Science and Technology of Weft and Warp Knitting
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Module - 12
Lecture - 49
Technical Applications of Knitting

Welcome participants. Now, in this particular final lecture, I am going to focus mainly on the technical application of knitting. Though you have seen weft and warp knitting are used in garments as well. But now, the key idea is to explore the knitting potential in different technical fields. So, I have selectively chosen some of the technical areas where knitting is having promising potential.

I have some of those products also, where you can figure it out how different types of knit designs are used. And there are some engineering aspects are there in those product development. So, the list is not only limited to only few technical areas, but definitely the list is broad. And I expect you to keep following many other literature and exploring other products of knitting.

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Let's move to the first application of knitting; is the shoe application. So, knit structures are now being used in shoes.

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So, in shoes, mostly they use weft as well as warp knit structures in making the shoe uppers. But apart from shoe uppers, they are now also making completely sockless shoes made up of knit structure. And the beauty of knitting is, not only you can just make the product, but also you can create very beautiful surface design on this product. So, that's why knit become very, very popular.

Warp as well as weft knitting, both are used in knit structure. But the key question is, how you can actually control the fabric properties for these shoe structures. Usually, if you see a weft knitted structure, they are very highly flexible and extensible. But in reality, you might have used some of the knit based shoes. But usually, those shoes are not that extensible, although it has the loop architecture in the fabric. But how is that possible?

What material we do use in these type of knit structures, so that, despite having loops, they become inextensible; and you can control the extensibility as well.

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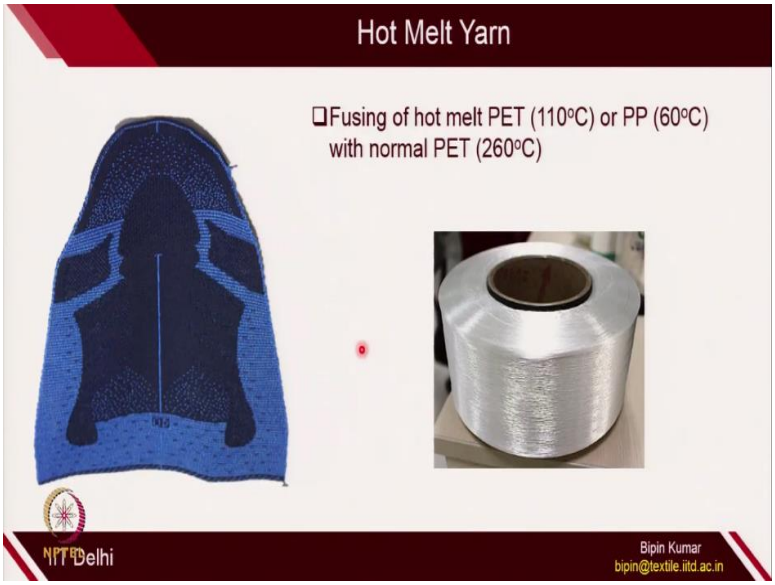

So, in reality, if you see a shoe uppers, it is a part of fabric. So, first, you create a fabric on, especially on jacquard machine. You can also create on warp knitting machine. But to get a desired extensibility in the fabric, we use hot melt yarn. So, hot melt yarn is actually fused with the normal filament like polyester or nylon or PP. So, usually we use hot melt PET which has the lower melting point, 110 degrees; or hot melt PP, polypropylene which has around melting of 60 degree Celsius.

And then we combine these 2 filament with higher temperature polyester which is around 260 degree Celsius. So, once you fuse this 2 different types of filaments and create a fabric structure; so, wherever these hot melt get melt and it lock that particular loop. Hence, you control the extensibility in the fabric structure. I have some samples with me where you can see how these are created; what type of knit designs we do use in making these type of structures.

So, I have a structure made on weft knitted category. So, the shoe upper. I somehow, I got it procured from one of the company which were making the shoe uppers. So, definitely, in a shoes, you have different parts. You have the foam; you have the **(Video Starts: 04:28)** braided laces; but the key part is the upper, upper portion of shoes. So, upper portion of shoes is nothing but a kind of fabric which, with multiple colors.

