Science of Clothing Comfort
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Lecture – 28
Clothing Comfort Related to Thermal Transmission (contd..)

Hello everyone. So, we are discussing the thermal comfort related aspects. So, we are at the last stage of the thermal related comfort thermal transmission related issues we will we are discussing. And our in next segment, we will discuss the moisture vapor and moisture in liquid form this transmission related aspects, which how this moisture in vapor form and in liquid form affects the comfort characteristics of clothing. So, we will continue with the effect of different convective modes and air gap, this we have already discussed. So, let us try to see what we have discussed in last class.

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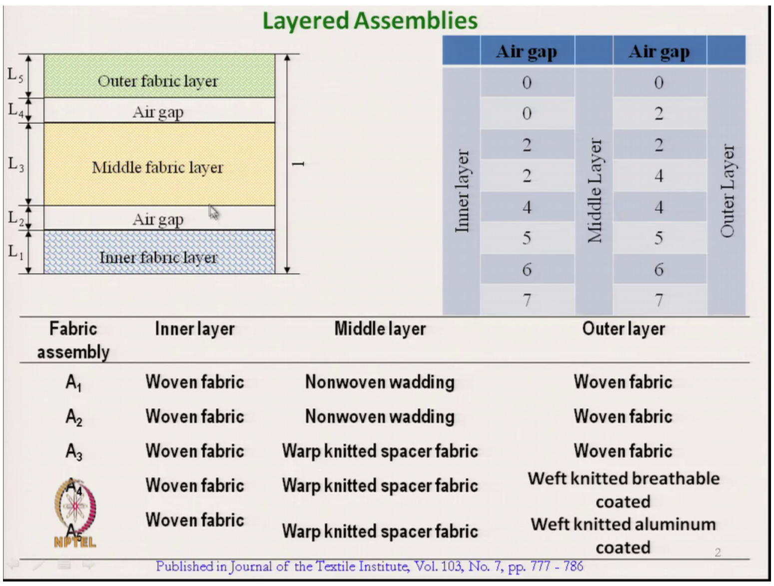

So, here the three different layers of fabrics have been used inner layer, middle layer, and outer layer. So, for most of the extreme cold climate clothing or most of the protective clothing, we use three layers of clothing; inner, middle, and outer layer. And the function of inner layer is to have it is a tactile function, it has go it gives the tactile sensation, it absorbs moisture and transmits to the middle layer ok. And accordingly, it will get transmitted to the environment through the outer layer. And the main function protective function, it is a middle layers function is that it is a gives insulation, and it gives bulk and also it is it has to have the better transmission characteristics.

So, in next segment, we will see the effect of the characteristics of middle layer have been studied in detail. Along with the outer layer has got its important function, it actually directly interacts with the environment. So, here the characteristics of properties of outer layer, it is very important, whether it is a say if it is flame protective clothing. So, if it is say a flame protective clothing, it is has to be a flameproof fabric. So, some finishing, we can add, it if it is what if we need to have waterproof.

So, all sorts of special characteristics we have to incorporate in this outer layer, but at the same time, the outer layer has to be breathable. So, the pore size of outer layer is extremely important which breathable means, it has to transmit the moisture in vapor form. And it most of the cases, it should be the water impermeable. So, it cannot it should not allow the water to come from outside, but it should allow the moisture vapor to come from inside to the, it should be released to the environment.

So, in this study, which we have explained earlier, so we have used a three different layers and the air gap is changed air gap. Thus thickness of air gap is changed from 0 to 7 millimeter. And here it is the testing is done in three convective mode; it is a non convection, natural convection and force convection. And three layers is are inner layer, it is a basically woven fabrics, same oven fabrics are used. The middle layer, it is actually the two different types of nonwovens are used, and warp knitted fabrics are used, warp knitteds are warp knitted spacer fabrics are used. And outer layer, woven fabric, it is normal woven fabric and coated woven fabrics are used.

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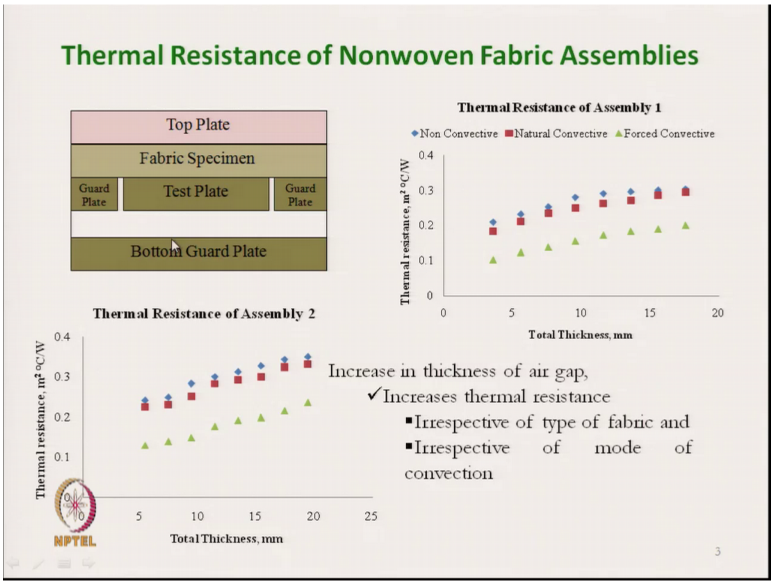

And three different modes of convection is used in a sweating guarded hot plate. In this guarded hot plate, if we want a non convective mode, top layers top plates are used. When top plate is removed, so natural convection the heat will flow in a natural convection mode. So, this natural and if we blow air parallel to the surface, and then the it will be in forced convection mode, where we have also seen that natural convection. Non convective mode gives maximum thermal insulation followed by natural convection. And the forced convection gives the least thermal insulation.

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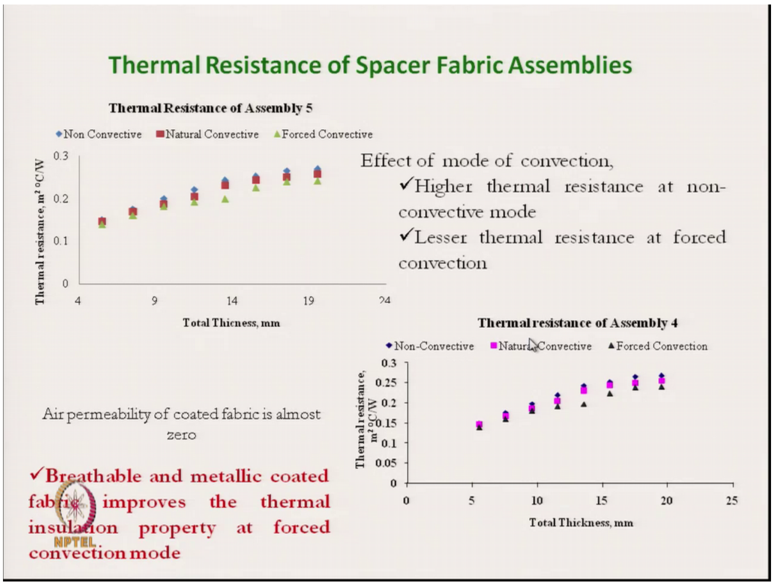

So, this we have seen. And when we use the fabric with coated structure or laminated outer layer, in those fabrics a like fabric 4 and 5, where the difference between the normal fabric non convective and forced convective mode, the thermal insulation difference is least. Also in this study, we have observed as we keep keeping the same fabric layer. As we change the thickness of air layer, the thermal insulation of the fabric assembly increases.

