Science and Technology of Weft and Warp Knitting
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Lecture - 36
Introduction to Warp Knitting

Welcome participants to the new topic in this particular week. So, last class we have done the revision of weft knitting. Now, we are switching to new type of knitting technology, which is called warp knitting. So, today in this particular lecture, we are going to introduce you what do you mean by warp knitting, I will show you many fabric samples. I will also try to show you the application potential of warp knitted structures.

And also we will try to focus more on the structural aspects, what exactly is happening in the warp knitted structures because the fundamental of any structure in textile is you need to first analyze the structure carefully and then go for technologies. So, again this lecture is all about trying to realize the network of yarn in a warp knitted structure as we started in weft knitting also we started with the loop intermeshing.

Similarly, here also I am going to show you the warp knitting structures and their potential applications and their technical aspects. So, let's move on to warp knitting technologies. What do you mean by warp knitting?

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So, in one of the week, especially in week number 1, I have given you a very small hint of comparing 2 types of knitting technologies, which was weft knitting and warp knitting.

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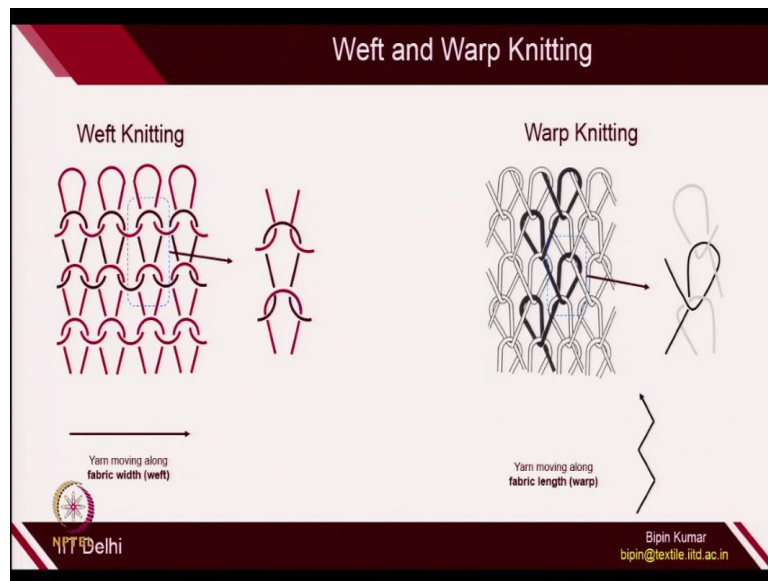
So, in weft knitting we have done so many lectures so far where the yarn is moving from left to right or right to left. So, this movement of yarn is along the fabric with or which usually woven fabric technologies, we call fabric with as a weft direction, so that's why this type of knitting is called weft knitting where the yarn is moving along the fabric width. Now, a new type of structure which is quite popular in knitting is warp knitted structure.

So, in warp knitted structure, the loops does not looks like stable loops just like you are seeing in weft knitting, they rather has different network of loop intermeshing. They are also created by loops but the architecture of loop in the structure is different than weft knitting. In weft knitting, you have seen the loop is intermeshed by upper loop and bottom loop and these loops are actually connected with left and right loop in the same course.

But in case of a warp knitted structures, if you carefully see any particular loop or if you try to see, follow the path of a yarn, it does not move along the width direction rather it moves along the length direction. For example, if you see the black color, if you try to follow the path, the yarn is actually following or moving towards the length direction. So, yarn movement is along fabric length and in woven technologies usually length indicates the warp direction.

So, that's why this type of knitting is called warp knitting. Warp knitted structure and weft knitted structures, you can easily visualize by looking the structure itself. So, in a warp knitted structures, the loop architecture is slightly disturbed, slightly disturbed in the sense, you can see here, first of all the loop is not standing vertical or symmetric just like in case of weft knitting.

So, in warp knitting, loop is either tilted right or tilted left. The intermeshing is there, each loop is intermeshed by top loop and bottom loop if you see any particular loop inside the structure. Each loop is intermeshed at the top point and bottom point. The only difference here is each loop is not connected with the loops in the same course rather it is connected with the loops of alternating courses.

For example, if you see the loops in weft knitted, the sinker loop is connecting each loop with the left loop and right loop, but here in warp knitted structure, a loop is connected in different courses. For example, this particular loop is connected with the loop of next course and also loop of previous course. So, the loop is not connected in the same course rather they are connected with the previous course and next course.

Because of that the sinker part of the loop or the legs of the loop are following on the same side due to which the symmetric of the loop is getting disturbed and you are not getting a symmetric stable loops rather you are getting an unstable loop, either it is bend on the left side or right side. So, this is the beauty of a warp knitted structures. So, the core line for you at this movement is to realize or differentiate these two types of structures.

In one structure, yarn is moving from left to right or right to left that's why it is called weft knitting. In other structure in which the yarn is moving along the length direction and loop is connected with previous course and next course. So, that type of structure is called warp knitted structures. So, for next 3 to 4 weeks, we will be focusing mainly on warp knitted structures.

