Science and Technology of Weft and Warp Knitting
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Module - 11
Lecture - 47
Warp Knits: Multi-bar Structures and Double Bed Designs

Welcome participants. This is the last lecture in week 11. In this particular lecture, I am going to explain some of the complicated warp knit designs which is produced on multi-bar machines or double bed machines. Please remember, some of these structures are very, very complicated. I expect you to follow other literatures as well in the details. Although these structures are not used so much compared to 2 bar structures, but these structures are highly technical importance. So, in a specific applications, some of these structures are used. These structures are very, very complicated in natures.

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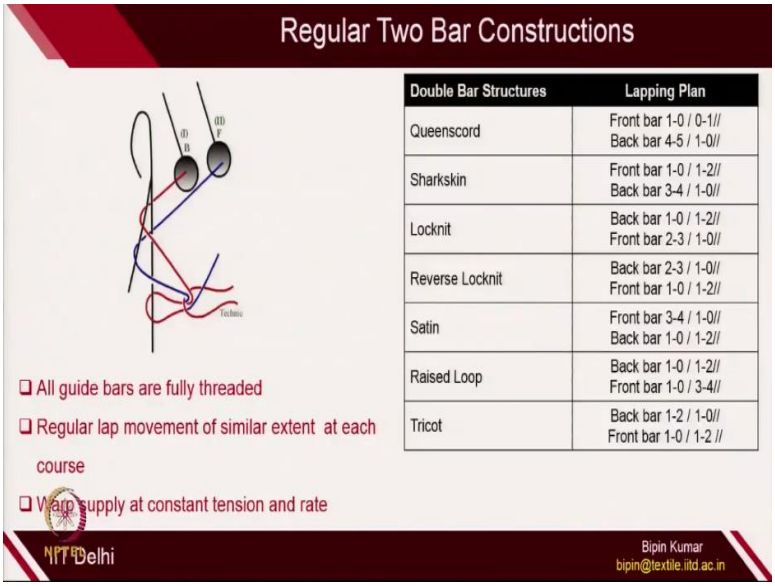

And their lapping plan and lapping diagrams are also complicated. I have selected only a few samples which was available to me. And I will going to explain you how these samples were created using multi guide bar or double bed raschel machines. So, let's move on. So, the first one is, what we have covered in the last class was 2 bar construction. So, in 2 bar constructions, we have seen the most common one was queenscord, sharkskin, locknit, reverse locknit, satin, raised loop and tricot.

So, the locknit was the most popular one, which has the lapping plan of 1, 0, 1, 2 in the back bar. And it has the lapping plan of 2, 3, 1, 0 in front bar. So, 70 to 60% of warp knit production actually follows locknit, because it is very much used in intimate apparel and lingerie. Other structures also give some specific properties. Especially, if you go for queenscord, it has the no underlap.

So, because of this, the structure is very, very rigid; while the back bar is very high underlap. Despite that, since the front bar is making pillars, due to which there is 0 flexibility in the structure. And the structure is very, very rigid. Sharkskin: the underlaps are there, but a smaller extent in the front bar. So, that is also very, very rigid compared to locknit structure. If you go for more extensible structure, the satin is the most extensible one, because it has the longest underlap in front bar.

So, if you have more and more underlap in the front bar, you will get very high extensibility. So, in the previous lecture, we talked about how the properties of different structures is controlled using the help of overlap and underlap; controlling their directions; and the positioning of back and front guide bar lapping plan. But in most of these structures, it has been decided that all the guides which is attached with both the guide bars are fully threaded.

So, each single guides on each bar is carrying 1 yarn. So, and also, most all the movement of the guides in all the courses are exactly equal. It means, in the first course, if the overlap is for 1 pitch; in the second course also the overlap is 1 pitch; so, the amount of movement or shogging movement in the each course does not varies. So, it results in very uniform structures.

And also, the warp beams were supplying the yarn at a constant speed. So, then only, we will get more uniform type of structures from 2 bars. But in reality, despite having controlling overlap and underlap, also controlling the uniform warp release from the warp beams, we have the flexibility of changing the threading of guide bars. So, we can, instead of fully threading the all guides of a bar, we can selectively threads different guides of the same bar.

Or, we can also change the extent of shogging randomly in the warp knit structure. Also, we can supply the warp at different tension intermittently during the fabric production. So, if we change any of these 3, then you will get a different kind of a structure. And the different

patterns and different properties of the fabric will come on the surface. So, some of these fabrics I have selected for you. And I am going to explain in the subsequent slides.

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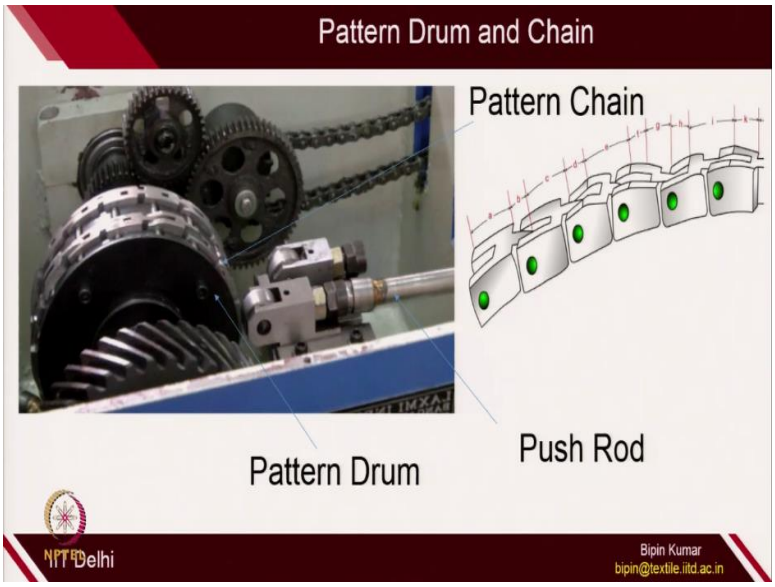

To make these 2 bar constructions, you have seen how we made the pattern chain and then put it on the pattern drum. So, the alignment of links is very, very important. So, in even more complicated structure, the link arrangement or drum arrangement will remain same. The only difference is how you are controlling the warp tension and how you are controlling the threading in guide bar.

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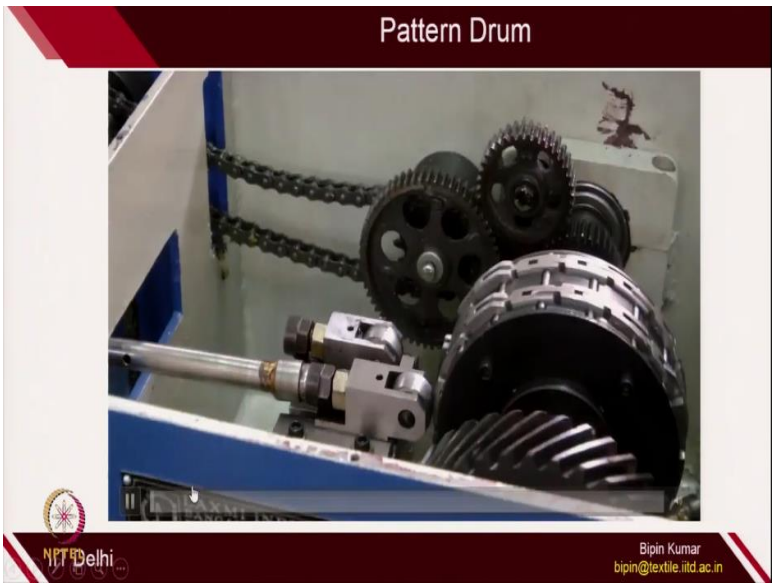

(Video Starts: 05:39) This is just the schematic of, it is a video of 2 guide bar structure. So, you can see the chain links for 2 guide bar. Now, let's move to some more **(Video Ends: 05:49)** complicated structure.

