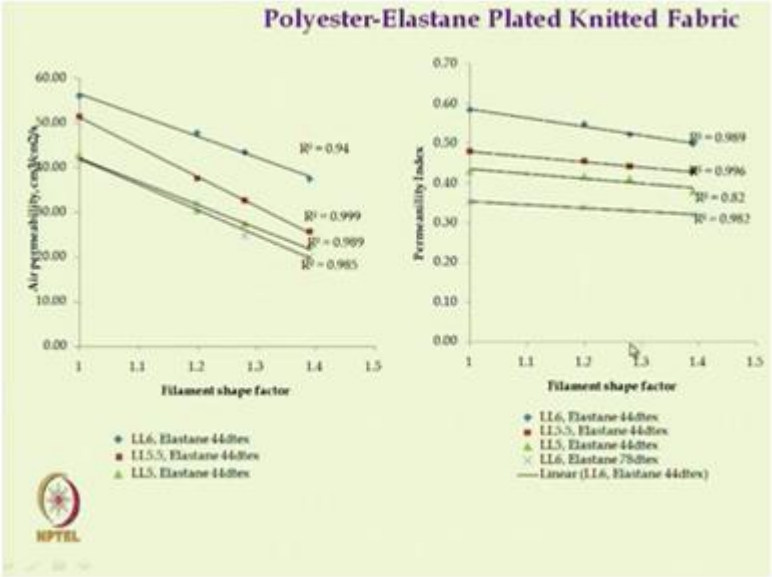

Now if we see the trend here, the fabrics were produced with three different loop lengths LL5 means loop length 5 and with the elastane denier of elastane it is the linear density of elastane 44 decitex, this is the fabric. Whereas LL6 means loop length 6 with same elastane we have used here, so this is shown here with the increase in shape factor, as we increase the shape factor of the polyester filament in this plated fabric for all the different loop lengths the reduction in air permeability is observed.

The air permeability reduction is due to the increase in shape factor that I have already mentioned as higher shape factor filaments are used and more air drag will be there. But another observation here is if we want to increase the air permeability we have to use the knitted fabric with higher loop length, so here the loop length 6 is giving higher air permeability for a particular shape factor than the other fabrics, similarly the permeability index also follows the similar trend.

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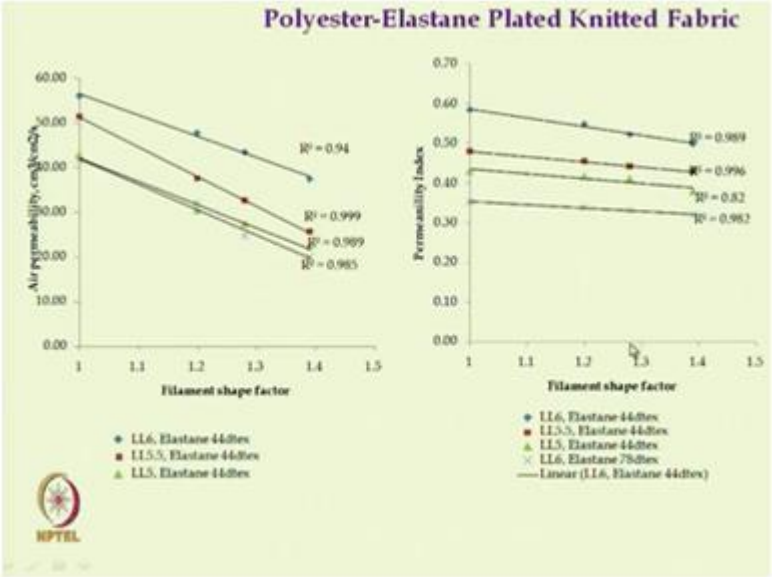

Now as per as wicking characteristics is concerned with the increase in shape factor wickability increases that we know there is wicking speed but, here the trend for wicking with the change in the loop length, so the fabric with lower loop length is giving higher wicking speed because the lower loop length means the yarns are the loop size is less and the wicking length will be short, so the water has to travel shorter distance, that is why the wicking speed increases with the reduction in loop length.