Let's try to get more understanding of the loop network in a warp knitted structure. I have many samples of warp knitted fabrics with me. I am going to show you those fabric samples but before I show you the actual fabric sample let's visualize the loop network in a warp knitted structures.

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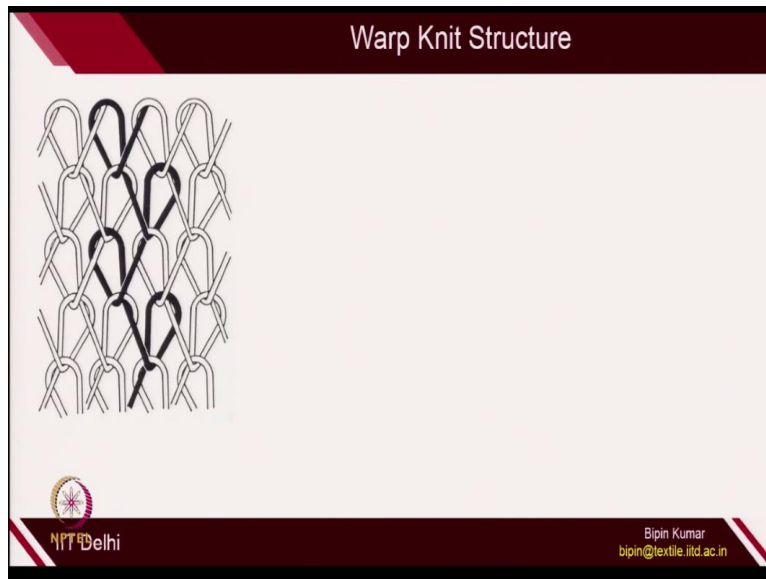
So, this is a simple warp knitted structures. I have this structure with me right now. Let me show you first the structures and then I am going to describe what exactly happening in these structures. So, one simple structure is with me.

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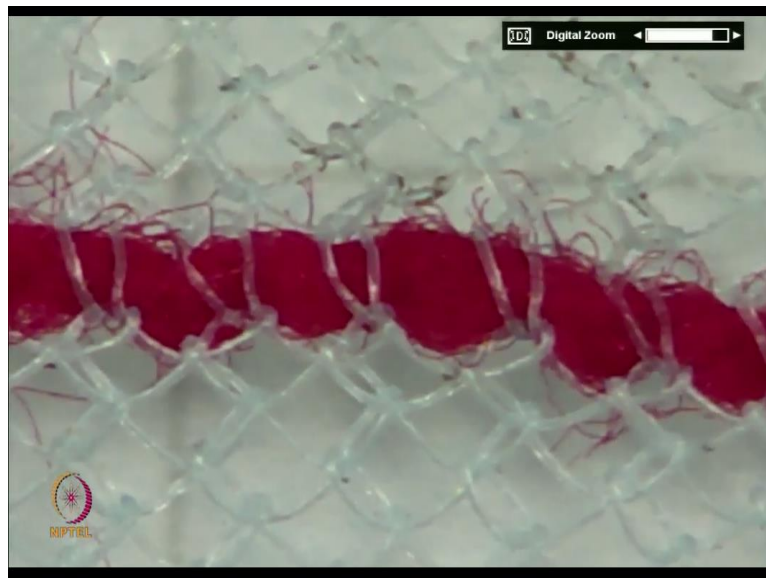
If you see these structures, somehow it will be very difficult for you to understand at this moment. If you try to see these structures, each loop is connected with bottom course and top course. At this moment, you would not be able to visualize carefully but somehow I have given some marker inside the fabric structures for you to understand. So, you can see this yarn is actually hold by one of the loop, so this is the loop in one course by one needle.

You can easily see this loop is not connected in the same course, so the middle loop which I am pointing is not connected with the left loop, so you can see here actually there are 3 loops, which is visible in this video. So, the middle loop is actually not connected with left loop or right loop rather the middle loop is connected with the loop of previous course and next course, so the previous course means if you are following this particular loop, it is connected somewhere here.

It is somewhere here and it is connected somewhere at this point just in the next course. So, the bottom line is the connection of the loop especially the sinker part of the loop is not in the same course rather the sinker part of each loop is moving to the 2 courses, so the left sinker and right sinker. So, the feet of each loop in a warp knitted structures are not remaining in the same course, so that is the bottom line.