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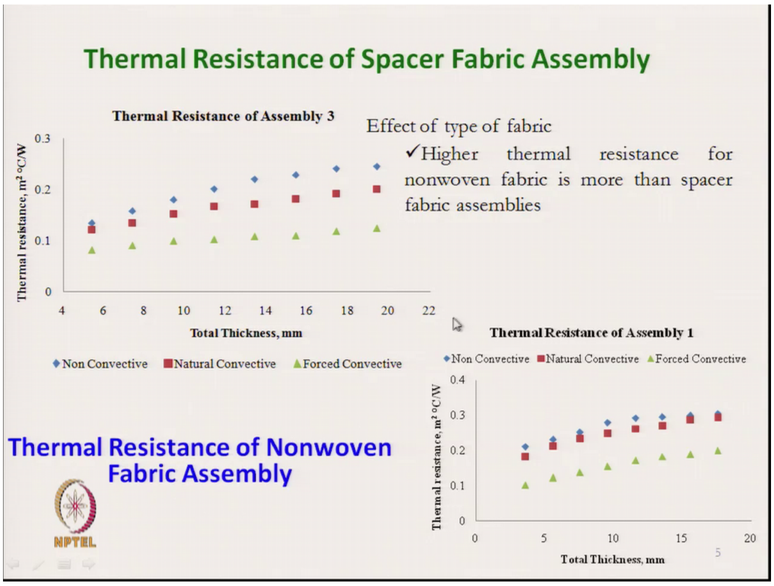

So, this study we have, it is carried out.

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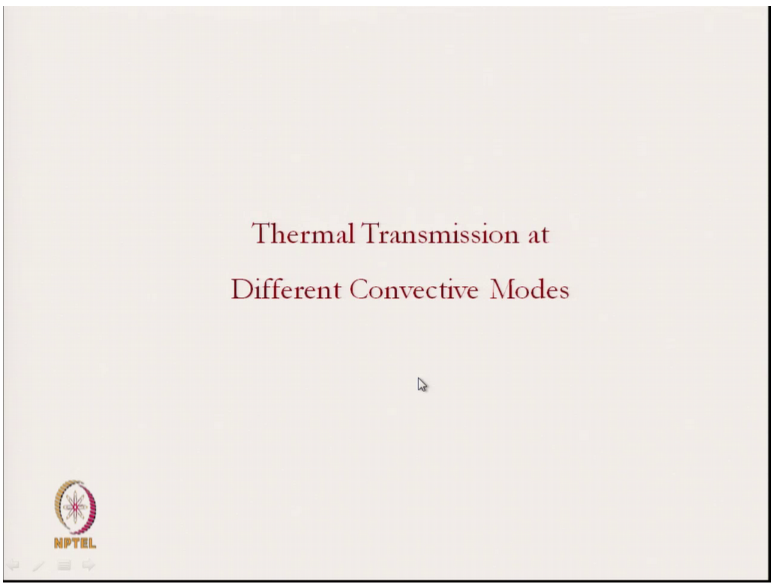

And now, we will discuss various few other characteristics, which affect the thermal transmission characteristics of the fabric.

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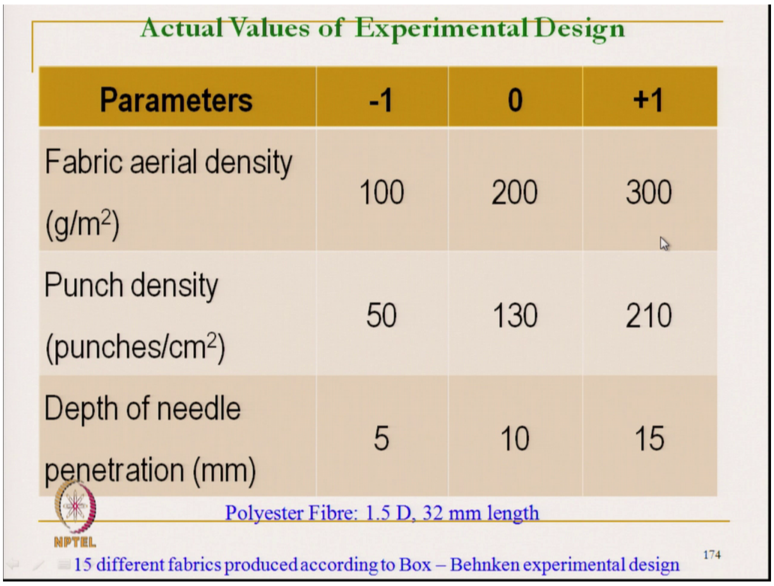

Now, different process parameters have been studied here. So, in the first study what we have used, the polyester staple fiber is used of 1.5 denier polyester staple fiber with 32 millimeter length. This polyester fiber is used to produce a nonwoven fabric. Nonwoven fabric with different mass per unit area it is a 100, 200, 300, we have used a Box and Behnken model, where punch density middle punch density is increased from 500, 130, and 210 difference of 80 is kept here. And depth of penetration needle penetration is 5, 10, and 15.

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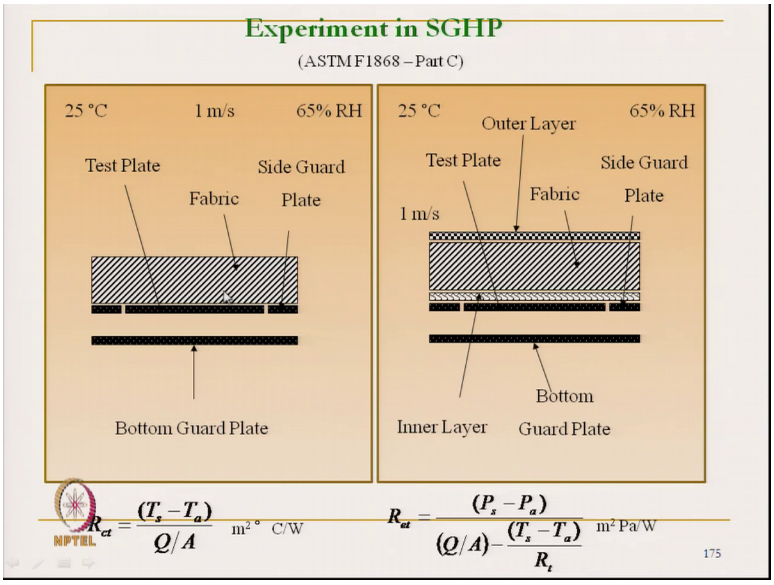

So, with this model with this experimental setup design, the fabric is produced the nonwoven fabric is produced. And here again sweating guarded hot plate is used to measure the thermal transmission heat dry heat transmission characteristics, where T a is T temperature is used at different ambient temperature. And the test plate temperature is used here. And this is here and the evaporative resistance is also used, where we have measured the vapor pressure at two different levels, and that is vapor pressure.

And these fabrics are used that this is the nonwoven sample, it is used only nonwoven fabrics are used and in addition to the only now and a second setup, where the three layers are used. The same nonwoven fabrics, it is there is no inner layer and outer layer. And in next set of experiment, we have used the inner layer, middle layer as nonwoven fabrics and outer layer. So, with this set up, we have used and just to see the impact of the inner and outer layer on thermal and transmission and evaporative resistance. So, thermal resistance and evaporative resistance, we can we can compare with this experiments.