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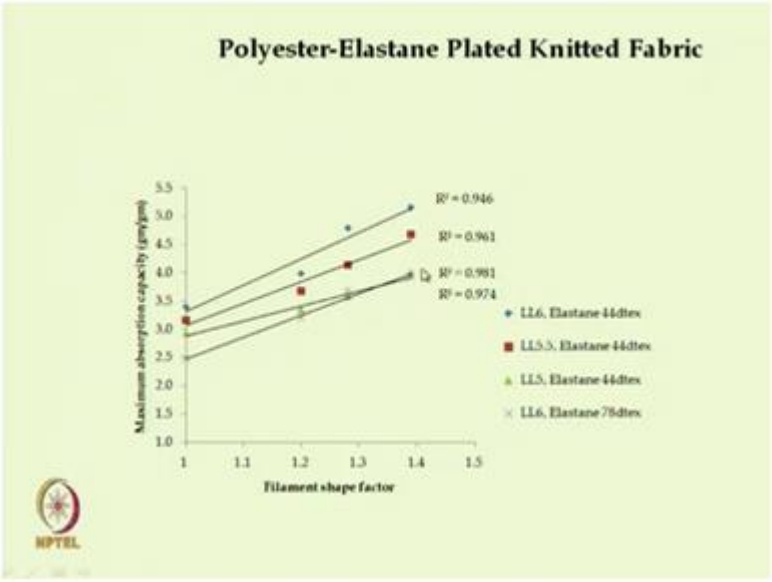

And moisture absorption increases with the increase in shape factor and increase in the loop length, so higher loop length means more space the higher porosity in the structure and the higher absorption will be there.

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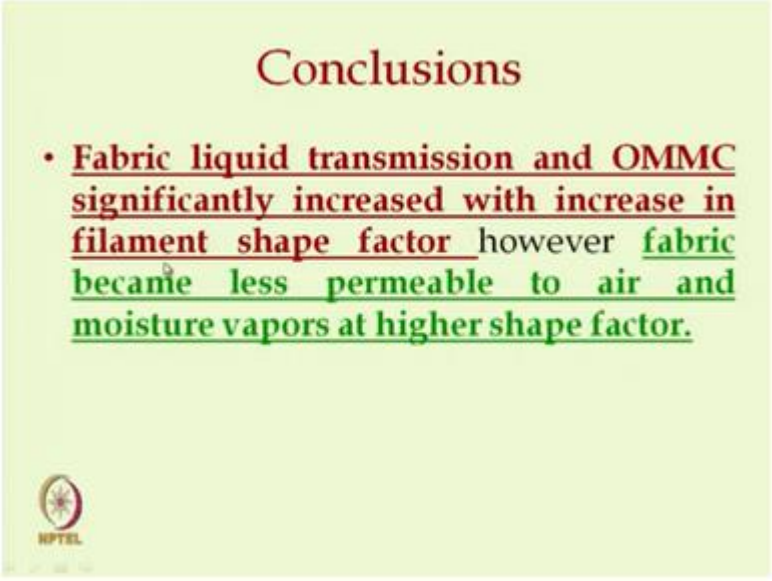

So the conclusions in this study as the fabric liquid transmission and overall moisture management capacity significantly increases with increase in filament shape factor. So if we want to manage the liquid sweat in the sportswear we have to increase the shape factor, however fabric becomes less permeable to air and moisture vapor at higher shape factors. So for high active sportswear the air permeability and moisture vapor permeability is not that important, the important factor is that the liquid moisture management.

That is why we must use the fiber or filament with higher shape factor. The fabric knitted at longer loop lengths are more permeable to air.

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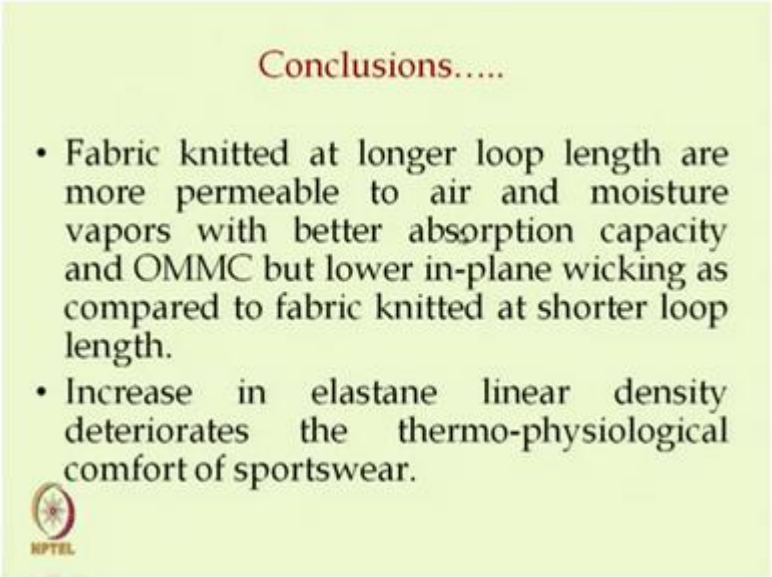

That is obvious we have observed, an increase in elastane linear density deteriorates the thermo-physiological comfort characteristics.