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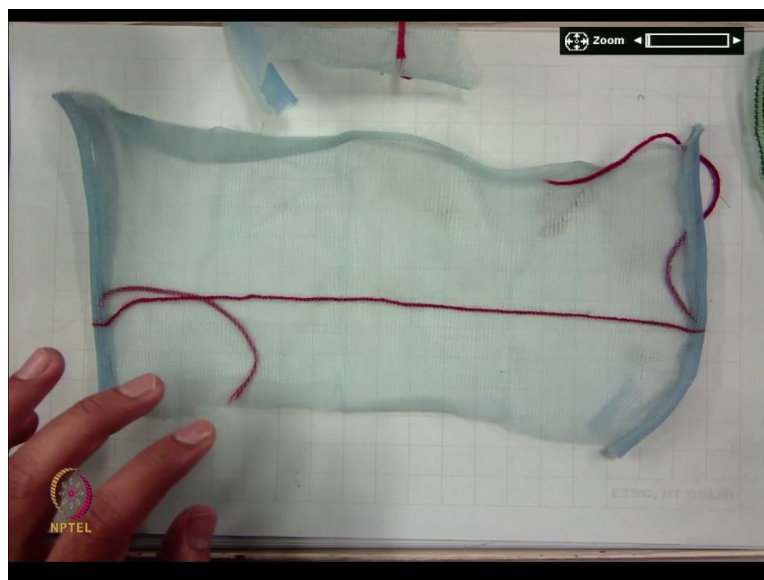
If you see otherwise, this fabric I have shown you the fabric the zoom version but in reality you would not be able to understand anything if you not enlarge the fabric structure. So, I will show you with the help of schematic I will try to explain how the yarn is moving in these structures.

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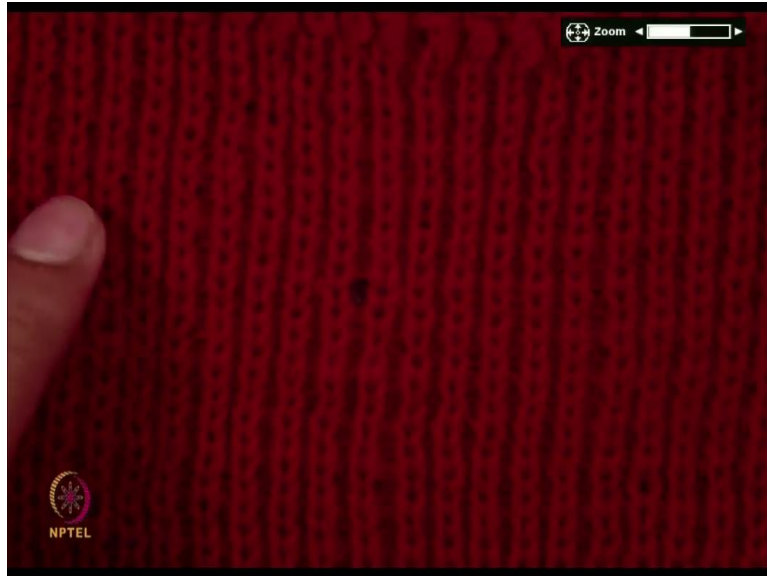
Otherwise, if you see a weft knitted structures, the structure is very simple and you can see the sinker loops are connected in the same course. So, the sinker loops are connected in the same course. This is the rib structures, so you can see these 2 structures has completely different nature of yarn movement. So, in one of the structures, you would not be able to find out the yarn movement like this.

Rather in the warp knitted structures, the yarn is moving actually vertically, so you cannot take out the yarn so easily. I have some structures where you can actually take the yarn from the length direction, but at this moment I would try to show you that you just understand how these 2 structures are different in terms of yarn movement. So, here the yarn is moving along the course and one yarn is sufficient to make this fabrics.

But especially in this type of fabric structures, so you can see each loop of the same course is created by different yarn. So, naturally to create this type of structures, a warp knitted structures, we need more than 1 yarn, we need multiple yarns. So, we need a warp beam to create this type of structures. I have 1 structure where I can show you how the yarn is actually moving along the length directions.

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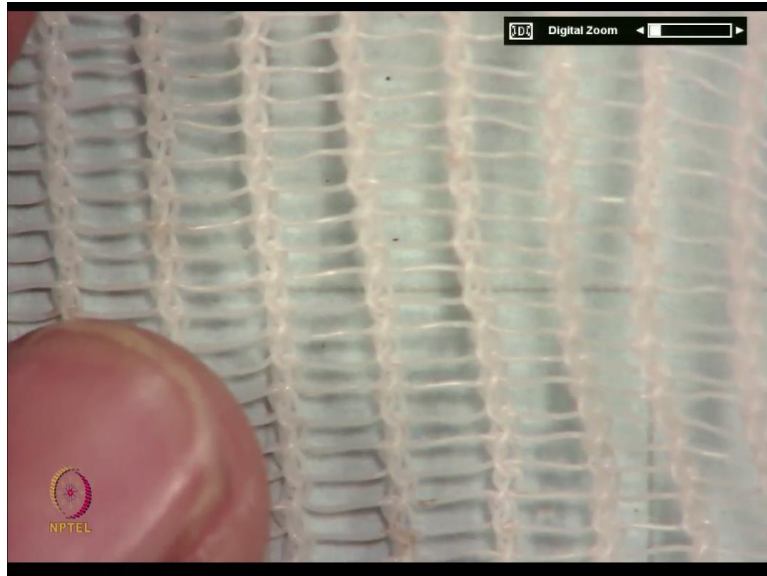
So, I have this structure with me where you can actually see the yarn movement in the length direction. So, let me pull the yarn for you, so actually if you see this fabric, this is fabric length direction and this is fabric width direction. This is another warp knitted structures and let me show you the movement of yarn along length direction by pulling it. So, I am pulling one of the yarns and you can see it is definitely created.