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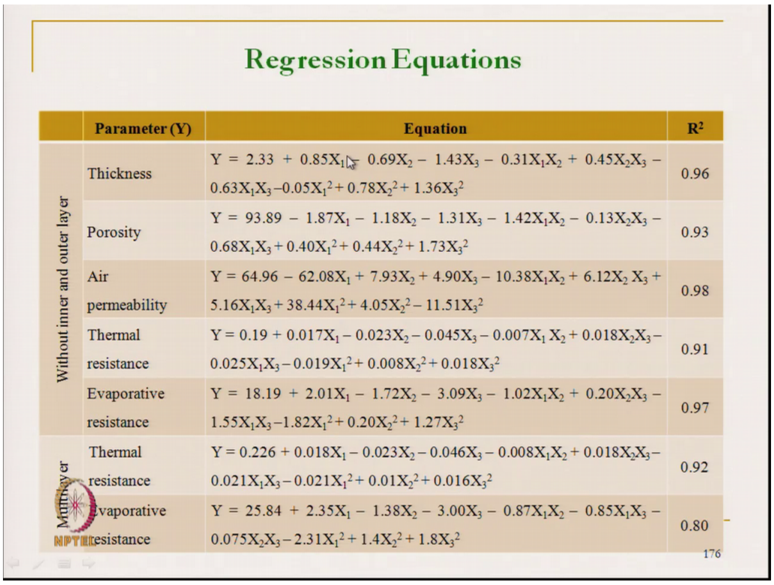

Regression Equations

	Parameter (Y)	Equation	R^2
Without inner and outer layer	Thickness	$Y = 2.33 + 0.85X_1 - 0.69X_2 - 1.43X_3 - 0.31X_1X_2 + 0.45X_2X_3 - 0.63X_1X_3 - 0.05X_1^2 + 0.78X_2^2 + 1.36X_3^2$	0.96
	Porosity	$Y = 93.89 - 1.87X_1 - 1.18X_2 - 1.31X_3 - 1.42X_1X_2 - 0.13X_2X_3 - 0.68X_1X_3 + 0.40X_1^2 + 0.44X_2^2 + 1.73X_3^2$	0.93
	Air permeability	$Y = 64.96 - 62.08X_1 + 7.93X_2 + 4.90X_3 - 10.38X_1X_2 + 6.12X_2X_3 + 5.16X_1X_3 + 38.44X_1^2 + 4.05X_2^2 - 11.51X_3^2$	0.98
	Thermal resistance	$Y = 0.19 + 0.017X_1 - 0.023X_2 - 0.045X_3 - 0.007X_1X_2 + 0.018X_2X_3 - 0.025X_1X_3 - 0.019X_1^2 + 0.008X_2^2 + 0.018X_3^2$	0.91
	Evaporative resistance	$Y = 18.19 + 2.01X_1 - 1.72X_2 - 3.09X_3 - 1.02X_1X_2 + 0.20X_2X_3 - 1.55X_1X_3 - 1.82X_1^2 + 0.20X_2^2 + 1.27X_3^2$	0.97
Multilayer	Thermal resistance	$Y = 0.226 + 0.018X_1 - 0.023X_2 - 0.046X_3 - 0.008X_1X_2 + 0.018X_2X_3 - 0.021X_1X_3 - 0.021X_1^2 + 0.01X_2^2 + 0.016X_3^2$	0.92
	Evaporative resistance	$Y = 25.84 + 2.35X_1 - 1.38X_2 - 3.00X_3 - 0.87X_1X_2 - 0.85X_1X_3 - 0.075X_2X_3 - 2.31X_1^2 + 1.4X_2^2 + 1.8X_3^2$	0.80

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So, here the regression analysis of say it is a without any outer layer, so without any layer, we have used without any inner and outer layer, and this is only it is a middle layer here. So, if we see the coefficient of regression, it is a it is a very high correlation. For most of the parameters, the thickness, porosity, air permeability, thermal resistance, and evaporative resistance, they are well correlated with the all these experimental parameters.

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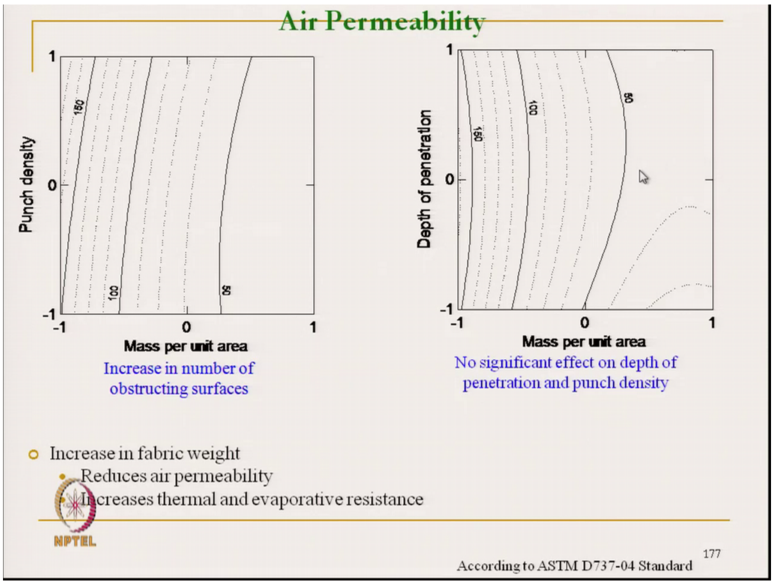

So, if we see here in this contour plot, the increase in number of obstruction that means, if we increase the mass per unit area, the air permeability reduces, so that is obvious, so that means, in a mass per unit area increase means, number of fibers in a cross section in a path of the airflow is increase. So, the number of obstruction is increased. So, more surface now surface of fiber is presented in front in path of the air, so it gives the more and more less and less air permeability. So, air permeability drops with the increase in mass per unit area. Whereas, if we see the effect of punch density, so if we increase the punch density, the air permeability its effect is not that significant at least within this experimental range.

The same is true for depth of penetration. So, impact of depth of penetration depth of penetration on air permeability is not that significant. So, increase in a fabric weight that means, reduce the air permeability, but in it actually it is there is no impact on air permeability. But, if we see the increase in fabric weight, it increases the thermal and evaporative resistance. So, in next of picture we can see.

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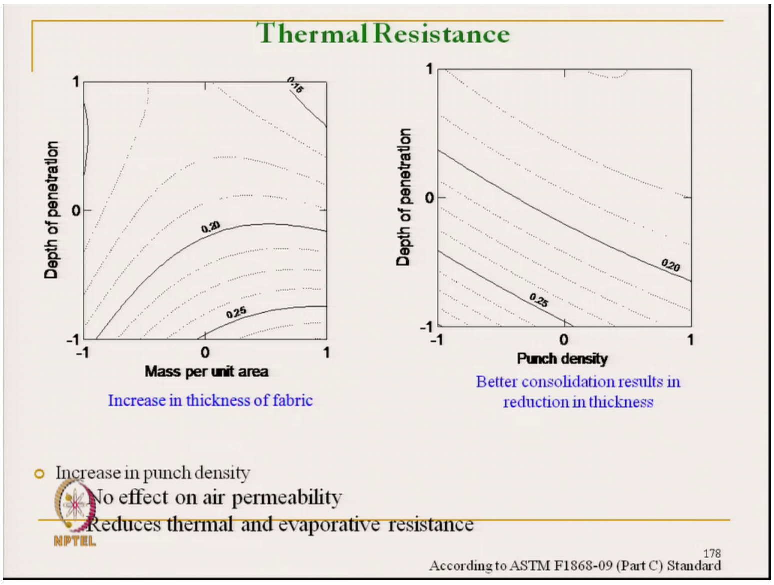

So, if we see that mass per unit area, if we increase, it shows that increase in the thermal resistance here in; but, if the increase in depth of penetration reduces the thermal resistance, which is interesting. So, keeping the mass per unit area same. If we increase the depth of penetration or if we increase the density of a needle punching, we have observed that the thermal resistance decreases significantly. This is due to the fact that if for keeping for a same mass per unit area. If we increase the depth of penetration, the fabric gets compacted.

So, more and more higher and higher depth of penetration or a higher punch density means, it the pore size inside the fabric structure gets reduced. The entrapped air is actually it is removed, so that means, its conductive heat transmission is reduced, so it increases. So, thermal resistance reduces. So, this is mainly due to the conductive heat transmission, and also evaporative heat resi stance reduces.