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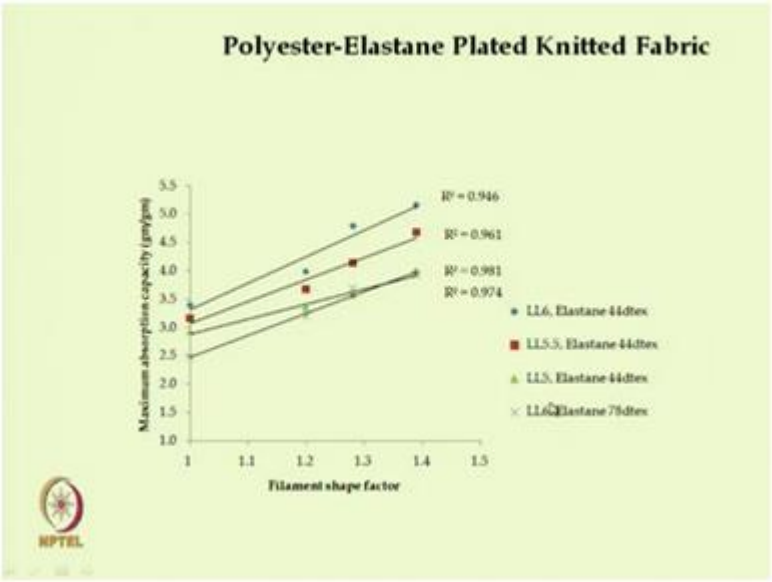

So I can just show here in this picture, we see that this graph is showing the loop length 6 with the 78 decitex elastane and this one is the loop length 6 with the 44 decitex elastane. So with the increase in elastane denier, if we compare this line, top line and the bottom line, this is made of the coarser elastane so moisture absorption capacity reduces with the increase in elastane.

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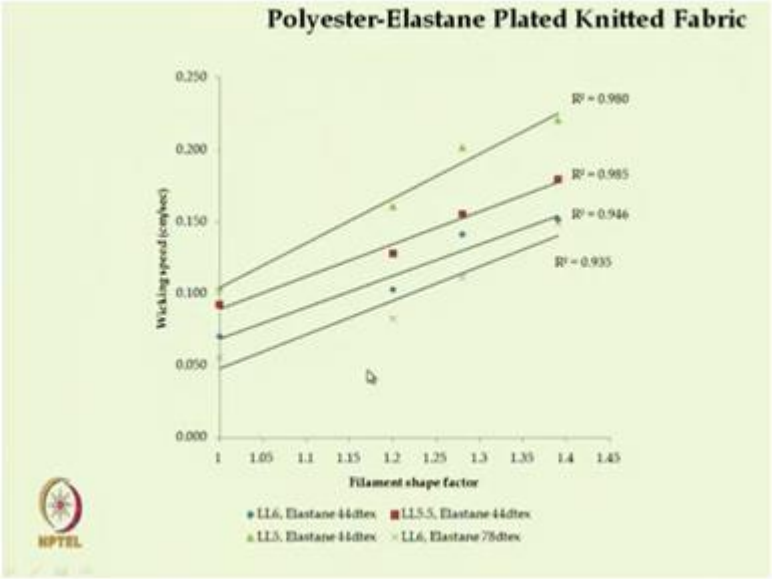

Also if we see here this is the 78, so wicking speed also reduces with the increase in elastane denier. This is the elastane with the 78 decitex here, it is a 44 decitex elastane, this is 44 decitex and this is 78. So this actually wicking speed also reduces with the increase in denier. So increase in elastane linear density deteriorates the thermo-physiological comfort characteristics of sportswear.

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Next study is dynamic compression behavior of compression athletic wear. Here we have used the exactly same set of fabrics, this is plated knitted fabric with polyester and elastane and here the elastic recovery was tested and dynamic interface pressure was studied.