So, yarn is actually moving in length direction. So, you can see it here, I am pulling the yarn and the loops is getting open up. This is another type of warp knitted structures but the idea is here the yarn is actually moving in length direction. This is the yarn which I am holding by hand, so you can see it here.

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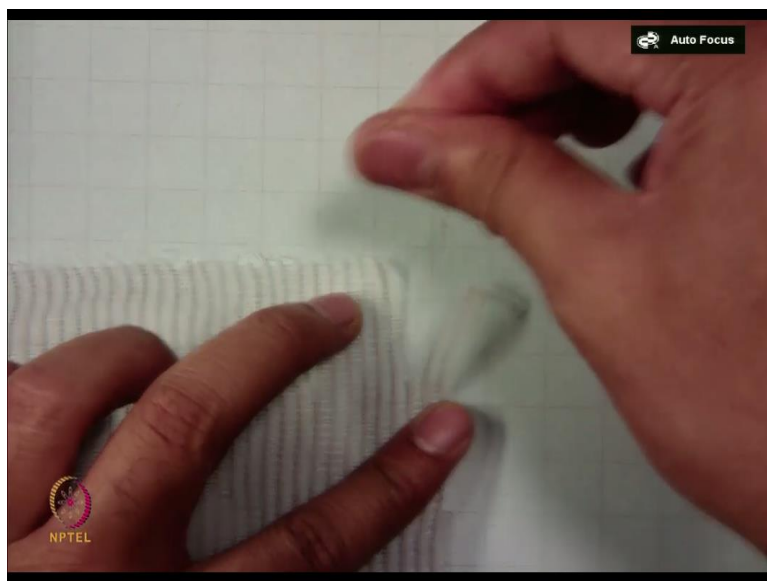
So, this is the yarn. I am opening the fabric, so I am just pulling it, you can open the entire fabric. Please remember this is just a special warp knitted structures where I can split the fabric but in most of the warp knitted structure it is difficult to take out the yarn from the length directions because they are knotted in such a way. So, this is how a warp knitted structure is different from weft knitted structure.

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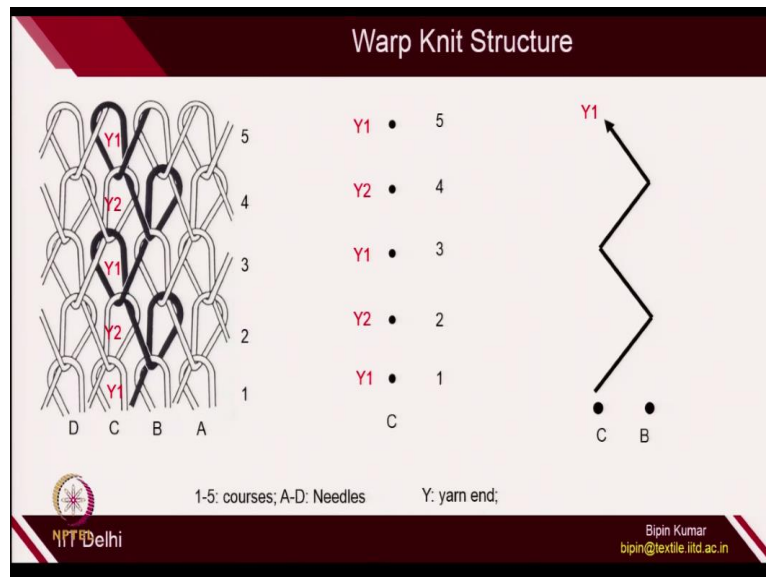
So, this is the simplest one where you can able to visualize what is exactly happening with the yarn movement. So, this is the warp knitted structures. If you carefully see the warp knitted structures, here you have 4 columns; A, B, C, D and each column we call it wales similar to weft knitting and each wale is created by 1 needle. So, if you are looking at A column, this is created by A needle.

If you are looking at B column, it is created by B needle. If you are looking at C column, it is created by C needle and if you are looking at D column, it is created by D needle and again the courses. First courses, second course, third courses, fourth courses, fifth courses, so this is the 5 courses, 4 columns. First courses it is not visible to see whether it is coming out or going inside.

Again, the definition of technical back and technical front will still be valid if you carefully see each of these loops, it is being formed at the back side of old loop. So, that's why all the loops here is technical back side. So, again the basic understanding of weft knitted structures will be actually helping you to analyze warp knitted structure as well. Now, let's try to focus on the movement of each yarn.

So, I have shown you just now in a weft knitted structure the same yarn is connected with all the loops. If you are making the weft knitted structure by single yarn, but here if you try to follow the yarn path, you will realize not all the loops are created by same yarn. So, definitely you need multiple yarns. So, here 1 to 5 is the courses, A to D is the needles, let's try to see the loops, which is created by C needle.

So, in C needle the C needle is loops for 5 courses; 1, 2, 3, 4, 5. So, each loop is created by C needle when a yarn is feed to that particular needle. So, in 5 courses if you try to follow the first loop which is created by C, so this is the first loop which is created by C and if I want to know what is the yarn which is provided to C needle, so let suppose if this loop is provided by Y1 yarn, I am naming the yarn as Y1, Y2.