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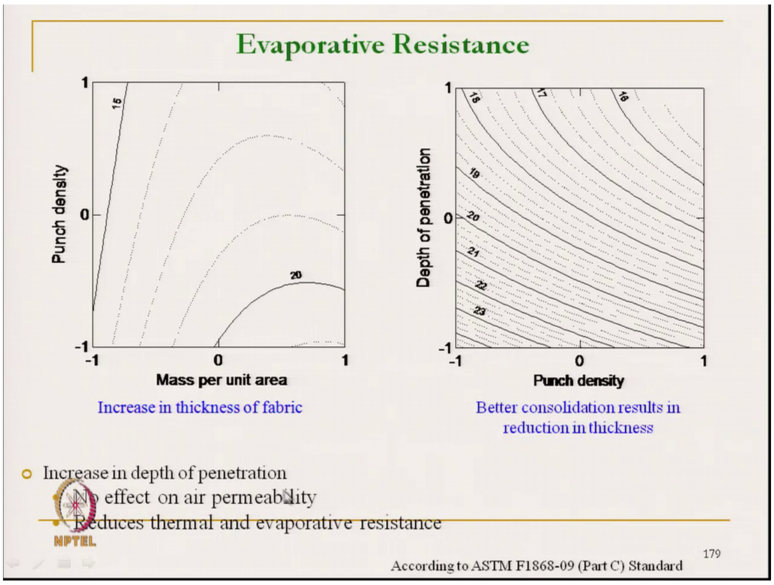

So, if you see that the evaporative heat resistance, it reduces with the increase in punch density or even depth of penetration. There is no effect of air permeability.

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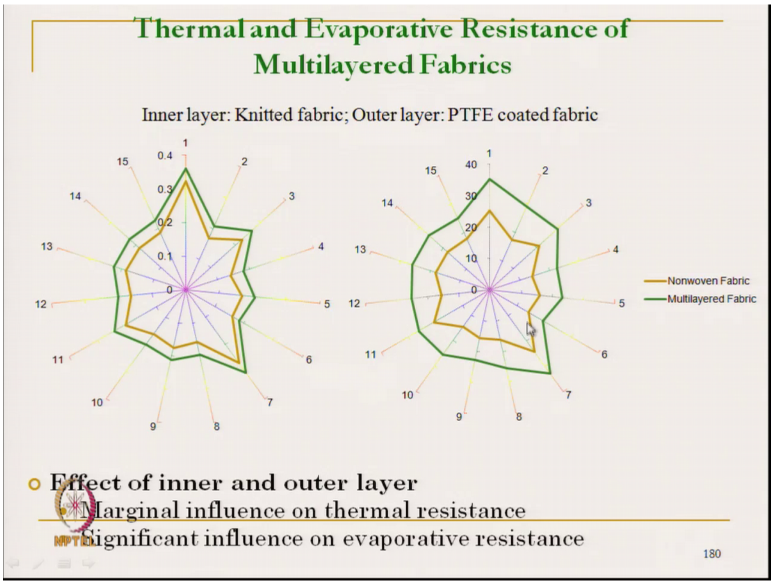

And here this picture shows the effect of layers present. So, without layer, this inner curve is it shows the fabric thermal resistance without a layer here. And this is the evaporative resistance of fabric without any layer, only nonwoven fabric. So, here it shows that the difference between although there is a with; if we change an green curve shows that the thermal resistance with outer layer. So, with inner and outer layer, if we use, so the thermal resistance increases, and also the evaporative resistance increases.

But, if we see the percent increase in thermal resistance or evaporative resistance, so there the , if we can calculate the percentage increasing evaporative resistance due to presence in the outer layer and inner layer is much higher than the percent increase in the thermal resistance. It in some of the fabrics, we have observed it is not that significant increase. But, here the increase in the in evaporative resistance is significant that means, the addition of layer inner layer and outer layer does not impact the thermal insulation too much that which means the main impact of thermal main contribution of thermal resistance is due to the middle layer. But, the contribution of outer layer particularly on evaporative resistance is very significant, so that is why. So, if we add the outer layer, it gives significant increase in evaporative resistance.

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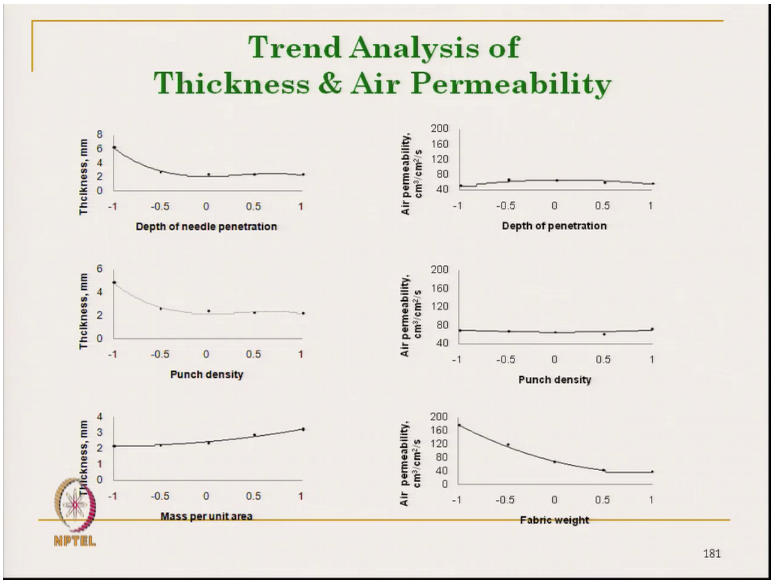

Now, let us see the impact of individual component on individual parameter. So, if we increase the depth of penetration, so fabric gets compacted. So, more and more entanglement between the fibers will take place, and so the thickness of fabric will reduce. But, after certain time, the it will reach its saturation point beyond that the thickness will not reduce, it will get its it will get stabilized. So, even after that if we keep on increasing the depth of penetration and punch density, the fiber damage will start. So, instead of consolidation, so it will start fiber damage. So, same trend is there in case of depth of penetration.

Now, if we see the mass per unit area, it is obvious the if the mass per if we increase the mass per unit area, thickness of fabric should increase, but the this curve shows that the rate of increase is not that high as compared to the rate of increase in mass per unit area. Because, as we increase the mass per unit area for a needle punch fabric, the more and more fibers will come into action of the barbed of barbs of the needle and more and more entanglement will take place. So, fabric will get consolidated. So, rate of increase in thickness will not be that high, although there is increase of thickness due to the quantity of material number of fibers present in the in the fiber in the fabric per unit area.

Now, as we see that a depth of penetration does not have that significant impact on air permeability that we have seen. The punch density is also, there is no such change in the air permeability. The reason may be due to the fact that as we increase the punch density, fabric becomes more and more compact, but at the same time the air may actually travel through the force created by the needles, so that may be the reason one of the reasons, maybe other reasons are there. But, if ultimately punch density and depth of penetration does not have significant effect on the air permeability whereas, fabric mass per unit area, it is air permeability, it has got its a impact. So, because more and more fiber comes into the path as we have discussed path of the airflow. So, the air permeability of fabric reduces with the mass per unit area.

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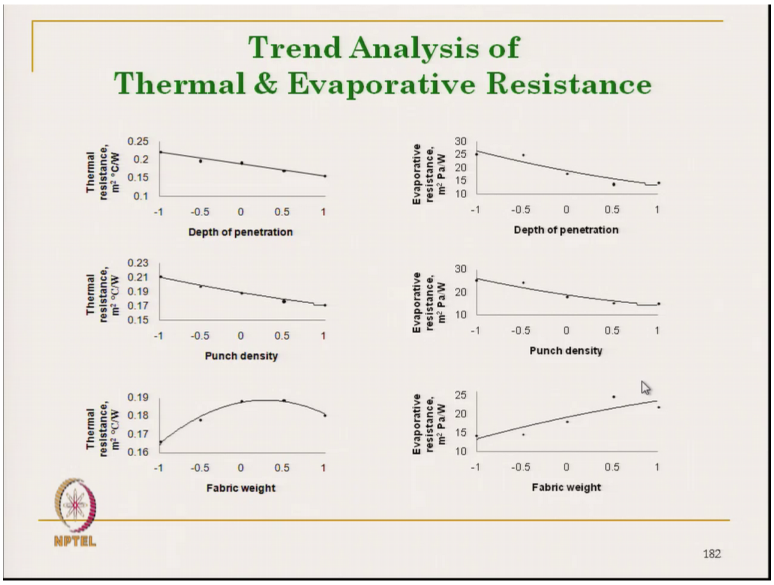

Now, coming to the thermal resistance; So, as depth of penetration increases, thermal resistance reduces consistently. It is a continuous reduction in thermal resistance at least within the range of the experimental values. This is due to that consolidation of the fiber, consolidation of the fabric, so less and less air will be entrapped within the structure. So, the conductive heat transmission will increase, so thermal resistance will drop. Same trend is observed in case of the punch density.