And you can see different types of designs are also created. So, not only you are changing the colors, but also the designs you are also changing. So, if you carefully see this structure, you can easily find out, this is a loop structure. Okay. So, you can easily see, this is a knitted

structure. Okay. So, and this is a weft knitted structure. And all the design principle which I already explained you in previous lectures, how you can hide different colors of yarn.

So, you can see here, black color yarn, as well as white color yarns are used selectively to create different patterns. And also, you are doing widening. So, you can see here, we are doing the widening. So, widening end has been used. Okay. And also at the edges, you are using rib design. So, naturally, the design which is used to hide the yarns are jacquard. So, if you see on the top side.

This is actually the face side of the shoe upper, on which you have different patterns. So, you first cut the fabric; and then you paste it on the foam of the shoes. Then it will give, get the look of shoes. So, this is how you do the pasting. So, pasting and other part is sticking with the foams is; many companies are doing it separately. But ideally, the one component of shoes is the shoe uppers, which usually use the knit design principle.

And what type of yarn do we actually use is hot melt as well as a normal filament. So, either polyester and nylons are used. So, this is your normal filament which is there. And this white one which is a hot melt. Okay. So, this is the white one. So, what happens when you mix these 2 filament and create a fabric structure. Once you compress it at a high temperature, these filaments actually melts.

And because of that, despite having loops in this structure, the structure become less extensible. Okay. Because of the fusing of hot melt yarn. So, that is one of the key principle of controlling the extensibility. So, if you use more amount of hot melt yarn, the fabric will become very rigid. Okay. But if you use less amount of hot melt yarn, the fabric will be very extensible.

Also, you can use pointelle design, tuck design, float design; depending on what type of creativity you want and what type of looks you want to give to the shoe structure. But this is how a shoe upper has been used. And if you want to see what jacquard we have used. So, you can clearly see, here the pointelles are also being used. These holes are basically pointelle. Okay.

And if you see the other side, basically we are hiding the yarn. So, other side, the looks remains similar. So, basically, here we use either birdeye jacquard and rib jacquard. So, these are the 2 jacquards we use in making this shoe upper. And if you remember, I have showed you different types of jacquard: tubular jacquard, float jacquard, birdeye jacquard. So, different types of jacquard I already showed you.

So, this is the tubular jacquard. This is your birdeye jacquard. This is your float jacquard. So, because here has the float. And this is your rib jacquard. So, if you carefully see the design on the backside. So, how this colors are hidden here. So, if you see the backside, so, it also has the similar sequence. So, actually rib jacquard are used to create this particular fabric. So, not only design, but also the material plays a important role.

Because, how much amount of fusing yarn and normal yarn, you are mixing it, you can control the property. **(Video Ends: 09:36)** So, let me show you the importance of fusing yarn as well. So, here is the importance of fusing yarn. So, **(Video Starts: 09:45)** this is the normal fabric which was created with polyester. And you can see it is highly extensible. But after mixing this with a fuse yarn, it is basically lock the structure, because the fuse get melt and the loops get locked.

So, this is how these 2 structures are different. So, depending on how much amount of fusing you are using in the fabric, that will decide the extensibility of the fabric structure. So, in this particular structure, if you carefully see, the fuse are actually melted at different locations. But if you see this particular structure, there is no fusing. So, you can easily able to extend it. So, one without fusing; another one with fusing.

And in this shoe upper also, it is created after mixing with the fusing yarn. **(Video Ends: 10:48)** The fusing yarn usually has in low melting temperature, either polyester, low melt polyester 110 degree or low melt polypropylene 60 degree. And it is mixed with normal polyester which is around 260 degree or nylon to create a shoe upper.