In the second course, if you see, this is the second course. If you try to see this particular loop, definitely this loop is not being formed by the same yarn. So, in the second course, the same needle is catching different yarn, which is white. In the third course, if you see this is third course, this is the loop which is created by C needle. So, when this loop is created, the yarn which is being caught by C needle is actually again Y1.

This is Y1 because if you carefully see alternatingly if you follow the sequence, you will realize the C needle is catching different yarns in alternating courses. So, first courses, it is catching 1, third courses again it is catching Y1, fifth course again it is catching Y1 and in even number it is catching Y2 yarn. So, there are actually 2 yarns, 2 different yarns are feed to the same needle okay.

This is different in case of weft knitted structure. If you look at the normal weft knitted structure, same yarn will be provided to each needle in each course. So, this is how a warp knitted structures is different than a weft knitted structures. Now, let's see the movement of each yarn. So, if you want to see the movement of this black yarn, you can easily see it, it is switching from C column to B column.

So, if you see the movement of Y1 yarn, it is switching from C needle to B needle. So, in the first course, it is with C needle. In second course, it is with B needle. In third course, it is

again with C needle. In fourth course, it is again with B needle. Then, in fifth course, it is again with C needle.

So, if you follow the path of yarn between C and B and if you follow the path of black yarn which I noted at Y1, it is moving from C to B and B to C in alternating courses. So, not only needle is catching different yarns in different courses but also each yarn is moving to different needles in alternating courses. So, this is the core principle of loop formation in a warp knitted structures and this is how this structure is different from a weft knitted structures.

And if you see the path of the yarn, it is naturally with the course it is moving towards the length direction, so that's why this type of structure is called warp knitted structures. I have shown you the fabric sample also, how the yarn was moving in the length directions and although the picture was not clear but this schematic will be helpful for you to understand a warp knitted structure.

Now, who is actually helping this yarn to switch from one needle to other needle or who is providing yarn to each needle?

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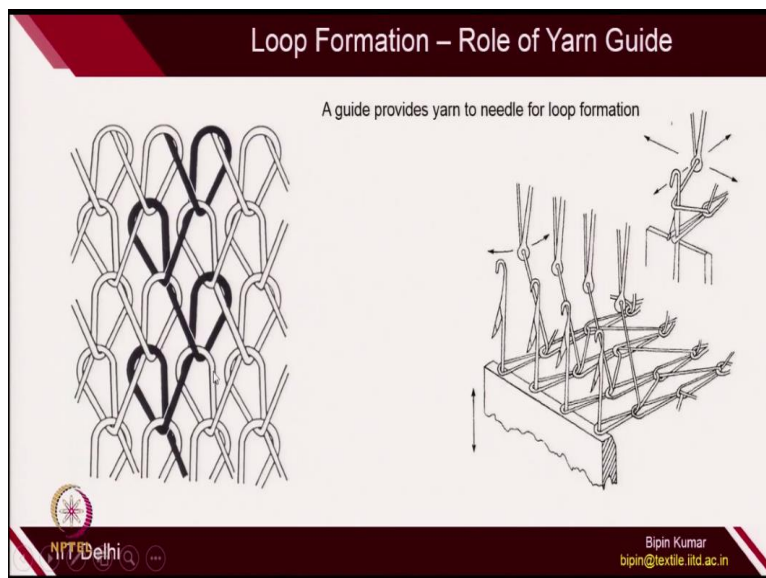
So, for formation of any warp knitted structure, there comes a different element in a warp knitting machine, which is called yarn guide. So, it is the guide which provides yarn to each individual needle. So, a guide actually provides yarn to each needle in the loop formation. So,

you can see this is the needle and for each needle, there is one guide which is providing yarn to that needle.

So, this is not the case with the weft knitting structures because the carriage itself was carrying 1 feeder and that feeder was providing yarn to all the needles, but here for each needle you can see for each needle you have different guides. So, 1 guide for each needle for providing yarn into loop formation. So, this is how the principle of loop formation is also different in case of a warp knitted structure compared to a weft knitted structure.

So, yarn guide become a very key element in warp knitting productions, not only the needle but the yarn guide is extremely important, which I will cover in the next class also how important is the role of yarn guide in providing the yarn because you have seen each yarn is shifting needles in alternating courses. So, that is only possible if the movement of each yarn is controlled.

So, here each yarn is controlled with a guide and that guide can be switched from one needle to other needle in alternating courses. So, this is how the principle of loops which is being formed in the warp knitted structure more depth clarification on the machine as well as in the fabric I will be covering in few subsequent slides as well as also in few lectures, so please hold on that.

But at this moment just try to understand the structural difference which you can observe in a weft knitted structure and warp knitted structures. If you try to extend the fabrics, you can clearly see because of the geometry of the loop inside the structure, the fabric will not be extensible. If you have any warp knitted structure and weft knitted structure in your hand, you try to extend the fabric, you will realize warp knitted structure will be very rigid, not so much extensible.

Because both the legs are on the same side, so because of that the loop could not be open up so due to which in terms of fabric properties also, these 2 structures will be different.