But, here you can see with the increase in fabric mass per unit area what happens? The interesting thing happens as we I have discussed earlier. With the increase in fabric mass per a unit area; keeping all other parameters constant. So, punch density and depth of penetration constant if we increase, initially there will be increase in thermal resistance. This is due to the fact that the more and more fibers will be present, so it will give more conductive, convective, and radiative heat resistance of heat loss; so that the total thermal resistance is increasing.

But, after certain level after certain level, it drops due to the fact that. If it is more and more fibers are there, there will be more and more entanglement. Due to the process of the that the barb needle, when it is moving through the more and more fiber, there will be more entanglement. This drop is due to the conductive heat loss. This is due to the conductive heat loss, because here the entrapped air will be less. So, this portion is the conductive, convective, and radiative heat loss. Here its drop is due to conductive heat loss. Similarly, if we see the with that increasing depth of penetration and punch density, the evaporative resistance is reduced. And with a fabric weight evaporative resistance is increased. The reason we have already discussed.

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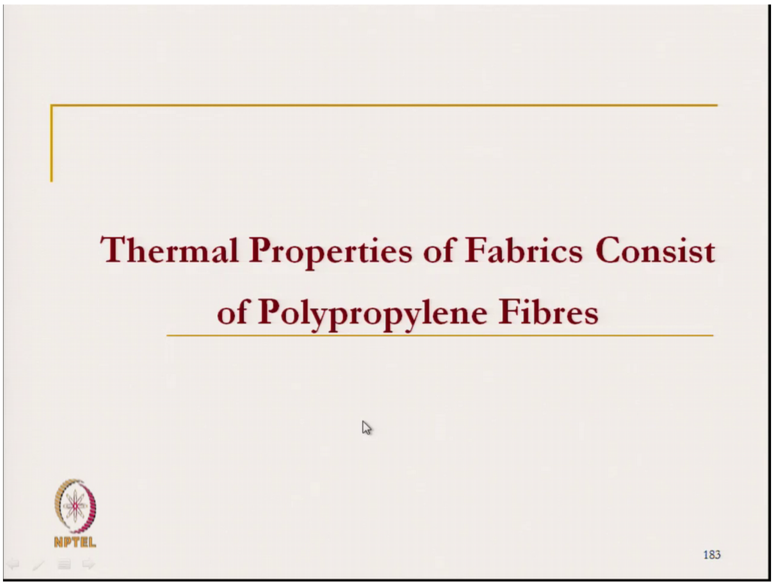

Now, coming to the next study, where the polypropylene fibers are used with two different denier two different diameter of polypropylene fibers are used. To see the impact of fiber diameter, whether there is an impact of fiber diameter on thermal transmission of fabric.

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Actual Values of Experimental Design

Parameters	-1	-0.5	0	+0.5	+1
Linear density of fibre	2.5	-	-		6
Fabric aerial density (g/m^2)	100	200	-	300	400
Punch density (punches/cm^2)	50	-	130	-	210

Full Factorial Design

Properties of Inner and Outer Layer Fabrics

Fabric	Ends (or) wales per cm	Picks (or) courses per cm	Mass per unit area (g/m^2)	Thickness (mm)	Bulk density (g/cm^3)	Porosity (%)	Air permeability (cm^3/cm^2/s)	Thermal resistance (m^2 °C/W)	Evaporative resistance (m^2 Pa/W)
Inner layer	17	12	80	0.35	0.22	84	321.3	0.067	6.85
Outer layer	44	38	136	0.23	-	-	-	0.072	10.25

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Now, here the experimental design is that linear density of fiber it is of in denier, it is a 2.5 and 6 denier two fibers are used. The fabric areal density 100 in gram per square meter 100, 200, 300 and 400, they are used. And needle punch density here we have use the punch density 50, 130 and 210. So, full factorial designs design is used. The properties of inner and outer layer fabric; so, we have used this is the use this nonwoven fabric is used for middle layer. And a fixed fabric same inner layer and outer layer fabrics are used here with the different ends per inch, picks per inch, mass per unit area, thickness, bulk density, porosity. So, all these parameters are there.

And here in outer layer, as it is coated fabric, so, bulk density and porosity, they are not used. And air permeability is also not measured, because it is a coated fabric. So, air permeability is coming very less and inner fabric. So, this in combination with this middle layer has been used as a total assembly.

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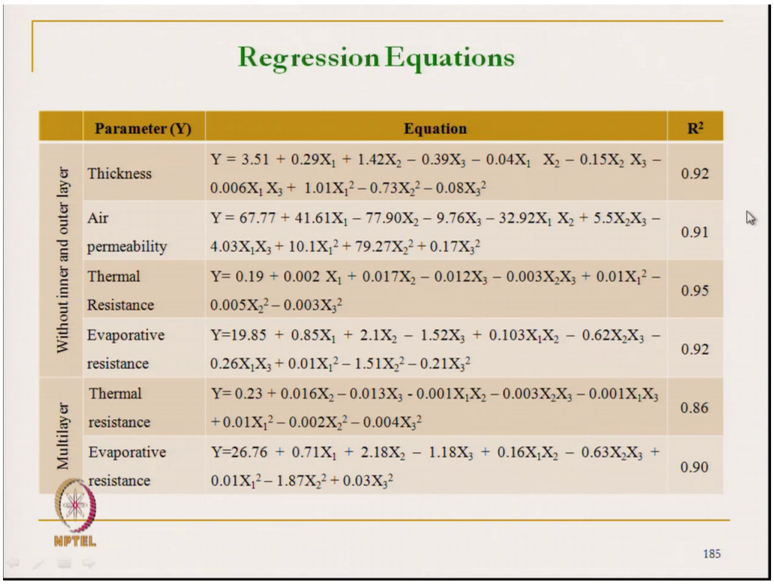

Regression Equations

	Parameter (Y)	Equation	R^2
Without inner and outer layer	Thickness	$Y = 3.51 + 0.29X_1 + 1.42X_2 - 0.39X_3 - 0.04X_1 X_2 - 0.15X_2 X_3 - 0.006X_1 X_3 + 1.01X_1^2 - 0.73X_2^2 - 0.08X_3^2$	0.92
	Air permeability	$Y = 67.77 + 41.61X_1 - 77.90X_2 - 9.76X_3 - 32.92X_1 X_2 + 5.5X_2X_3 - 4.03X_1X_3 + 10.1X_1^2 + 79.27X_2^2 + 0.17X_3^2$	0.91
	Thermal Resistance	$Y= 0.19 + 0.002 X_1 + 0.017X_2 - 0.012X_3 - 0.003X_2X_3 + 0.01X_1^2 - 0.005X_2^2 - 0.003X_3^2$	0.95
	Evaporative resistance	$Y=19.85 + 0.85X_1 + 2.1X_2 - 1.52X_3 + 0.103X_1X_2 - 0.62X_2X_3 - 0.26X_1X_3 + 0.01X_1^2 - 1.51X_2^2 - 0.21X_3^2$	0.92
Multilayer	Thermal resistance	$Y= 0.23 + 0.016X_2 - 0.013X_3 - 0.001X_1X_2 - 0.003X_2X_3 - 0.001X_1X_3 + 0.01X_1^2 - 0.002X_2^2 - 0.004X_3^2$	0.86
	Evaporative resistance	$Y=26.76 + 0.71X_1 + 2.18X_2 - 1.18X_3 + 0.16X_1X_2 - 0.63X_2X_3 + 0.01X_1^2 - 1.87X_2^2 + 0.03X_3^2$	0.90

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And here also we have seen that the total layer, the total all the parameters had they have very good correlation with the experimental parameters.