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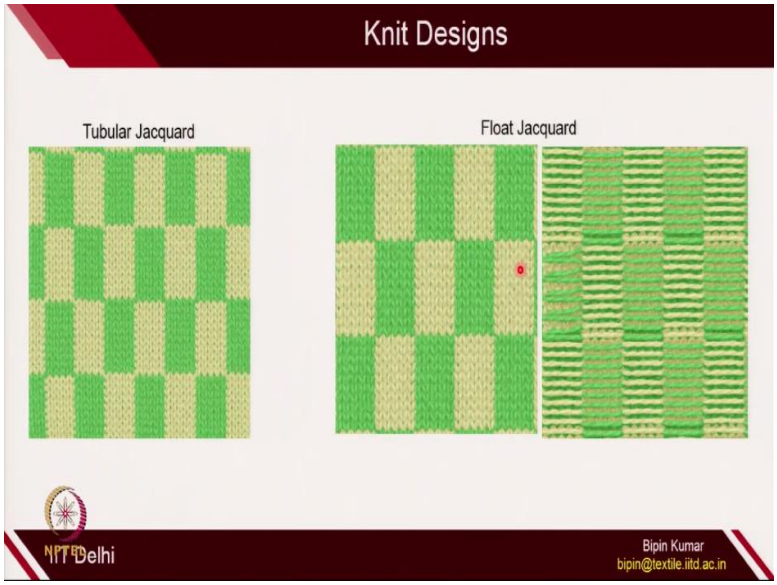

And knit design, sometimes we use tubular jacquard and float jacquards. But here also, rib jacquards are used.

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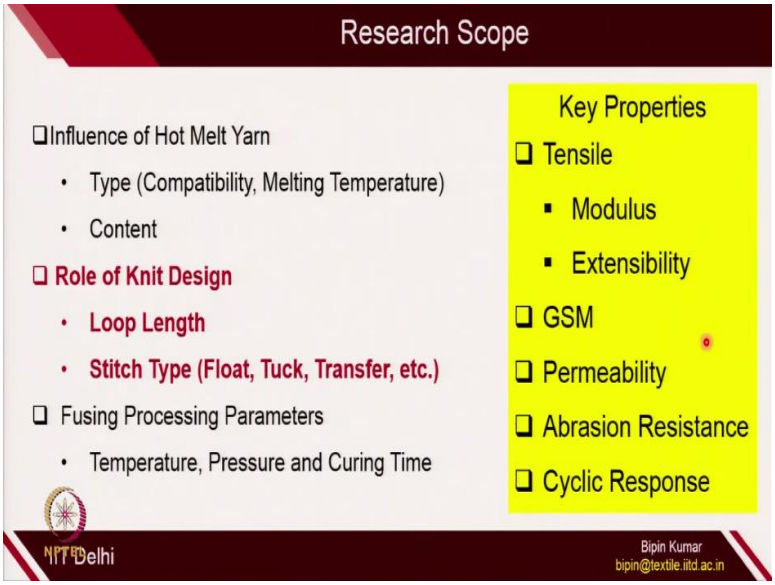

So, if you want to work in this shoe design aspects, you can also see the influence of hot melt. What type of hot melt yarn you are using and how they are controlling the properties? What is the content or the compositions we are using; whether using 10%, 20%, 30%. Roll of knit designs: So far we used the jacquard design. But also, you can play with different stitch type and see the properties.

Also, whenever we are going for fusing process or the composite process, the influence of temperature, pressure, curing time can be also checked. And you can see how the properties of this shoe uppers changes in terms of tensile characteristics, GSM, permeability, abrasion

or cyclic. So, many scopes are there. So, if you are really interested, you can pick any of these small project from shoe part; and keep doing research; and explore knitting in this area.

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Now, let's move to second area which is surgical mesh. So, surgical mesh is very, also very, very important, where whenever there is any surgery, especially in hernia meshes. Hernia is one of the key medical problems, where we do the surgery. We cut the component of certain part of the body and we provide some mesh or support surface. So, surgical meshes are also one of the key market of weft and warp knitted structure.

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And here, mostly warp knit designs are used. And it provides support surface near to the surgical area. And once it provide the support surface, depending on the fibers and the pore size and volume, the cell growth is controlled. So, you can see it here. So, this is one of the

mesh which is created by the loops of the fabric. If you zoom it, it will look like this. And these are how the cells growth and do the wound healing.

So, usually in surgical mesh, the materials that are used for creating surgical mesh are PP, polyester, polytetrafluoroethylene. Those type of meshes are used. But from the engineering point of view, from the structure engineering point of view, warp knit designing is also very, very important here.