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Now, let's try to see the application potential of warp knitted. So, similar to weft knitting, warp knitting also has a very unique potential in applications. The first application is shoe.

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Shoe knitting both weft knitted as well as warp knitted structures are used. A lot of companies around the world, they are making shoe uppers using warp knitting technologies because it gives you very beautiful design of mesh fabrics, which you can generate and that looks aesthetically good as in shoe uppers.

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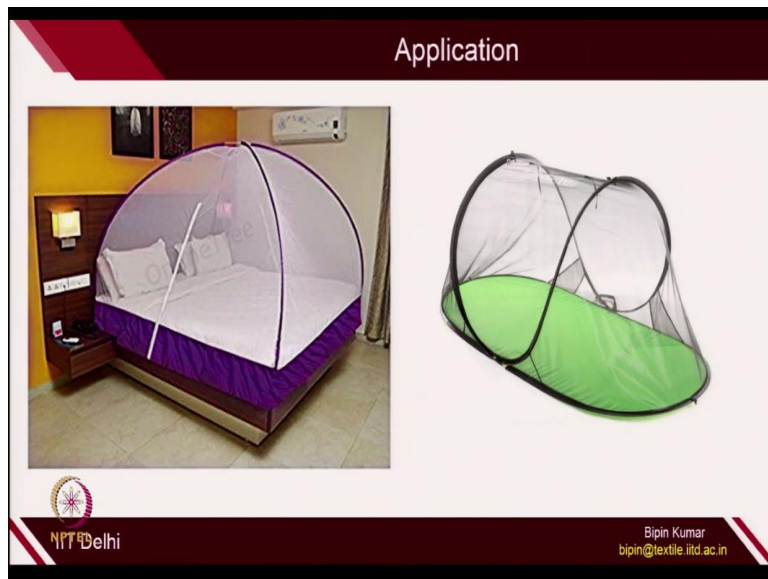
Mosquito net is widely popular in many countries especially in Asian countries for preventing babies from mosquitoes and this type of also structure is actually a warp knitted structures and you can see it is a messy structures and the pores, porosity is very good, you can control the porosity and that's why warp knitted structures is very useful in this type of applications.

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In composites also, we can create a warp knitted structures and we can put resin inside and we can make very stable composites which can be used for wind turbines and other composites applications.

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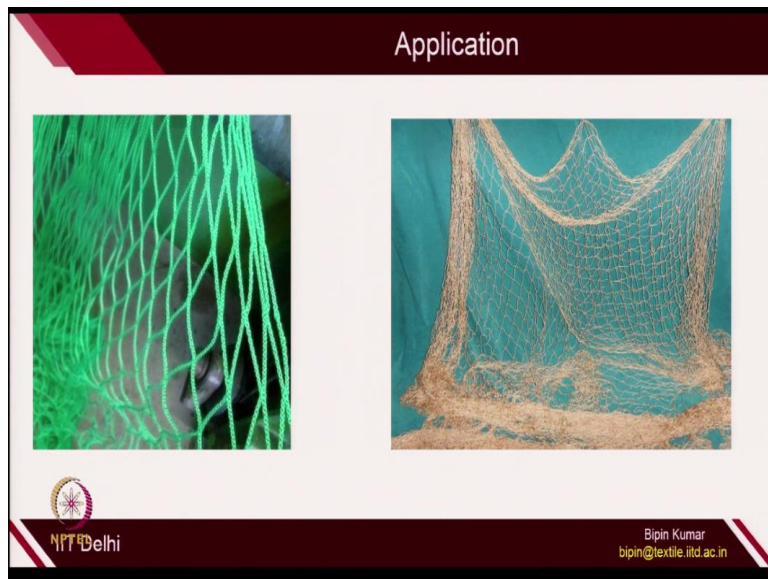
Also we used warp knitted structure in geotextile and civil applications for fencing. So, if some construction is going on and if you want to protect it from one side, so you can simply hang a mesh fabric. Those types of fabrics is also again in warp knit fabrics.

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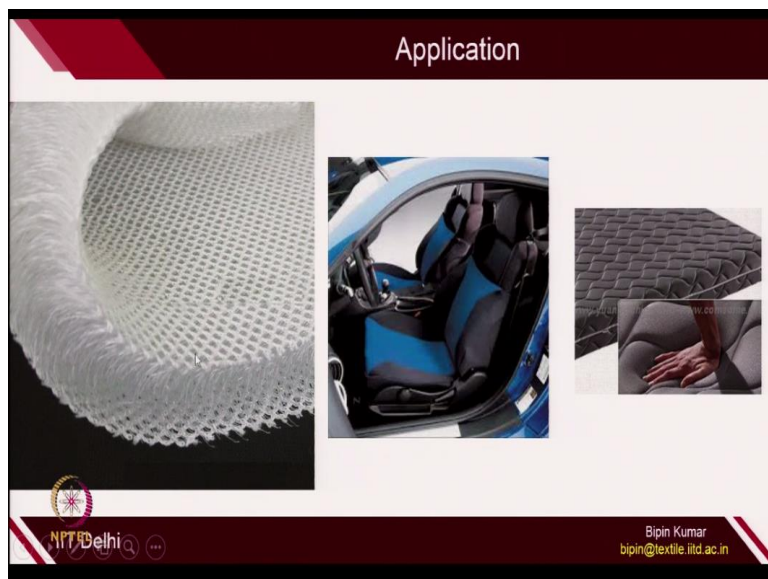
Warp knit fabrics more advanced version is used in car seats also where this is a spacer fabric, we call this in the market 3-D spacer fabrics, again a warp knitted structure, very good cushioning effect and this is again made by warp knitting technologies.