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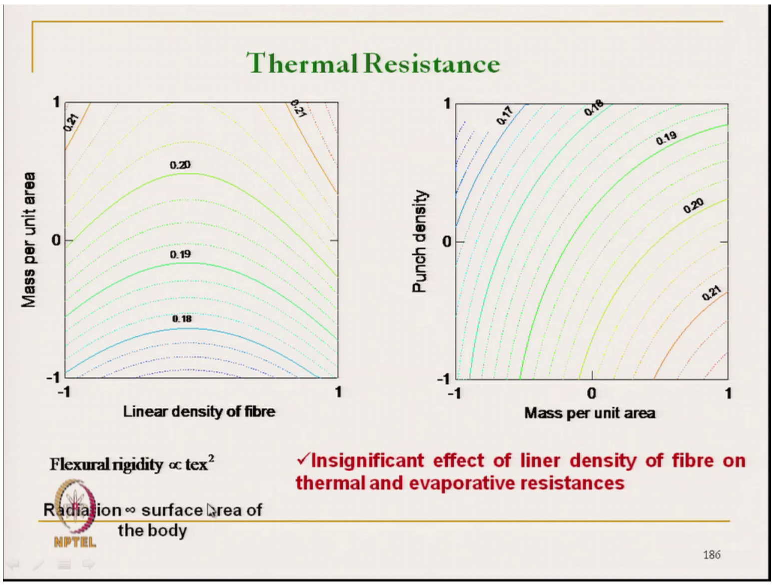

Now, what we have observed here, the linear density. If we change the linear density with the change, so there is no significant impact of thermal resistance ok. So, insignificant effect of linear density of fiber on thermal and evaporative resistance, so there is no such impact on thus. But, as we increase the mass per unit area, so mass per unit area if we increase, the thermal resistance will increase, so that the reason we have already discussed earlier. With the increase in punch density, similar trend is observed here. So, if we increase the punch density, we have observed here the reduction in the thermal resistance. The reason is same, because it is a entrapped air, fabric becomes compact, entrapped air quantity is reduced. So, finally, it gives lower thermal resistance.

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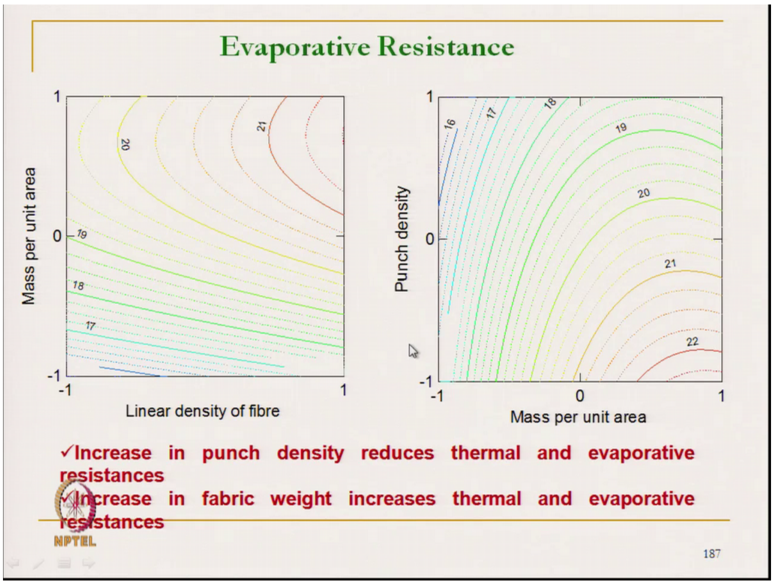

Now, coming to the evaporative resistance here; so, increase in punch density reduces the thermal and evaporative resistance. So, this evaporative resistance also it is a, this is the mass per unit area, the evaporative resistance also increases. So, this is the, with the increase in mass per unit area, and the linear density has got least effect. So, increase in fabric weight increase the thermal and evaporative resistance ok. So, punch density if you increase. So, if we increase the punch density, the evaporative resistance it decreases ok, it reduces the evaporative resistance. So, from 22, it comes out around 18, so that type of evaporative resistance, it reduces with the increase in punch density.

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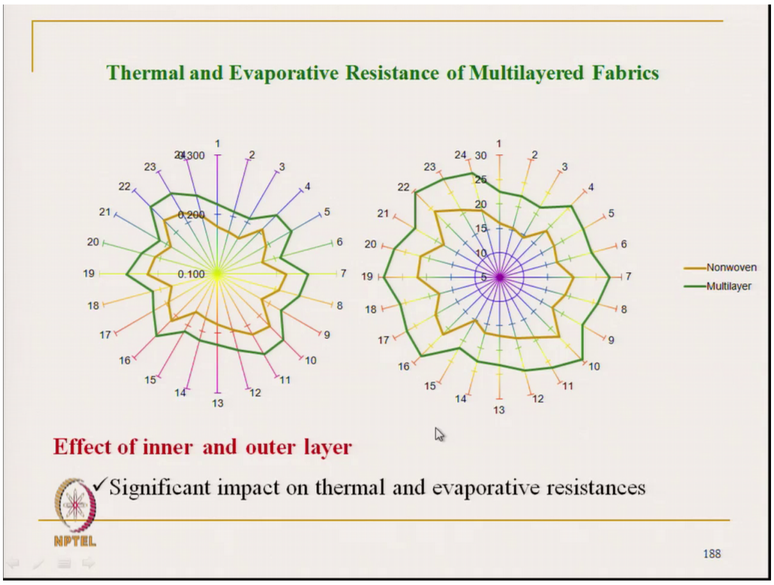

So, here again the similar trend is observed for thermal resistance and evaporative resistance. So, in thermal resistance here, the inner and outer layer has got less effect than the evaporative resistance. The significant impact on thermal and evaporative resistance is there here for nonwoven fabric, but the effect is more in case of the evaporative resistance.

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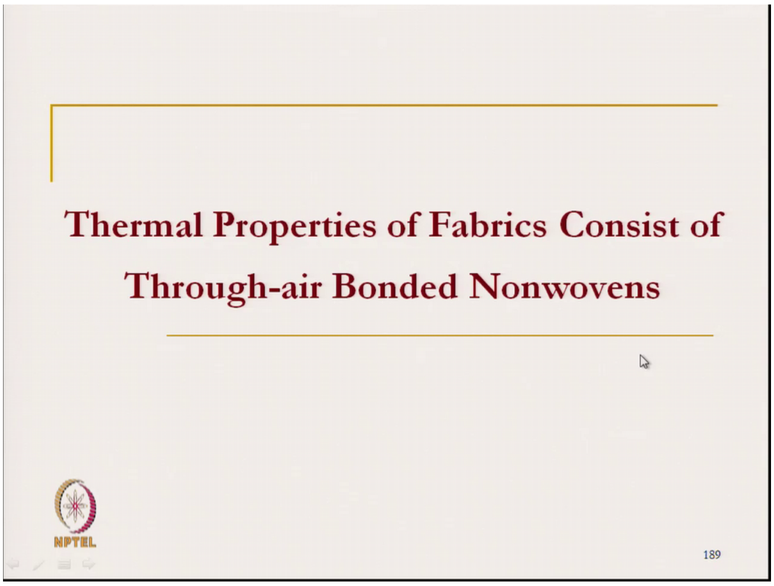

Our next study is the, which is the last in this segment, it is the thermal properties of fabrics consists of through-air bonded nonwoven. So, in earlier study what we have observed, the it is a nonwoven needle punched fabric. And in this study, we have used a through-air bonded nonwoven fabric. The through-air nonwoven fabric has got its characteristic, it is a highly bulk, and high amount of air is entrapped inside the structure. And the fabric is as it is a bonded, so it is resilience characteristics is very high, it comes out from its come compression, it retains is its structure pore structure. So, it was thought that this fabric will give better insulation better thermal insulation, and also we wanted to study the evaporative resistance. So, for to use this fabric as a one of the inner layer; one of the layer in the extreme cold climate clothing, it is mainly middle layer.