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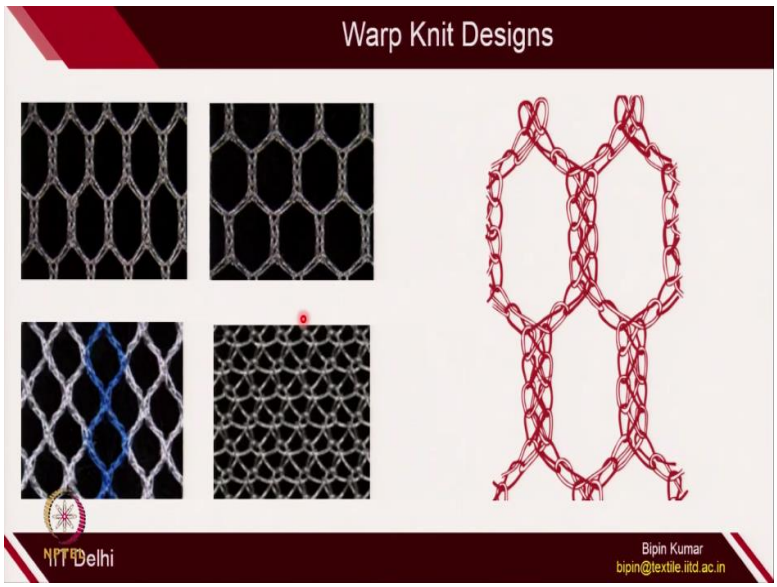

So, anyone who is actually working in the mesh areas, they need to understand the warp knitting very carefully. Because what will be the dimension of these meshes actually play a important role in terms of cell growth and tissue engineering. So, this mesh will have different responses. If you change its pore size and dimensions. So, warp knit designs here, plays a very, very important role.

So, in one of the lecture also, I showed you how you actually control the size of this mesh with the help of loops. So, I have many types of meshes with me, where you can actually see how I can control different types of structure. So, let me show you different mesh which is possible of different sizes. **(Video Starts: 14:39)** So, if you see from the left, the this, here the mesh size is very, very small in mm.

Here also if you see, compared to the blue one, the mesh size is slightly bigger. If you go for even different mesh size, here little bit bigger holes are there. If you further go, this one, here you can see, the size are even bigger. And then, if you go, here the size are even much, much

bigger. And the finally, the last one, whose size is even much bigger. So, you can see how warp knit gives you the flexibility in terms of controlling the mesh size.

But the key idea here is, even if you have to really control the mesh size in a warp knit structure, you need to really be confident on overlap and underlap variations **(Video Ends: 15:41)** that you can do it on the guide. So, as I showed you in the lecture also, if you really want to create these meshes, first of all you need to first understand what should be the right dimensions which is required for surgical mesh.

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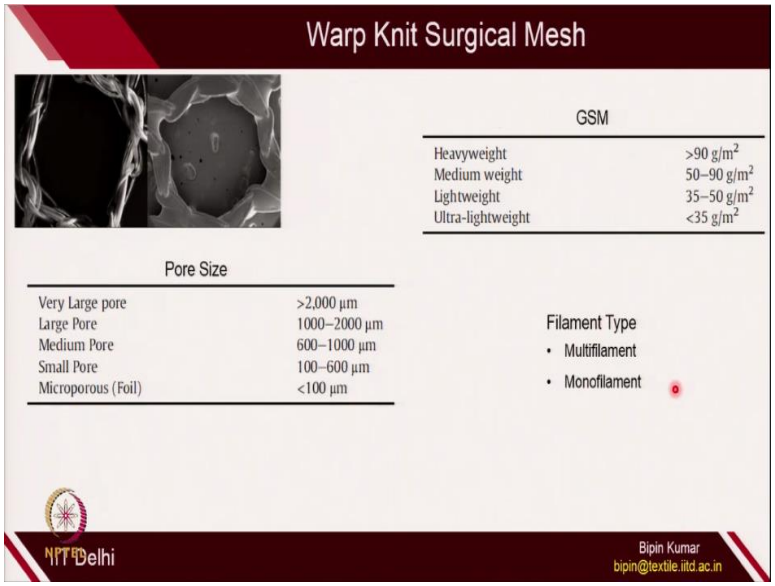