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The first one is the net structure. So, let me show you what do you mean by net structure. In a net structure, I have 4 types of fabric with me, which looks completely different. **(Video Starts: 06:03)** So, this is 4 types of fabric. So, if you carefully see these 4 fabrics, you will find, there is a spacing between the loops is increasing from left to right. So, if you see the first fabric, if you see the first fabric, if I zoom for you, it is highly dense, because there is no spacing at all.

But if you see the second structure, you can see the mesh or the open space between the loops is bigger. If I go for even more bigger structure, this is here, even much bigger mesh size. And here also, you can see, it is, the mesh size is smaller compared to this one, where the mesh size is bigger. We can also go for even much bigger mesh size. So naturally, all the fabrics are produced on the same machine, but we are getting different types of meshes in the fabric. So, how do we generate **(Video Ends: 07:18)** a net structure.

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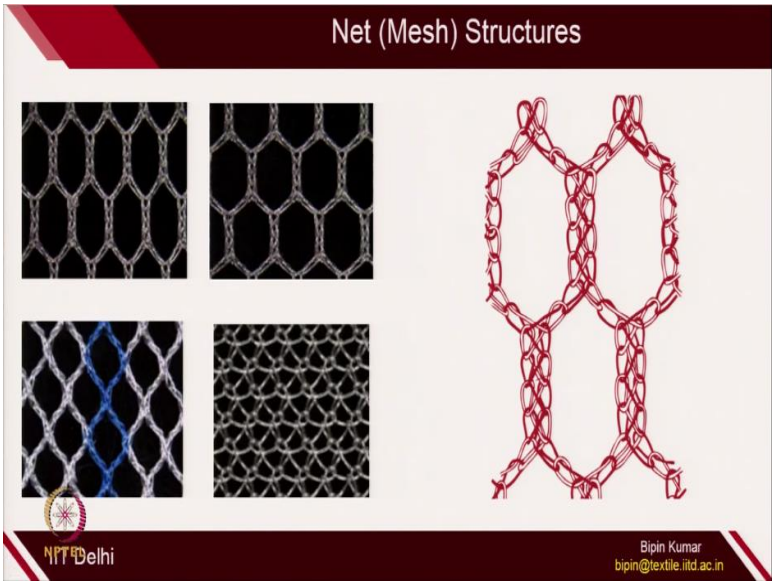

So, in net structure, if you see, is basically we call these type of a structure as a mesh structure. So, you will create a different kind of meshes or holes in the fabric structure. This was the highly dense loops and this is the more porous one. This one is also, it looks like a rhombus. This looks like a hexagonal. So, here also, the schematic if you see, this looks like a perfect hexagonal structure. So, how do we actually create these type of structures?

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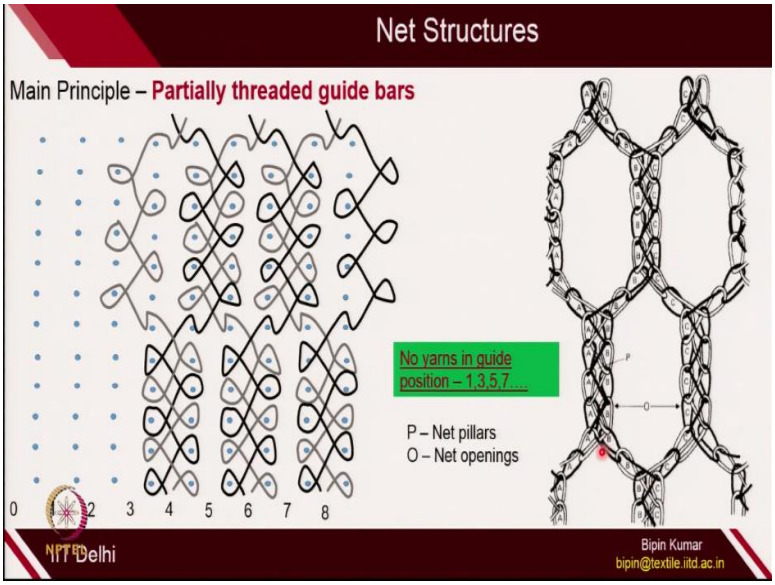

So, to create these type of structures, we do need only 2 guide bar on the machine. Just like front and guide bar for locknit or sharkskin. The machine will remain same, only what we need to do is the, we need to thread the guide bars selectively. So, in a regular warp knit structure where all the guides of each bars were filled with the warp yarns, but in case of net structures, we have to leave some guides empty.

So, what do you mean by that empty? Is like, if you see this particular structures, if you follow the path of black yarn. So, in this vertical line, if you follow my cursor; so, in this vertical line, if you follow the black yarn, it is moving alternatively in 2 columns. And then changing the directions, if you start from here. So, it is moving in 2 columns; then changing to the next vertical line; moving in 2 columns; then coming to this side of the hexagonal.

So, how do we actually make this? So, if you follow the lapping diagram of the black yarn, this will be look like this; or the white yarn. So, it is doing tricot for few courses. Then it is switching and moving to the next column and again making tricot. So, in this way, it is switching from one side to other side. So, this black yarn or if you see the white yarn. So, this is shown for the white yarn.

If you follow the black yarn, it is also doing the tricot and then switching to the next column. So, this is done by the yarns which is attached with the sixth position. So, the guides at sixth position is doing these type of lapping movement. So, one guide which is attached with the back bed is following the path of white yarn. And the another guide which is attached with the front guide bar, it is making the lapping plan followed by the black yarn.

So, this is how this structures is created. Now, the question is; if you see the sixth position guides, they are making the lapping plan like this. Similarly, if you go for the fourth position and eighth position, there also, these 2 guides at fourth position from back guide bar and front guide bar, they will be also moving the exactly same fashion. So, if such pattern is achieved on the machine, you will realize the guide bar at position number 5 and 7 is not doing anything.

So, the column which is generated by the needle between 4 and 5 position and the needle between 5 and 6 position, they are not connected at all. So, these 2 columns are not connected. So, this is, because of that, you will get some this kind of opening. Because, the needle between 4 and 5 position and 5 and 6 position, they are not connected at all. Similarly, if you go at this position, the needle at sixth and seventh, they are not connected.

So, between 5 and 6, this needle; and between 6 and 7 guide position, this needle are not connected. So, since they are not connected, because of that, you will get the second opening. So, this is how the net structure is connected. So, if you carefully see the guide position at

odd number; third number fifth number and seventh number has no role to play. So, no role to play means, it is not carrying any yarn at all.

So, it is just doing the swinging motion. It cannot provide overlap or underlap of any warp yarn, because no warp yarn is attached to guide position number 1, 3, 5, 7. So, if no warp yarn is attached to such position, because of that, 2 adjacent columns will not be connected. And a opening will be created in the fabric, resulting in net structure. Okay. So, if you see this particular net structure, the structure has 2 characteristics.

One is net pillars. So, this vertical line. The distance of this vertical line is the net pillars. And O is the net openings. So, distance between 2 vertical lines, this is the opening. So, dimension of the net structure actually depends on what is the pillar you are achieving and also how much opening you are created. So, the opening is actually done with the help of transition. So, if you see carefully, here also, after doing the pillar, it is actually doing the transition to the third column with the help of closed loop, open loop and again closed loop.