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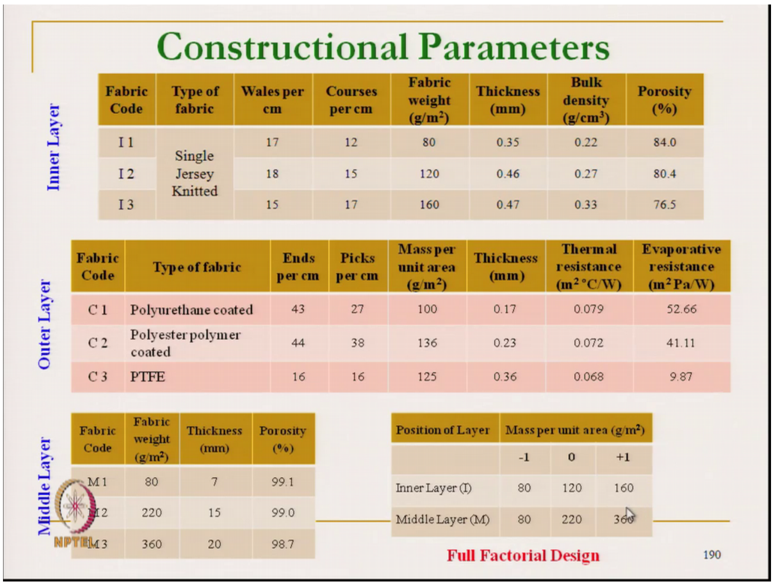
Constructional Parameters

Inner Layer

Fabric Code	Type of fabric	Wales per cm	Courses per cm	Fabric weight (g/m²)	Thickness (mm)	Bulk density (g/cm³)	Porosity (%)
I 1	Single Jersey Knitted	17	12	80	0.35	0.22	84.0
I 2		18	15	120	0.46	0.27	80.4
I 3		15	17	160	0.47	0.33	76.5

Outer Layer

Fabric Code	Type of fabric	Ends per cm	Picks per cm	Mass per unit area (g/m²)	Thickness (mm)	Thermal resistance (m² °C/W)	Evaporative resistance (m² Pa/W)
C 1	Polyurethane coated	43	27	100	0.17	0.079	52.66
C 2	Polyester polymer coated	44	38	136	0.23	0.072	41.11
C 3	PTFE	16	16	125	0.36	0.068	9.87

Middle Layer

Fabric Code	Fabric weight (g/m²)	Thickness (mm)	Porosity (%)
M 1	80	7	99.1
M 2	220	15	99.0
M 3	360	20	98.7

Position of Layer	Mass per unit area (g/m²)		
	-1	0	+1
Inner Layer (I)	80	120	160
Middle Layer (M)	80	220	360

Full Factorial Design

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So, here what we have used here in the inner layer, it is a knitted fabric is used. Three different inner layers are used I 1, I 2, I 3 that is a single jersey knitted fabric with different characteristics ok. And the outer layer in outer layer what we have used, it is a coated fabric. Here the polyurethane coated fabric, polyester polymer coated fabric, and PTFE coated fabric. And here we have used different the parameters. And in this outer layer, we have taken we have measured the pore size, pore size of this outer layer. And pore size of the outer layer has been taken as a one of the experimental parameter here. From it is made up all these ends per inch, picks per inch, and all these fabrics, and with different types of coating.

And middle layer, here we have used three different that air through-air bonded fabric, 80 grams per square meter, 220, and 360 gram per square meter with thickness 7, 15 and

20 millimeters with porosity is more than 99 percent. So, around say 90 percent 98 percent. So, these are the porosity even very highly porous fabric. And with three different mass per unit area we obtain used. And here the inner layer, it is a 80, 120 and 160 inner layer is taken. And middle layer, it is a 80, 220, and 360 are taken. As I have mentioned that outer layer we have used the pores, it is a GSM is not the criteria we have taken, we have used the pore size. We have tried to understand the effect of pore size on this thermal and moisture vapor transmission of the multilayer clothing.

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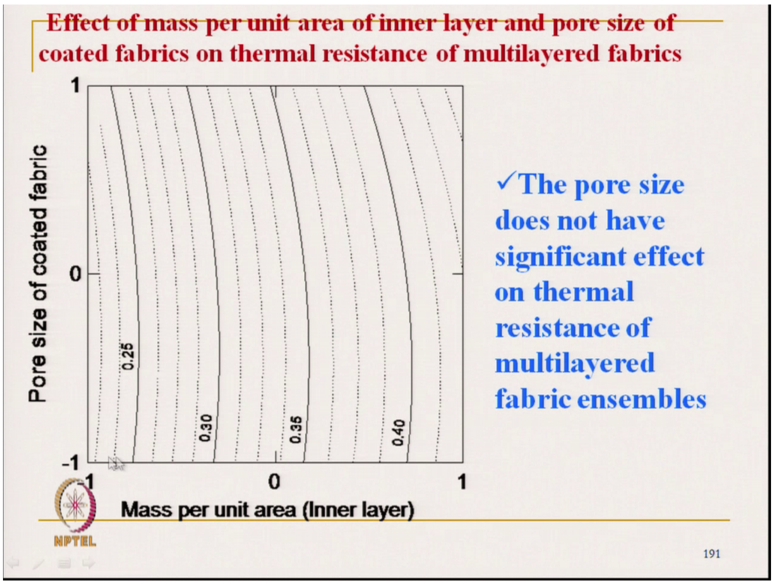

Now, here what we have seen we have that effect of mass per unit area of inner layer this is the mass per unit area of inner layer and pore size of the outer layer coated fabric that is plotted in this contour curve on thermal resistance of multilayer fabric. So, what it is showing? The mass per unit area of inner layer if we increase if we change mass to mass per unit area of inner layer there is a clear increase in the thermal transmission characteristics. So, the so a thermal insulation value it increases. But if we change the pore size pore, pore size of the a coated fabric outer layer fabric it has got a least effect there is no effect. So, pore size do not it does not have any effect on thermal transmission of multilayered fabric. So, if the pore size is changed little bit, it does not affect the thermal transmission of a multilayer clothing.

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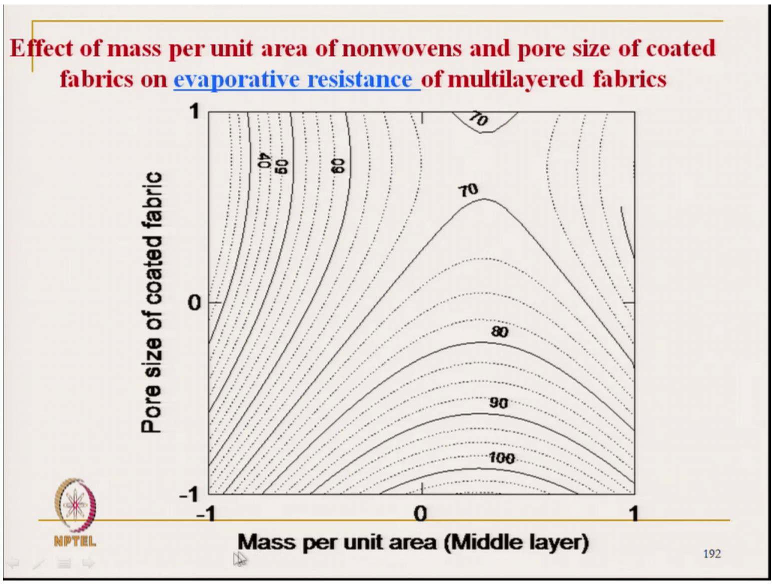

Now, let us see the mass per unit area of middle layer that is a through air bonded layer how it does it affect the evaporative resistance, so and the pore size of outer layer coated fabric. If we see that if we increase the pore size of outer layer, the evaporative resistance reduces which is very good idea that is a; it does not affect the thermal transmission, but it affects the moisture vapor transmission. So, moist it allows the moisture vapor transmission nicely it is a easily. So, evaporative resistance is reduced from say 100 to 70, so that much reduction in evaporative resistance if we change the pore size of the fabric. But interesting thing is that here the mass per unit area if we increase the mass per unit area, initially the evaporative resistance increases.