So, some standards are given, like the pore size. If the dimension is > 2000 micrometer, it is a very large pore. And if it is < 100 micrometer, it is a micro pores. So, depending on micro pores to large pores, the size of the mesh is different. And the GSM, actually, if the GSM is > 90 gram per meter square this is a heavy weight. And if it is < 35, then it is ultra lightweight. So, depending on the requirement, either you have to control the pore size or GSM. You can also use multifilament and monofilament yarn, if you want to create different types of fabric meshes.

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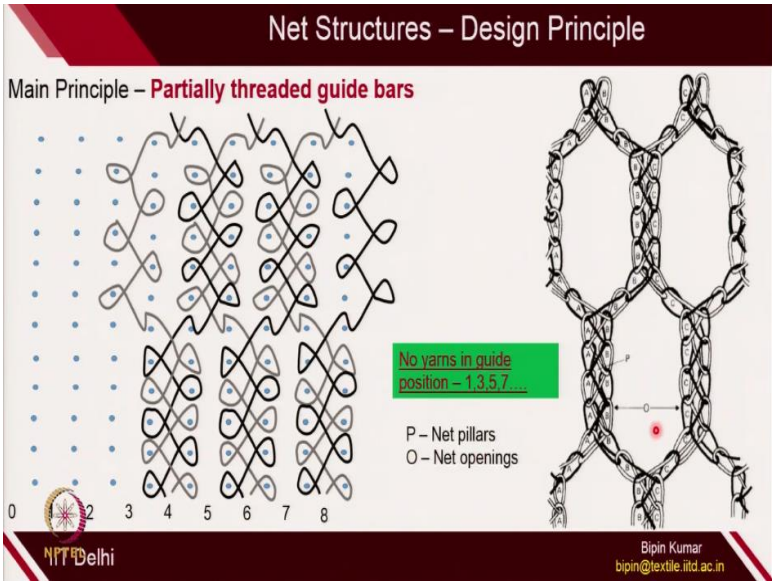

But if the design principle, if you really want to design a particular mesh, the main principle for making mesh is partially threaded design guide bars. So, in a guide bar, instead of filling the warp yarn in each guides, you actually place selectively some of the guides. So, in making a uniform net structures, usually alternate guides are kept empty intentionally, so that, a holes can be created in a warp knit structure.

So, for example, if you see the black and blue one, if you see the, follow the black yarn, so, it is actually making 5 loops in this pillar section. So, 1, 2, 3, 4, 5 loops in this pillar section. And then, it is shifting to next pillar section. So, this is the pillars, pillar height. And the warp yarn is first making tricot in this section. And then, it is shifting to next pillar. So, this is how it is moving between needles.

So, this particular guide bar which is there at the sixth position, it is actually moving to 3 needle position. So, first it is making a tricot. And then, with the help of open loop and it is shifting to third column or third needle. And again, here they are making a tricot in 2 consecutive columns. Similarly, if you follow the white yarn at the 6 position, it will be doing exactly in opposite direction.

So, the white yarn in this position. So, this is how it is doing. So, the black one is moving towards left direction, transitioning towards right direction. And the white one is transitioning towards left direction, which you can see it from here. So, here is the transition. So, the black one, after making loops, it moves to the right-side pillar. And white one after making loops, it moves to the left-side pillar.

And this is how the transition has been done. Similarly, the position at fourth position, they will be doing the same thing; eighth position and fourth position. So, you have, you can easily see the guide bars at fifth position, seventh position, third position and first position are empty. Because of this, these 2 pillars are not connected. So, a holes are being created. So, these 2 pillars.

So, this is 2 pillars are not connected and a holes has been created. So, this is what is opening is created. And because of having partial threaded guide bars. So, this is how you create the mesh. But overlap and underlap are very, very important. Because, the way you play with different overlaps and underlaps, you create different pillar designs and different shapes of this mesh. So, net pillars and opening. So, these are the 2 key thing.