So, this is what is happening here also. So, after completing the pillar, the guide bar is changing the position along this side of the hexagon. And all guides are doing exactly the same sequence. So, all even number; 0, second, fourth, sixth and eighth are doing exactly same sequence. All odd number guides of both the guide bar is not having any yarn. Because of that, you will get gaps between connectivity. So, this is how you control the pillars and the opening in the net structure.

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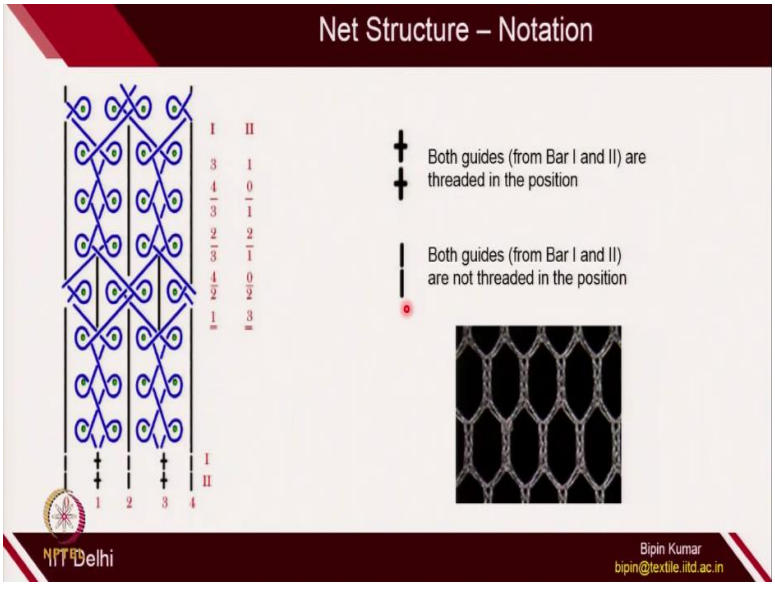

In reality, you have a different way of denoting the net structure. So, in net structure, actually you need to find out, not only you have to describe the position of guides, but also you have to explain which guides is carrying the yarn and which is not. So, plus plus, both guides from bar 1 and bar 2 are threaded in this position. So, for example, if you see this figure. So, first position and third position, both the guides are carrying the yarn.

And if you see 0, second and fourth position, which is denoted dash, dash; it means, the guides is not carrying the yarn. So, whenever we go for net structure, partially threading of the guides in each guide bar is important to create such kind of mesh structure. So, if you want to understand this. **(Video Starts: 15:10)** So, this is your needle and this is your guides. So, during the threading, you are not providing yarn to each guides.

Rather, you are selectively or partially providing yarn to some of the guides in the guide bar. So, because of this, whenever the lapping is happening with partially guides, some open structure is created in the fabric. And due to which you are getting these kinds of net shape; because some of the guides is not carrying the yarn. **(Video Ends: 15:58)** In normal conditions, alternate guides of both the bars are left empty; and we create very uniform net structure.

If you randomly select guides and fill, no concrete pattern of the fabric will be generated. The sequence of threading of each guides on each bar has to be properly selected for getting a particular type of net structure.

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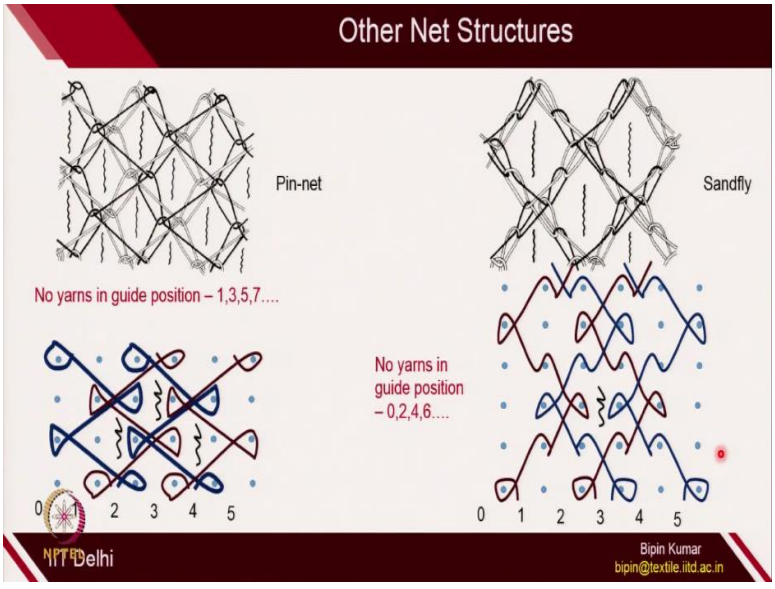

Some other net structure, if you are, which is very popular is, pin-net and sandfly. So, in pin-net, this is how it happens. So, it is based on tricot 2 cross 1. So, 2 underlap and 1 overlap. So, the first guide bar and the second guide bar in the second position is doing 2 cross 1 tricot in opposite directions. So, this is how it is happening. So, one is doing overlap from right to left and the other one is left to right.

This one is doing right to left and this one is doing left to right. Okay. And you get these type of structure. And here, you are leaving the guides in first, third and fifth position empty for both the guide bars. Okay. So, no yarns in guide position 1, 3, 5, 7. So, only even number is working. And they are making 2 cross 1 tricot. If you see sandfly net, this is also same. And you are also leaving the guides in selected positions.

So, the first guide is doing closed loop; open loop; then closed loop; then open loop; then closed loop. This is how it is following. So, it is a kind of atlas, having combination of both closed loop and open loop. The other guide in the same position is doing the atlas in opposite direction. So, here, closed loop in opposite direction; then open; then closed; then open; then closed; in this way.

And this is how, in the first position and fifth position is also doing. So here, the even number position guides are missing. Because of that, the opening is created between these loops. So, in most of the times, the net structures, the dimension of these meshes is dependent on how you are controlling the lapping movement of guides and what type of spacing or what guides you have left empty during the fabric formation.

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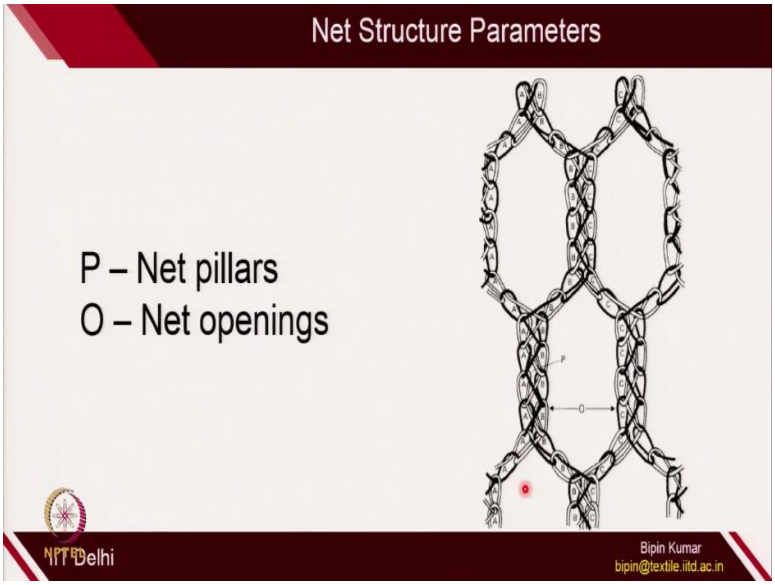

So, net structure parameters. There are 2 main parameters in net structure. One is the pillars, the vertical line of the mesh. And the O is the net opening. So, what is the distance between 2 vertical pillars. And the other sides are just the transition of guide bar from one pillar to next pillar.