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In tensile structures also, we use warp knitted structure, very rigid, very stable and we can create this 3-D network of structures using warp knitting technologies. This is also very popular nowadays.

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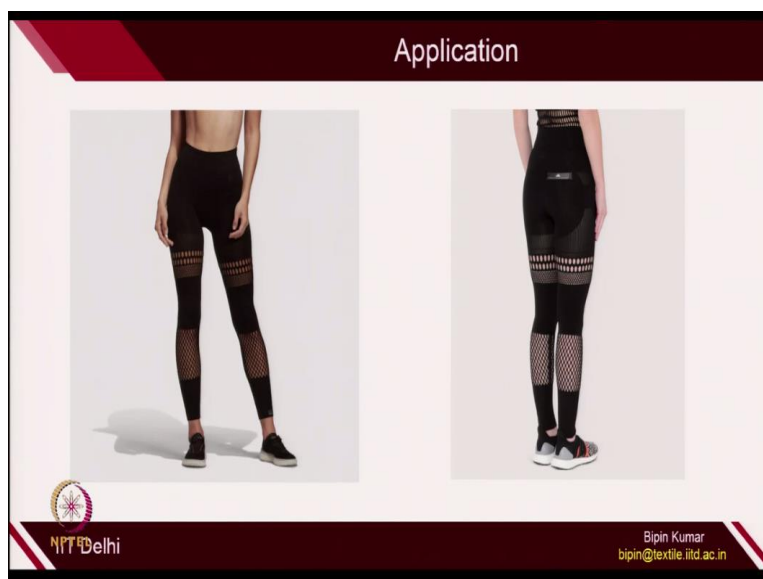
Apart from these technical applications, warp knitted structure is also used for garmenting, for creating very fancy designs on the garments but weft knitted is naturally the first preference because of its characteristics but nowadays warp knitted is also being used extensively in garment purpose. So, this is the overall applications of warp knitted structures in real life. There are n number of applications are there.