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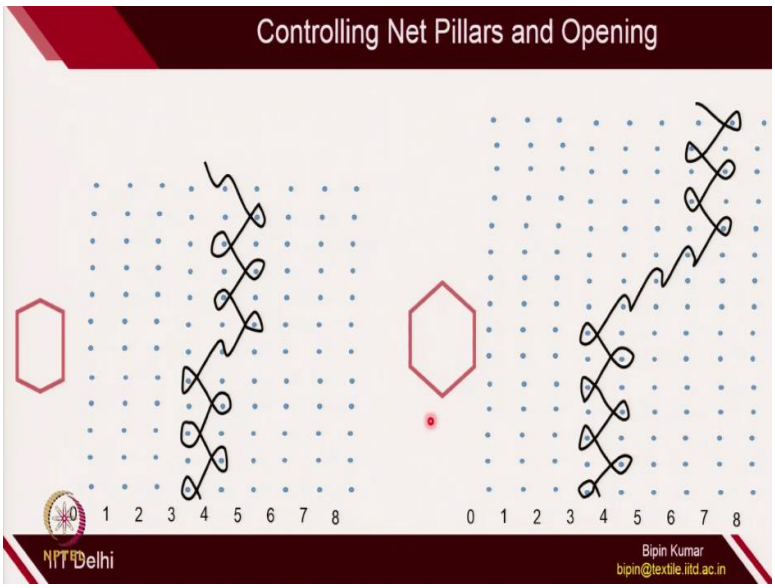

I also mentioned you, if you really want to change the shape of this mesh, you can change the shifting. So, for example, here, after making pillars, it is shifting to the third column. And here, it is shifting to the 1, 2, 3, 4, fifth column. So, this is how you can change the shape of the mesh. So, I have some from the literature.

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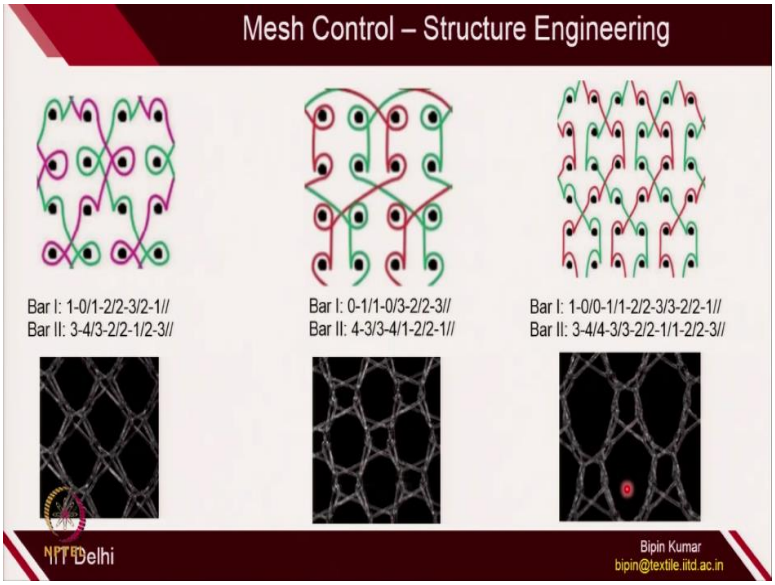

I founded some useful notation of lapping movement as well as lapping plan for bar 1 and bar 2 structure, where you can get different size of mesh. So, for example, if you want to create this type of mesh, this is the lapping plan. For bar 1: 1, 0, 1, 2, 2, 3, 2, 1. Bar 2: 3, 4, 3, 2, 2, 1, 2, 3. So, this is just the, a lapping plan. So, you arrange the chains in that sequence; and you will get this type of mesh.

Similarly, if you go for this type of meshes, here you can easily see, the holes are of different sizes. Some bigger holes and smaller holes are also created; compared to this one where all the holes are of uniform size. So, this is more uniform mesh. This is more non-uniform mesh, because it has bigger as well as a smaller size. If you go, if you see this one, the much bigger holes and smaller holes are there. So, this is how, depending on what type of lapping movement you are giving to bars, it creates different types of holes.