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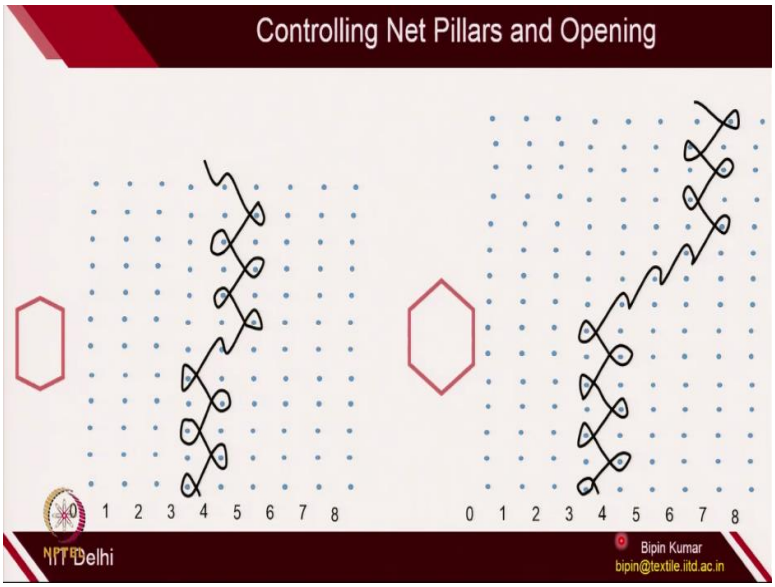

So, for example, if you see this particular, a simple example, just to give you a hint, how you can change the dimension of this mesh. So, here is the lapping position of both the guides. And in one case you are doing tricot for 5 courses. And then, you are doing the transition. You are just doing 1 transition with the help of 1 open loop. And then, again you are doing 5 course of tricot.

So here, the transition length is much, much smaller. And this length is higher. The pillar length is higher, because you are doing 5 course of tricot followed by transition for only 2 courses. So, because of that, the side length is very, very small. So, this one, you can follow. This is the line which is made by this. And this is the side length, which is smaller compared to the pillar length.

If you want more uniform structure, then you need to give more transition time or more courses of open loops at this position. So, for example, if you see, there are 6 courses of pillars. And then, for the transition, you are taking more and more open loops. So, because of that, thus, whenever the transition is happening, the loops is getting stretch more in that particular direction; and that side is much, much higher.

You need to have a very uniform geometry. The net pillars and openings can be controlled by the lapping plan. And the threading of guides has to be done intermittently. So, you have to thread 1 guide. And 1 guide next to the threaded one has to be kept empty. So, alternative guides has, is carrying the yarn. And this is how you create net structure.

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Now, let’s move to the inlay structure.

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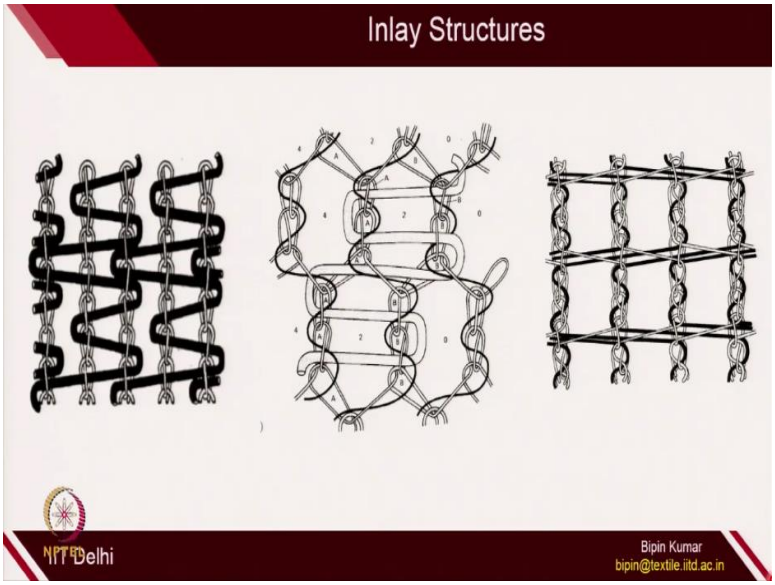

So, inlay structure is like, here the yarns are actually floating in the fabric structure.

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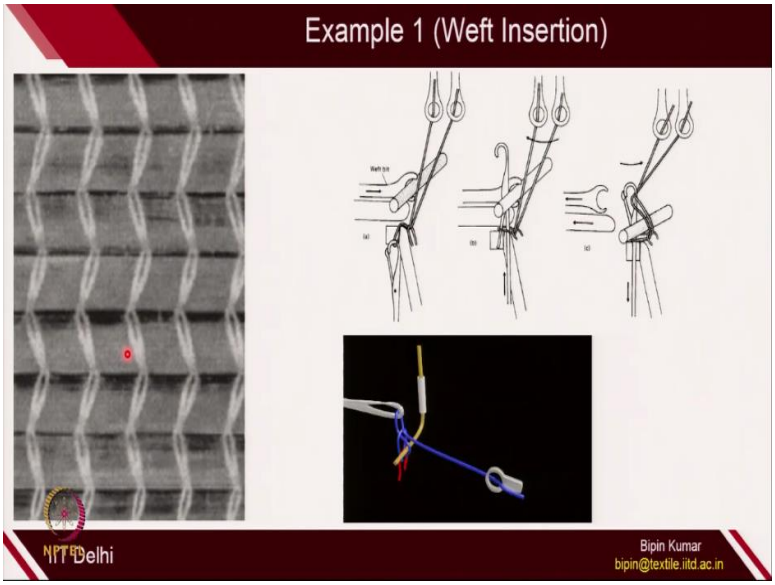

For creating inlay structure, the most easy way is the weft insertion. So, once the guide bar is at the back position, you can carry the yarn and put it at the back side of the needle. So, this is how **(Video Starts: 21:32)** you do the inlay. So, you put the weft yarn at the back side of the needle. And then, you are doing the overlap and underlap. So, because of overlap, the weft yarn is locked between the loops.

So, I have also made one simple fabric **(Video Ends: 21:52)** showing you how the inlay was created. **(Video Starts: 21:56)** So, you can see, this is the inlay yarn which I have inserted in the fabric structure. And this is the part of the fabric. So, you cannot pull it out, because it is

hold tightly by the underlap. So, let me show you how I created this. So, at the back side, I put it, I have kept this yarn in a floating way.

And once the guide bar switch from the back side to the front side, it automatically lock the yarn in this position. So, this is how you can create a inlay structure in a warp knit. **(Video Ends: 22:36)** So, weft insertion is one method.