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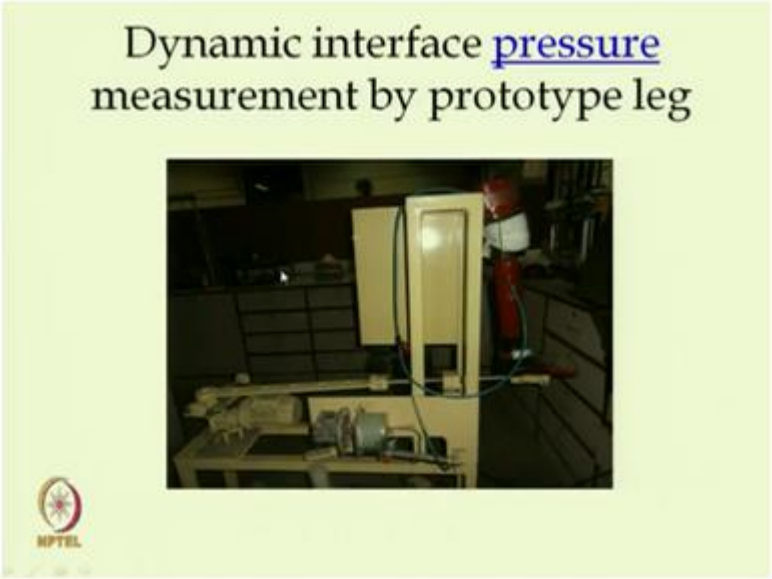

This was studied in this instrument.

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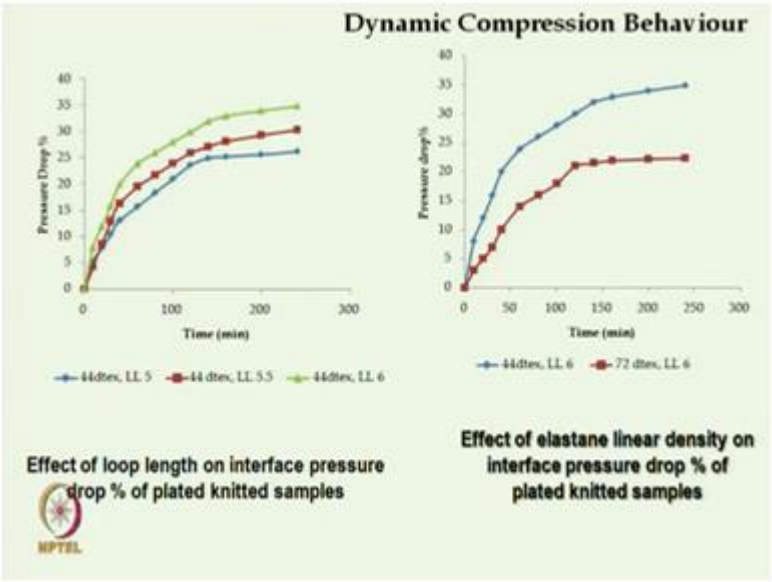

Now this diagram shows that the effect of the time on pressure drop, so for elastane fabric the tight fit sportswear like swimwear or athletic wear where we wear tight fit sportswear to enhance our performance. So here compression force is extremely important as I have already discussed but there are some factors which affect the pressure drop. So higher pressure drop means the sportswear will not be able to retain the pressure on the body, here again we have studied the effect of loop length.

So with the increase in time the pressure drop is increasing, that means the fabric becomes gradually loose, it is not able to retain the pressure. This is true for all the fabrics and this blue line is for loop length 4, so loop length 5 with 44 decitex elastane. So here this figure shows that with the lower loop length, the pressure drop is low as we increase the loop length the pressure drop increases, so the highest pressure drop is for loose structure with loop length 6.

So to retain the pressure drop we must use the lower loop length to retain the compressive pressure, here this is the loop length with 44 decitex with 6 loop length and 72 decitex with 6 loop length, these are the two fabrics. This figure shows if we use the higher denier higher decitex elastane in the plated fabric, the pressure drop is low. So coarser elastane we have to use to maintain the pressure.

So it is suggested that for the high active sportswear where we need the compressive pressure ,compressive behavior for those applications we must use the elastane with higher linear density to retain the pressure.

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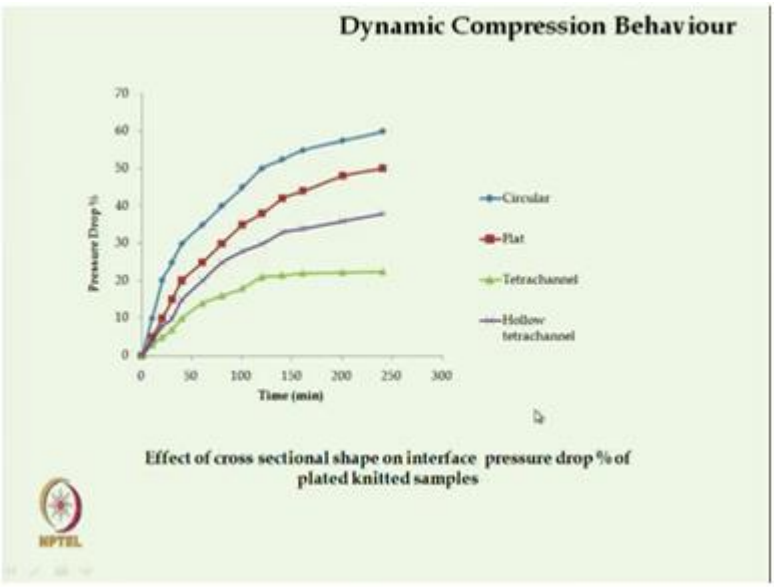