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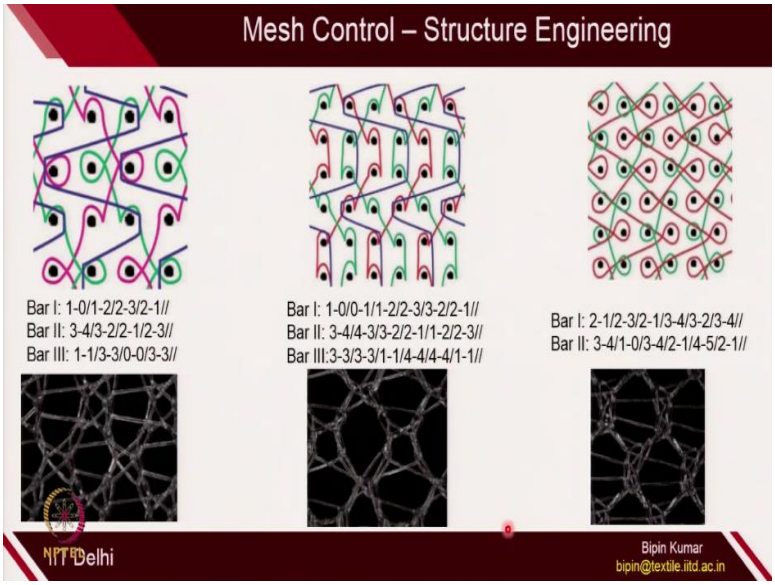

Also, sometimes you can also have more random types of meshes. So, these are 3 bar structure. This is also a 3 bar structure. So, here you are intentionally decreasing the size of the holes, because it actually helps in cell growth. So, naturally, this is the medical part. So, once you design this meshes, you can collaborate with some of the medical professionals. And you can create these type of meshes and see how the cells are growing on these surfaces.

So, that is again the engineering part. So, you need to understand 2, 3 different engineering. Not only just knitting is sufficient, but also you need to collaborate with medical professionals to work on surgical meshes. Because the design possibilities are important. Similarly, medical professional also would not be able to understand and appreciate the importance of warp knit structure. But then, naturally, when you collaborate together, you can do a smart engineering in surgical meshes.

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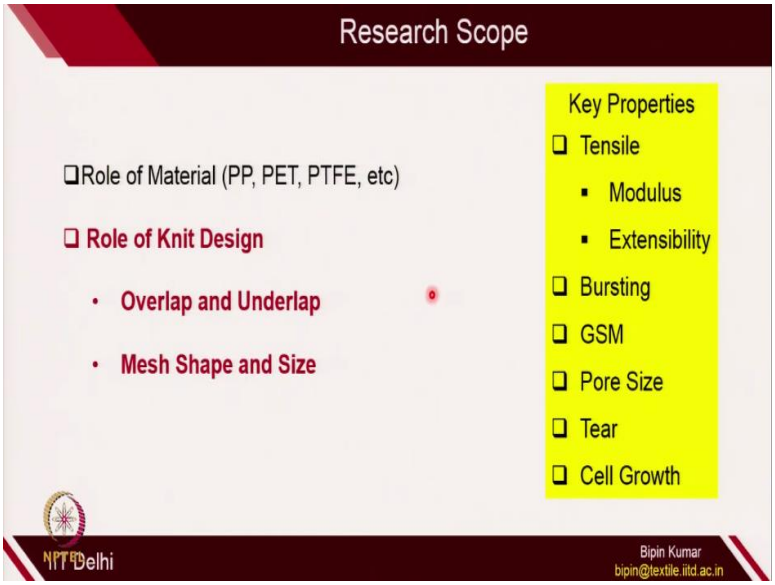

So, the research scope, if you see, there are different materials which is available: PP, polyester, polytetrafluoroethylene. So, you can change the material and you can see the performance of different mesh. From knitting part, you can change the overlap and underlap variation; you can control the mesh shape and size; and you can see the performance of mesh. So, key properties of the mesh that need to be studied is:

Like tensile; like, what is the modulus, extensibility, strength. The bursting properties of these type of meshes. GSM: Because, when you are playing with different overlap and underlap, definitely the GSM of the fabric will be changed. So, that also need to be checked. Pore size: You can also learn how overlap and underlap controls the pore size. Tear and cell growth.