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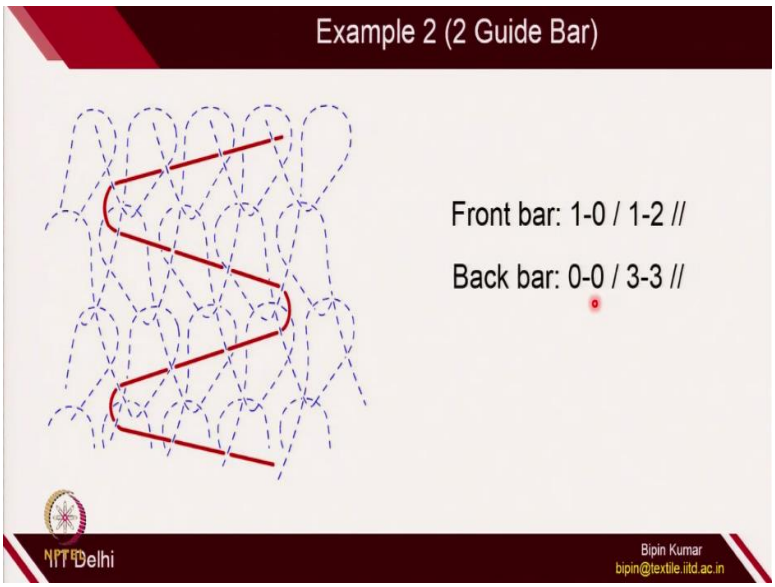

The second one is also 2 guide bar structure. Here, front one is making tricot 1, 0, 1, 2. And back bar is just doing underlap, no overlap. So, here they are 0, 0, no overlap; 0 to 3, underlap.

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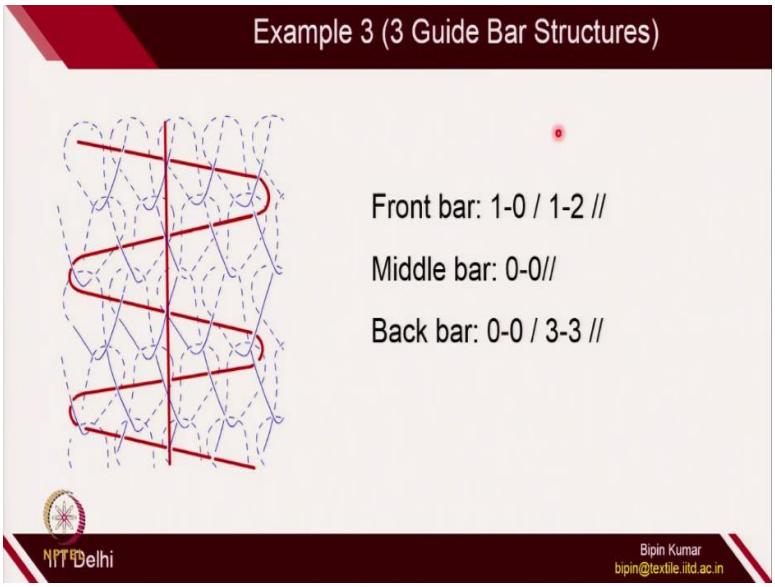

3 guide bar structure: Sometimes, 3 guide bars can be there. So, front bar is making tricot. Middle bar is just doing neither overlap nor underlap. So, it is moving in a straight fashion. And back bar just doing underlap 0 to 3. So, this is how you create 3 guide bar structure.

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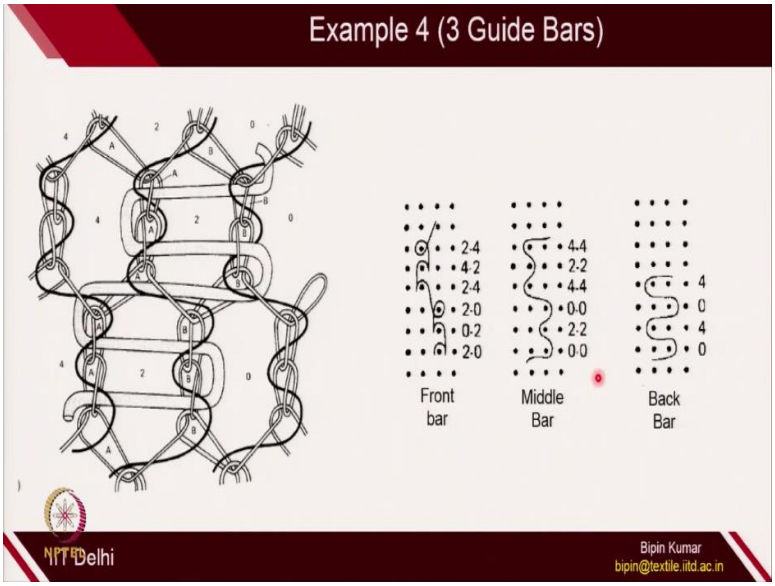

Similarly, even more complicated structures can be generated. So here, this is the front one. And the middle one is just doing the inlays. And back one is also doing inlays in a different way. It made from 3 guide bars.

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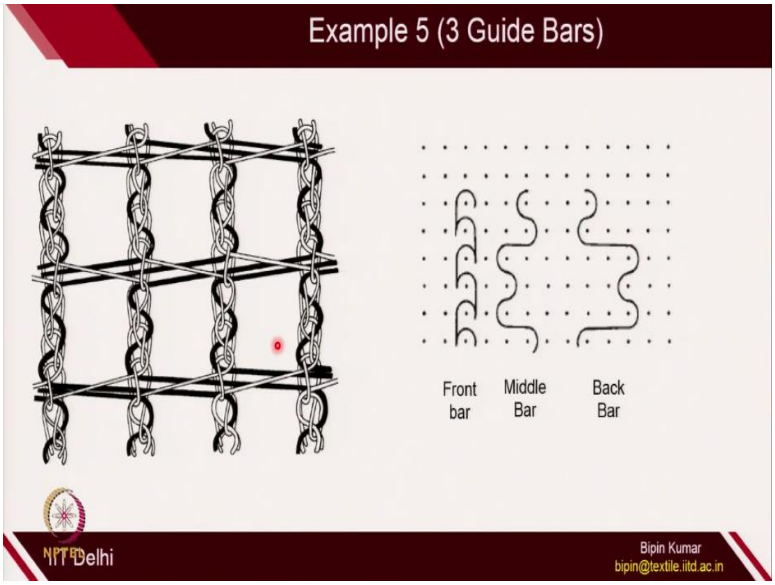

Even you go for more complicated one. So, here the front one is making pillar. And middle and back one, other 2 guides are doing inlays. So, here also you can generate very uniform mesh structure. So, this is another alternative way. You can use the inlays selectively to create mesh pattern.

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Introducing held loop. So, the other complicated structure is, you can also get miss and tuck. So, like float or tuck, similar to the weft knitting, you can also hold the loops for 2, 3 courses. Because of that, there will be a tension variation; and a different structures will be generated.

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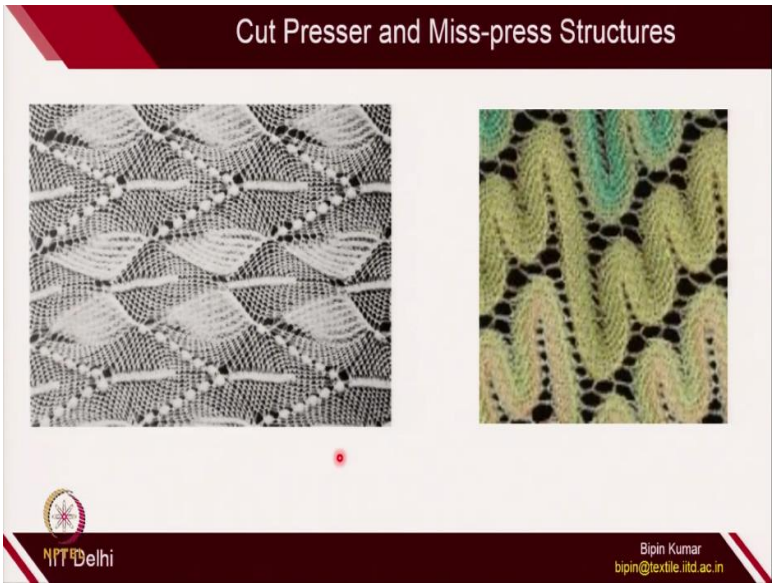

So, as you have seen in warp knitted, the loop geometry is highly, highly complicated, because the positioning of underlaps which is not providing equal tension to the each loops. So, because of that, you will get a different kind of pattern. And including with such a complicated underlaps, if you can play with the held loop, tuck loop or miss loop, you can get even more complicated structure.