So, this is the it is a increase in evaporative resistance fabric is giving higher and higher evaporative resistance, but after certain time that evaporative resistance drops after certain thickness of fabric. So, that means, there is something that is the moisture vapor pressure has dropped suddenly. So, this the what we have studied; we have studied try to understand the reason behind that then in this what happened as the mass per unit area increases that is the it is our through air bonded fabric. So, if we increase the mass per unit area, we can see here the thickness has changed a lot.

So, from M 1 first fabric to M 3 fabric the thickness has increased a threefold increase in thickness, so that means the moisture has to travel a longer path. So, due to that during travel the moisture has actually started condensing in between; it started condensing within the fabric structure. So, suddenly the moisture vapor resistance evaporative resistance drops here.

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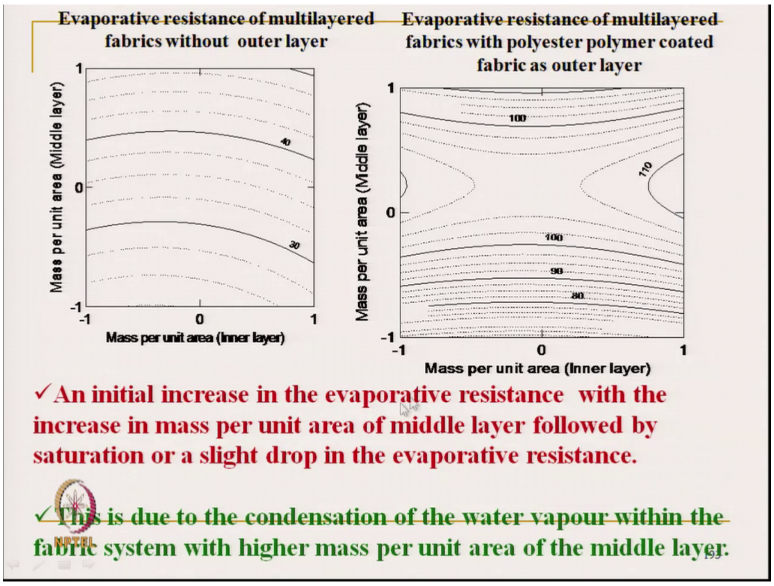

So, an initial increase in evaporative resistance with the increase in mass per unit area of middle layer followed by saturation or slight drop in evaporative resistance, so that is a it is a due to saturation that is a drop in evaporative resistance. This is due to the condensation of the drop in evaporative resistance. So, this is due to the condensation of water vapor within the fabrics system with highest higher mass per unit area that means higher thickness.

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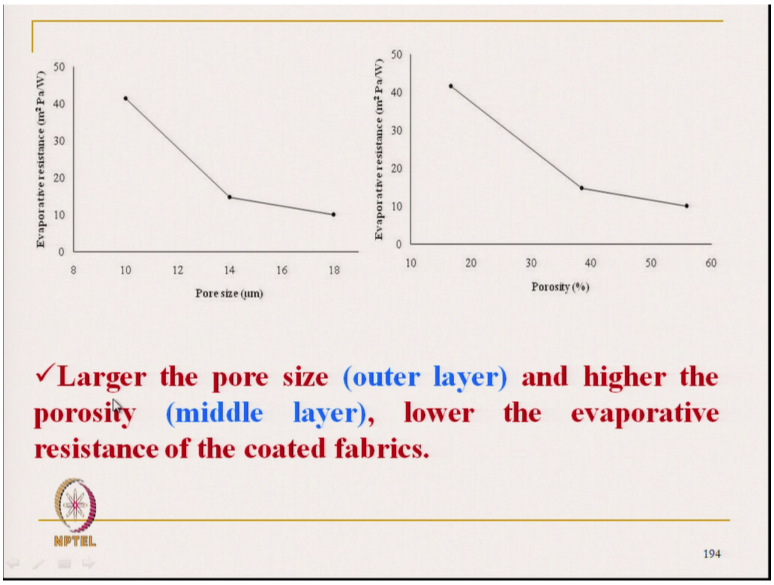

And you can see that larger the pore size that is the at outer layer. So, the evaporative resistance it drops. So, higher pore size, if we see though it will actually reduce the evaporative resistance due to the fact that the moisture can flow freely and the porosity with the increase in porosity the evaporative resistance, again drops that porosity of the mainly middle layer. So, if we have to reduce the evaporative resistance, so we have to use the outer layer with the larger pore and middle layer with a higher porosity, so that will in a in a multilayer clothing to reduce the evaporative resistance that means for better flow of moisture through the fabric system.

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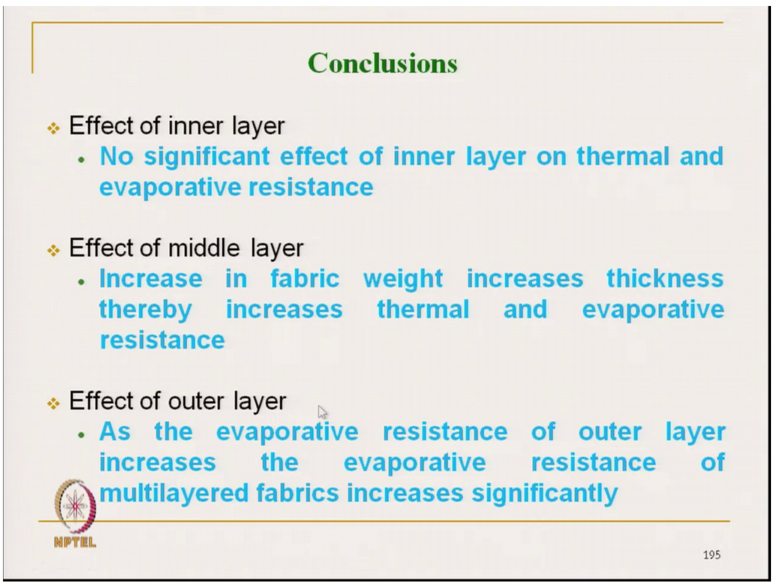

So, you can conclude now. So, the effect of inner layer; so, what we have observed that there is no significant impact of inner layer on thermal and evaporative resistance of total fabric assembly because as we have seen that inner layer is it is an open structure wave heated fabric. So, single jersey of heated fabric. So, it is a open structure. So, it is a impact is least in terms of thermal and evaporative resistance. Whereas, the middle layer has got its impact direct impact on thermal and evaporative resistance and the mass of fabric that is the middle layer its weight; as its weight increases the thickness also increases and which controls the thermal moisture vapor transmission. So, at as the thickness increases that the moisture vapor path of moisture vapor will be longer, so it will increase the chances of condensation.

And so if it gets condensed, so its evaporative resistance will change sometime, it has been observed that the thickness if it is high particularly in this case where through air bonded is used with the high bulk. So, during its travel the moisture vapor gets condensed due to the cold weather cold temperature and in extreme cold temperature sometime it happens that it gets condensed, and it is it becomes liquid; and sometime in extreme cold temperature it becomes ice. So, that will give negative impact on thermal insulation, and total fabric assembly total clothing assembly will lose its insulation.

So, it will actually then the heat from our body will actually start going out. So, our body will feel extremely cold. So, this type of we have to take care when selecting the middle layer that the thickness should not be too high. So, we should not have this type of problem of using the thermal insulation. And the outer layer effect of outer layer is its very significant particularly in the moisture vapor transmission. So, evaporative resistance is controlled by the basically outer layer. So, if the outer layer has got higher evaporative resistance the total multilayer structure will give the higher the evaporative resistance, but thermal resistance for thermal resistance outer layer has got its least effect that we have already seen.

So, we can conclude here, we can stop here for the, that thermal transmission segment. So, in next segment, next class, we will start the thermal comfort clothing comfort related to moisture, and in the form of liquid and vapor transmission

So, thank you.