So, all of these key properties, you can link. So, this is again a one good opportunities. If you are really interested and want to pursue some career in surgical meshes and medical one, you can use the importance of warp knitting in your field.

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Now, let's go to the third part, knitting for agriculture and construction. So, again, agriculture and construction is one of the key areas where warp knit structure are mostly used.

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Usually, if you see, in knitting; shade nets: For shading some areas, we use a fabric which is actually made up of warp knit structure. Windshield nets: For separating the fields or making some kind of partitions we use nets. That is again a warp knit structure. Sometimes we use anti-birds nets, insect nets to protect the crops. Crop covers; also sometimes we use mosquito nets. So, all those nets which is highly porous and give some advantage. Here we use knit, warp knit for making these type of a structures.

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So, whenever any of such meshes are used in agriculture textile or construction textiles, the key aspects has: The ventilation should not be bad. It is used in covering, but one need to make sure that there is sufficient permeability in the structure, because the good amount of moisture and air should be proper throughout this fabric structure. So, the ventilation is very, very important.

It should be also mechanically strong. Because of the wind, the fabrics should not torn out very easily. It should be very flexible, because the contours will be very difficult to match up. So, whatever warp knit structure you are using; apart from these 2 property, the flexibility is also very, very important. What type of materials you are using, because such type of nets are exposed to the harsh sunlight, water, wind.

So, all of these, it should be resistance with wind, water, sunlight. And also, it should be non-toxic. So, it should not harm the crops. So, agriculture textiles is also very, very important; and where warp knit structure is very popular. So, I have some of the samples with me. I can show you how they are used. So, how they can be used in different structure. So, this is **(Video Starts: 26:07)** one of the structure which is used in agriculture.

So, this is the pillar structure. And the second bar is just making the underlap connecting it. So, this is used in agriculture for shading. This is, this one is a insect nets. You can see, the pore size is very, very poor. So, only, it is a very good permeability, because it is highly porous. But the pore size is so small that no insects can come out. So, this is also used in **(Video Ends: 26:42)** agriculture.

This is insect nets. The another one is also; here you can see the much bigger nets. **(Video Starts: 26:51)** This is also used in agriculture for making partitions. And all this material are high density polyethylene. **(Video Ends: 27:01)** So, it is very, very strong; for protecting the nets. Here also you can see the net size is **(Video Starts: 27:08)** slightly bigger. So, it is used in mosquito nets and insects of those size, it can be easily trapped.

So, this is a mosquito **(Video Ends: 27:19)** net fabric. I have another set also, where you can see **(Video Starts: 27:30)** different types of shading. Because, sometimes to protect the crops from harsh sunlight, we use different sheds of fabrics of different colors. So, this is all made up of pillar stitch on one bar and only underlap on the second bar. So, if you see these 2 structure, the green one and blue one.

So, blue one is little bit porous, but the green one is highly non-porous. So, the shading, it almost shade almost 80 to 90% of the sunlight. This is of 60% sunlights. So, to protect this crops from different seasons, we use different types of shading. More open structures are also there. So, this is even more open. So, depending on what type of lapping movements you are giving, **(Video Ends: 28:34)** you can control the shading behavior.

So, in agriculture and construction also, there are lot of research scope you can go for. You can check different types of materials, especially PP, polyester, polytetrafluoroethylene is also used. Similar to surgical mesh you can play with different knit designs, overlap and underlap; different types of mesh sizes and shapes. Some of the key properties you can check is like tensile, bursting, GSM, tear and porosity.

So, these are the some of the research areas that need to be explored. Because, in the market, you will find these type of fabrics easily available, but you will hardly find any literatures which study on how having different types of materials and knit designs, how you can control the fabric properties. So, that is also a small project you can work on different aspects. So, in the next class, I will talk about more application related to e-textiles, which is a more demanding in this twenty first centuries. So, catch you in the next class.