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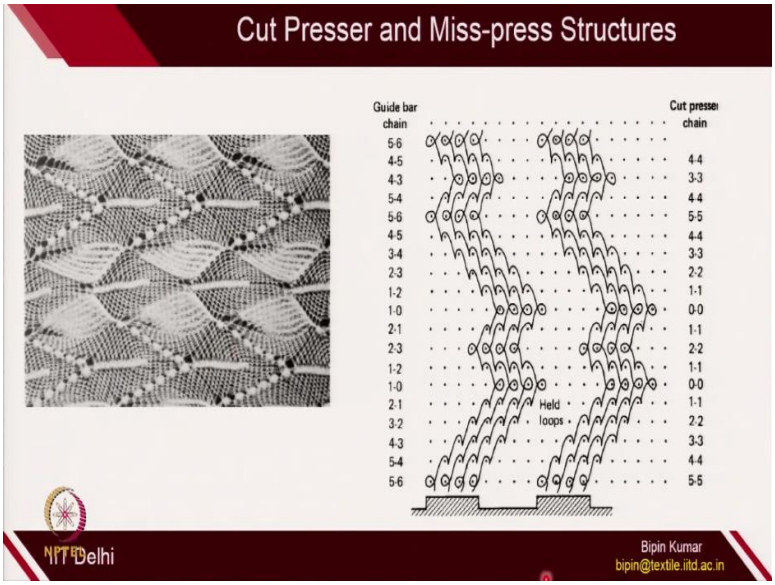

So, for example, if you want to create this structure; so, you are doing the lapping of some of the guide bars, while the other guide bars is holding the loops. Okay. So, this needle is hold the loops for 5 courses. And because of that, some opening is being created. So, somewhere, you have more dense areas, because more loops are being generated. And wherever you have more held loops, there the structure is more open.

So, you can see, if you follow the movement of any needles, you can see here, after 4 courses, the loops are being generated. So, again, for the 3 course, no loops, only held loops. And this is how you create cut-presser or miss-press structures. These structures are very, very complicated, you do not have to go in deep. If you encounter, you can just follow its lapping pattern. So, this is how the lapping pattern is decided. And you are controlling the held loop and controlling the miss and tuck in the structure to get more designs on the surface.

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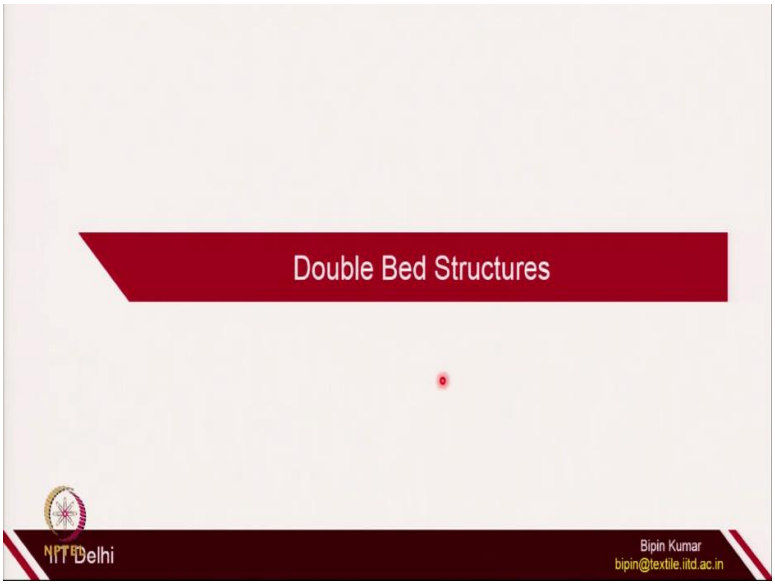

Now, the last part is double bed structure. So, double bed structure is the structures which is created by using 2 beds.

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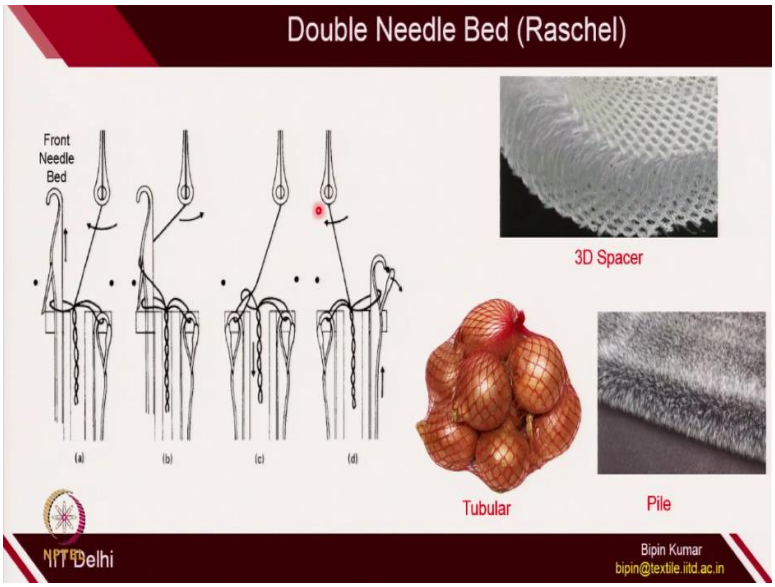

So, you can see here, in double bed structure, there are 2 needle beds, first bed and second bed. And the guide bar is actually switching the yarn from one bed to other bed. So, in double needle bed categories, they are 3 major structure which is found in daily routine is: First one is the 3D spacer structure, which is very, very common. Especially in cushioning applications, these structures are very, very common. Tubular structure is also very useful in packaging. And the third one is, pile structure. So, it's gives you more soft feel. So, let's see how a double bed structures is created.

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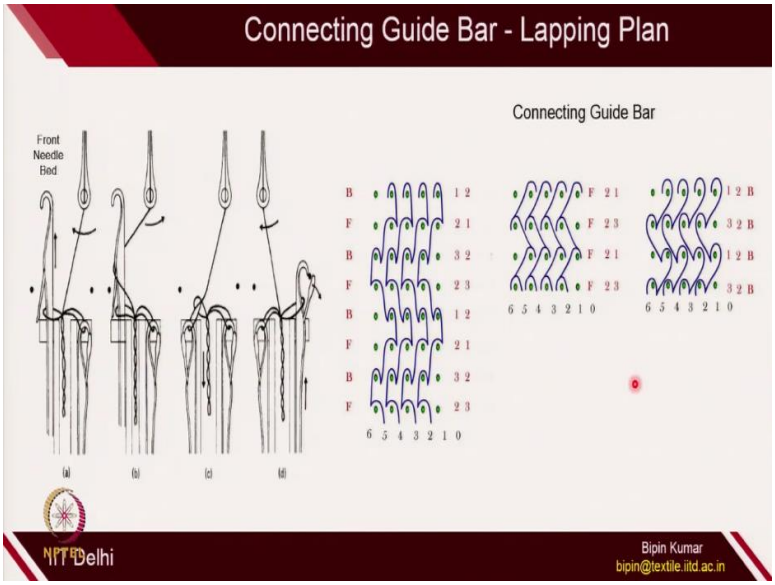

So, in double bed structures, naturally there are 2 beds and multiple guides, guide bar. So, now the onus is on the guide bar, to switching from one bed to other bed. So, if you see this guide. So, first it is making loops in the front bed. After making loops with the front bed, it is moving to the back bed. So, when it is moving loops with the back bed, the front is resting. When it is making loop with the front bed, the back bed needles are resting.