This figure shows the effect of the filament cross section. Here we can see the circular cross section filament gives the maximum pressure drop and whereas the tetra channel with higher shape factor results lowest pressure drop. So to retain the shape and to retain the compressive

pressure from this study we can conclude that one should use the polyester filament with higher shape factor, elastane filament with higher linear density and the knitted fabric with lower loop length, to maintain the compressive pressure to enhance the performance.

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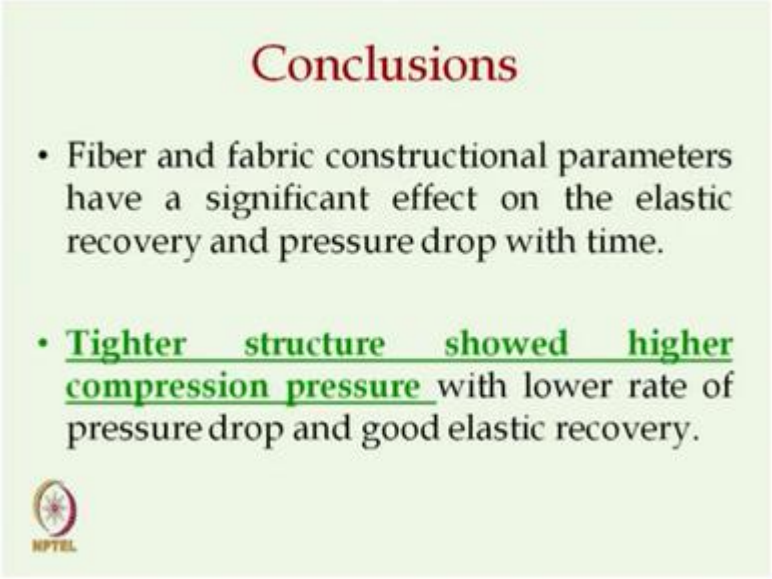

So the conclusions, the fibers and fabric constructional parameters have significant effect of elastic recovery and pressure drop within a certain time. So pressure drop we must actually showed the lower pressure drop so that the compressive pressure is maintained. Tighter structure shows higher compression pressure with lower rate of pressure drop and good elastic recovery, tighter structure means we should go for lower loop length.

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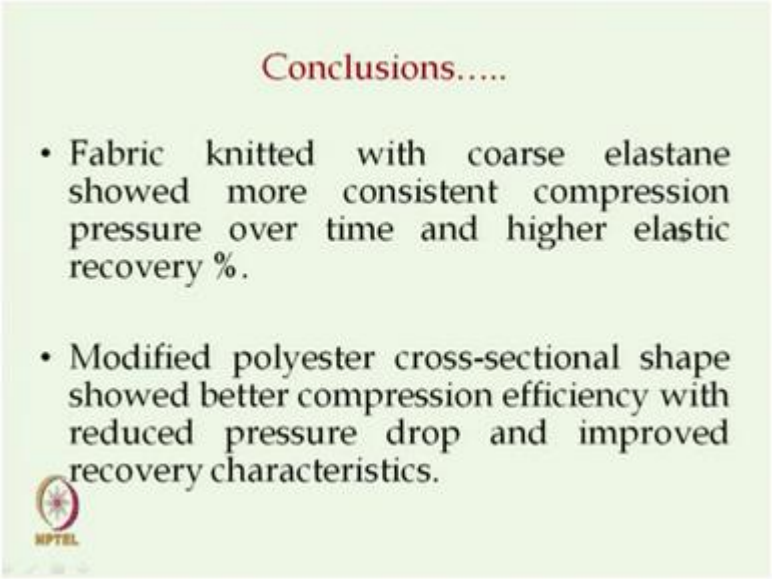

Fabric knitted with coarse elastane shows more consistent compression pressure over time that is lower pressure drop. Modified polyester cross-section shape shows better compression efficiency that is it reduces the pressure drop with increased shape factor. So if we increase higher shape factor polyester it reduces the pressure drop and improves recovery characteristics. So that is all with sports textile, in next class we will start with a new topic. Till then thank you.