So, the connecting guide bar which connects the 2 beds has a different types of lapping pattern. If you follow this lapping pattern of connecting guide bar which is moving on 2 beds. This is actually synonyms to 2 different types of a structure that is created by single guide bar, if it is moving in same bed. So, for example, if you see here, the first guide bar is actually making the lapping with the front bed.

In the next course, it is making lapping with the back bed. Again, it is making lapping with the front bed; then back bed; then front and back. So, alternatively, it is switching from front to back and back to front. So, if you selectively remove all the front bed lapping diagram, it is 1 cross 1 tricot. And if you remove all the back bed lapping plan, it is also 1 cross 1 tricot. But instead of making 1 cross 1 tricot consecutively in 4 courses, it is doing alternatively for each bed.

So, first, it makes the loops which is 2, 3 lapping plan on the front bed. In the second course it is making the lapping plan of 3, 2 on the back bed, which is the first course of back bed guide bar. If you go for third course, it is 2, 2, 1 on the front bed. So, third is nothing but the

second course of actual fabric which is 2, 1. Then, again back bed. So, the second course is 1, 2. So, that's why this is 1, 2.

Then, in the fifth course, again it is following the movement of front guide bar lapping plan. And then, it is switching to back. And then, again it is moving to the front which is 2, 1. And then back, which is on the back side. So, the denotation is actually different compared to the normal notation of regular guide bar. So, regular guide bar actually makes all the courses in the same bed.

But connecting guide bar in 2 beds is actually making courses in alternating bed. So, because of that, it is switching from front to back, front to back and front to back. And rest of the lapping plan, whatever is set as per the pattern chain links, it will be following for that particular bed. So, the lapping plan for connecting guide bar, actually has to be written in the form of front, back; then front, back; then front, back; and then front, back. And this is 2, 3, 3, 2; then 2, 1, 1, 2; then 2, 3, 3, 2; then 2, 1, 1, 2. So here, for 1 course, actually you have to write 2 lapping plan for connecting guide bar.

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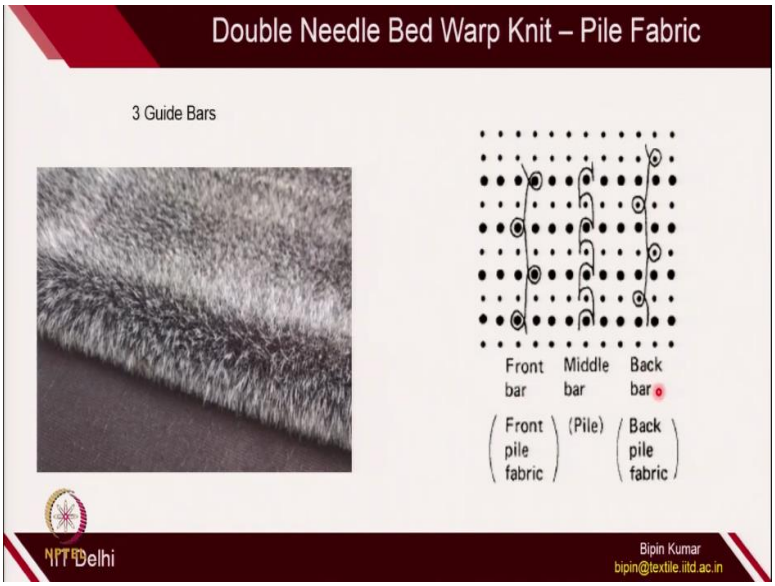

The most simplest one, which is used in double needle bed warp knit is pile fabric. So, here is the sequence of pile fabric. So, front bar is making the loops on the front bed. So, there are 3 bar. So, one bar is only making loops on the front bed. So, here if you see, the bigger dot which represent the needles on front bed; and the smaller dot which represent the needles on back bed.

So, the front bar, if you see front bar, it is actually making loops only with the needles of front bed. And if you see the back bar, it is making only loops with the back bed, which is the smaller needle. Okay. And then, there is one bar which is connecting both the beds, is the middle bar, which is the connecting bar, which is making loops with front and back needles. So, it is making loops with the bigger dot as well as smaller dot.

So, the bigger dots is the needles of the front bed, smaller dot is the needles of the back bed. So, the connecting bar is moving to the needles of both the beds, while the front bar is only making loops with the front bed. Back bar is making loops only with the back bed.

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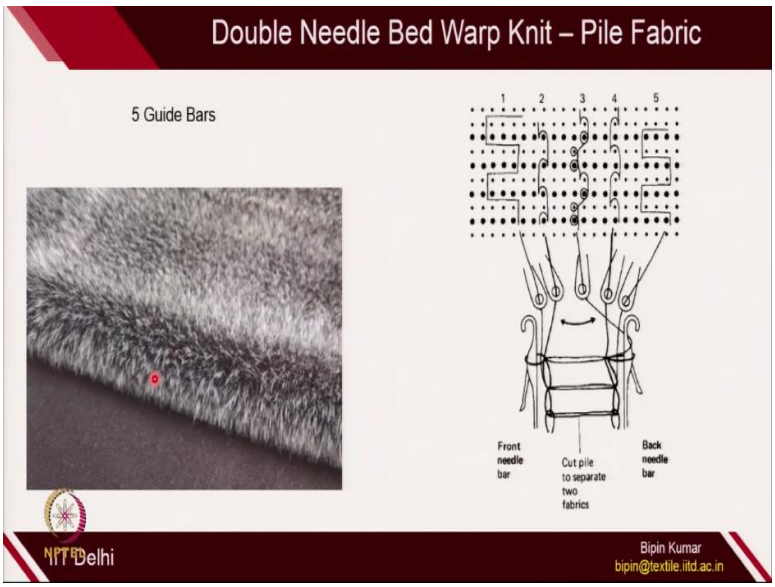

Similarly, you can have 5 guide bar structure. So, here also, you can see 5 guide bar structure. So, there are 5 guides, 2 beds. So, 2 guides is focusing only on making fabric development with the first bed. And 2 other guides is making only fabric with the back bed. And there is 1 connecting bar. So, again if you follow the bigger dot and smaller dot. So, the guide number 1 is just doing underlap on front bed.

Guide number 2 is also doing pillar stitch on the front bed. So, these 2 guides, 1 and 2 is focusing only on the front bed. And if you see fourth and 5, fourth is also making pillar only in the back bed. And fifth is also making underlaps, only underlaps in the back bed. And then, there is a third one which is connecting both the beds, which is this one. So, this guide is connecting both the beds.

So, it is moving on the bigger dot and a smaller dot. So, connecting both front bed and back bed, because the loops is being formed by the same yarn on both the beds. So, this is how the sequence is generated. So, once the fabric is being formed, you can simply cut the fabric at this position; and you will get a floating yarns on the surface. And it's a having a pile structure.

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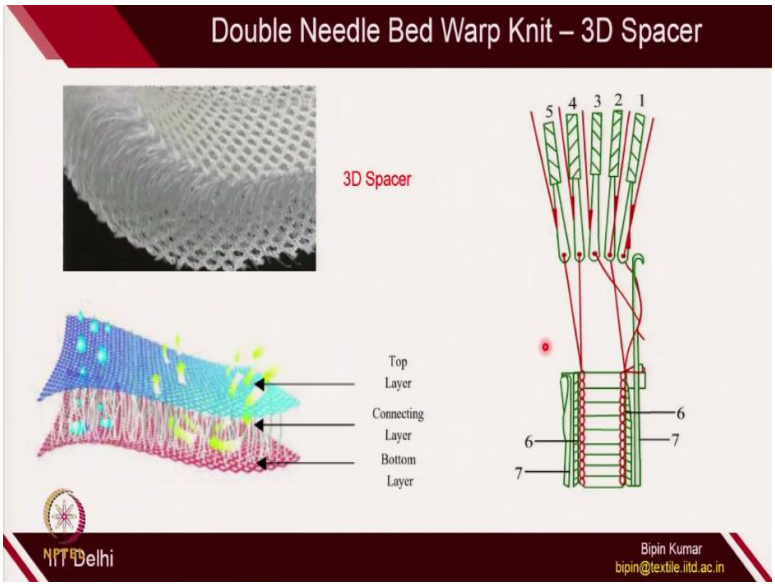

The other important structure is 3D spacer structure. So, 3D spacer structure is again, you are making 2 fabrics on 2 different beds. And there will be 1 connecting guide which is connecting both the fabric layers. So, there is top layer and bottom layers. And these are connecting layers, which is called spacer yarn. So, here also, if you see the 5 guide bar is there.

So, 2 is making on the front bed. 1 and 2 is making on the back bed. And third is the connecting one. So, it is similar to the pile one. In the pile, you are cutting the fabric. But if you do not cut the fabric in the middle, it will be a 3 dimensional structure; it's a 3D spacer structure.

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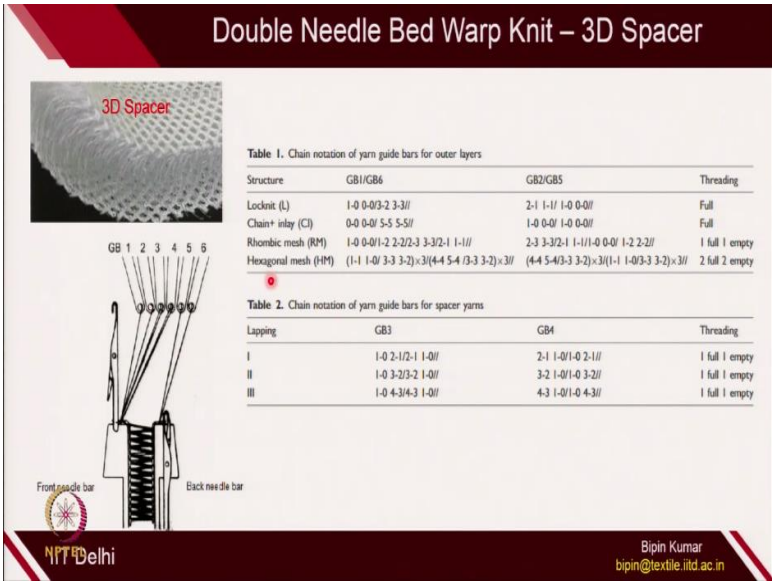

So, in 3D spacer structure also, there are lot of possibilities. You can go for 6 guide bar which is most popular. So, let me show you one simple structure of spacer. **(Video Starts: 34:24)** So, now you can see, this is the spacer structure. So, they are 2 layers. So, one is, this one is front layer. Okay. And the other one is the back layer. And they are actually connected with connecting yarn.

So, this is your connecting layer. So, 2 layers are being formed on 2 different beds. And then, there is one connecting layer. So, this is your spacer fabric. So, on one side, if you see, it is a mesh type of a structure. So, you can clearly see, it is a mesh structure which we just studied. It's a net structure. And the other side is the simple loop. So, it is just like a pillar. Okay. **(Video Ends: 35:25)** So, this is how it is created.

So, in double bed warp knit structure, 6 guide bar are used and 2 beds are used. So, on the first bed, you can make any type of a structure. It could be a locknit, it could be a rhombic mesh or it could be a hexagonal mesh. And on the other side, on the back bed, also you can choose any type of a structure. These are the lapping plans. This is the structure, you can see, this is the bottom layer; this is the top layer.

And then, there are 2 guides which is guide number 3 and 4. They are actually doing the connections. So, it is actually moving from front bed to back bed or back bed to front bed. So, this is how these type of structures are created. So, the structure I just showed you has the, on one surface it is having rhombic mesh. So, this is the mesh. And the guide bar 3 and guide bar 4 has the lapping plan of this, which is the connecting one. Okay.

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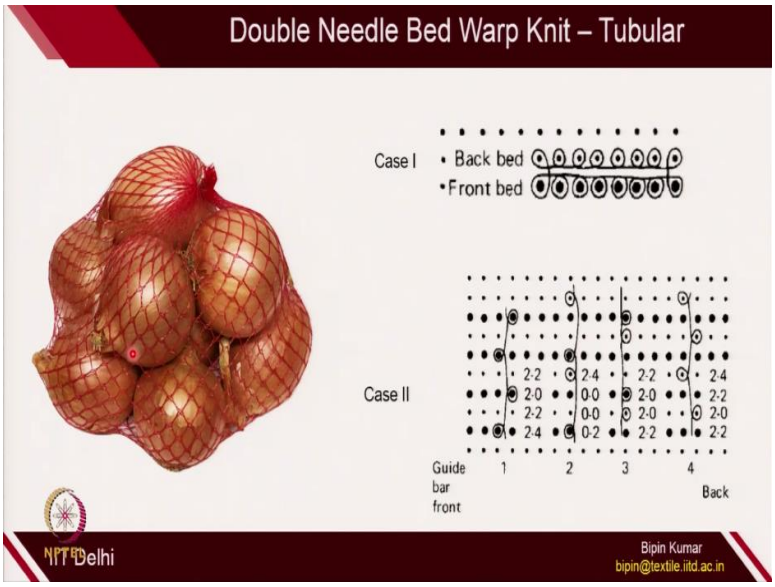

The last one is the tubular fabrics. So, this is the tubular fabric. So, here also, you need 2 beds. So, 2 fabrics layers will be created on each of the bed. And from the ends, there will be 2 guide bars which will be connecting just these 2 structures. So, here you can see. So, on one side, you are making 1 cross 1 tricot on the front bed. And the other side also, you are making 1 cross 1 tricot on the back bed.

And then, there are 2 guides. One is connecting from left side. So, which is connecting both bigger front bed needles and short needles. And here also, the second guide, connecting guide is connecting the other end. So, in this way, you create a tubular fabric. Warp knit designs are really very, very complicated. And for any specific interest on any of such a structure, whether it is a net structure or pile structure or inlay structures or 3D spacer structure or tubular structure, you need to follow a specific references.

In this particular series of lecture, it is practically impossible to go deep in such complicated designs. But hopefully, if you are clear with warp knitting notations lapping plan, it is just the selection of different guides and selection of different lapping plan for each of those guides and selection of beds depending on what type of complicated structures you want to create. So, with this, we are ending the lecture on warp knitting, because we have covered so many aspects.

In my opinion, you should be focusing more on overlap and underlap variations for 2 guide bar structures. That is the core principle. And then, you should follow for more complicated

designs. Many useful literatures are available, where you can go for such complicated structure. Especially 3D spacer structure is the most common one. And you will find a number of literature in this.

From next week, we will be focusing more on the application aspects of warp knitted and weft knitted structures. So, some of the research part which can be done in both warp knitting and weft knitting. We will be explaining some of those application areas in detail. So, thank you very much. Catch you in the next week. Thank you.