Probably, in the last week, I will try to cover some unique aspects of warp knit applications where you will see how these structures can be used for many technical applications.
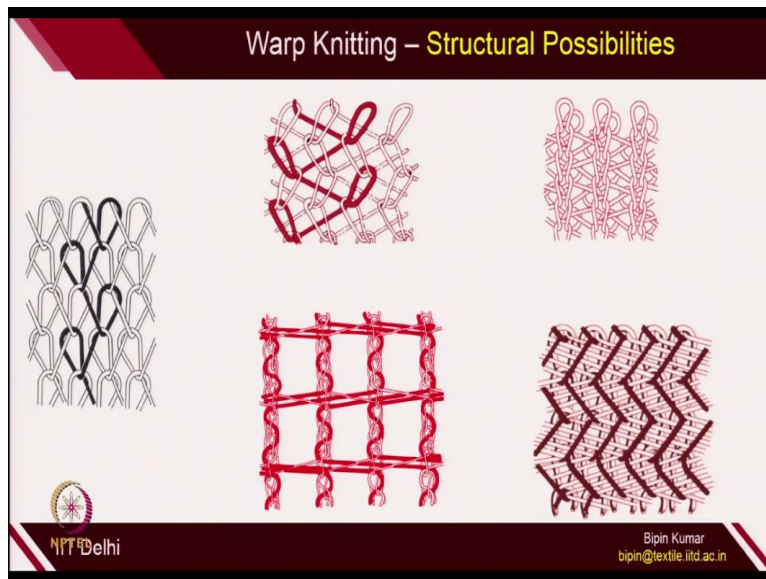
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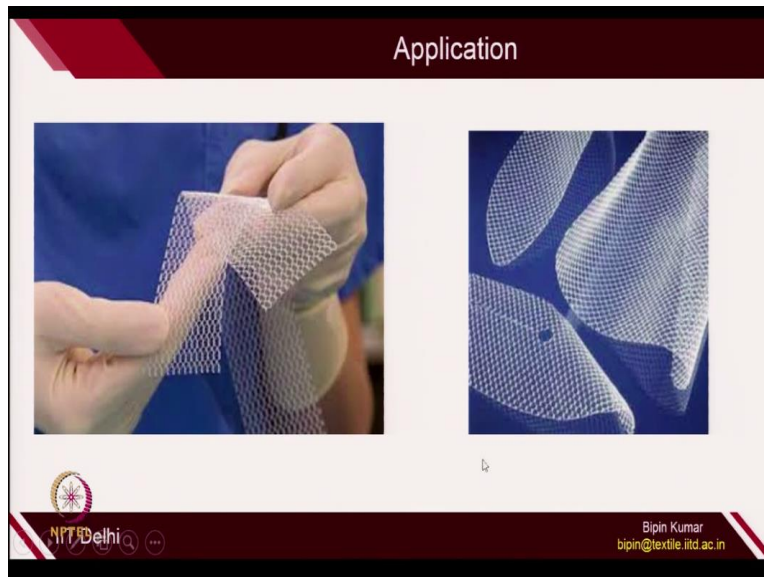
The other beautiful application is in medical where for hernia mesh for mesh fabrics we use warp knitted structures, very highly stable, porous. So, this type of structure is also a warp knitted structures.
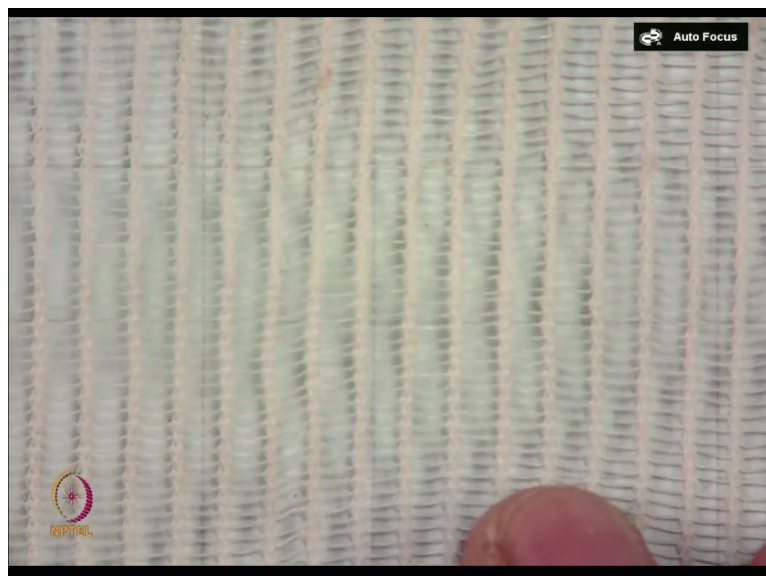
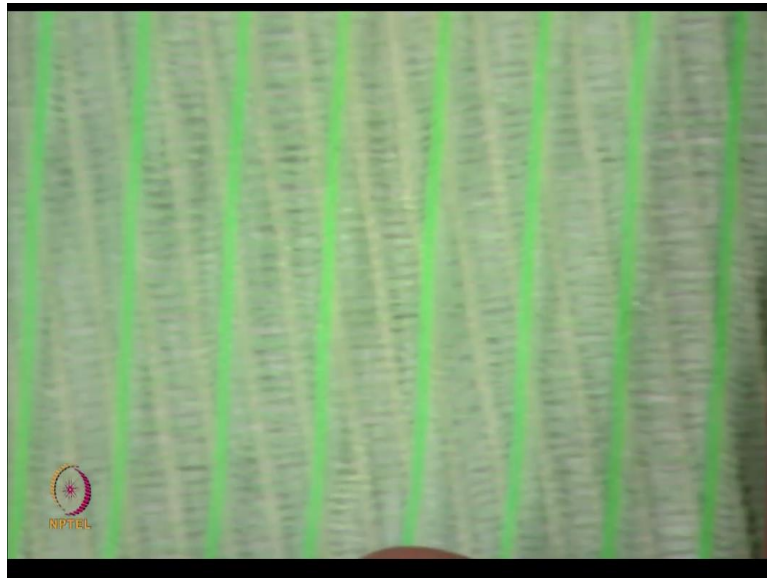**(Refer Slide Time: 26:03)**
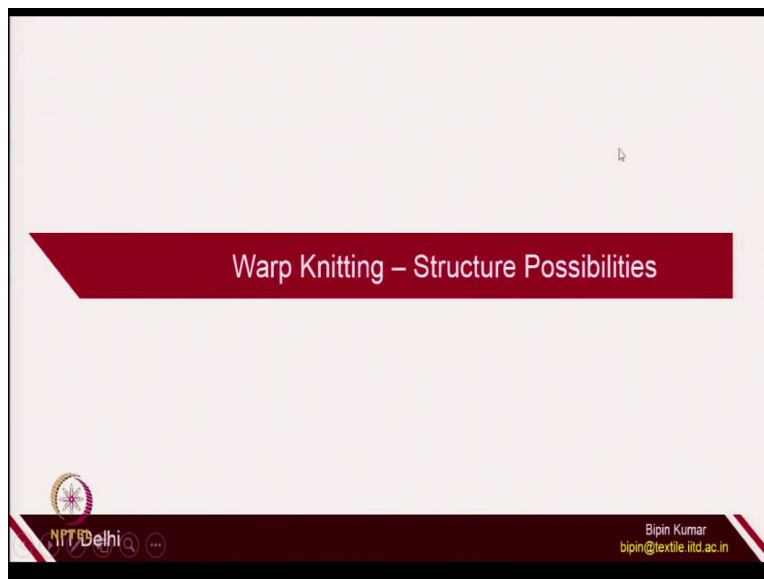
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In warp knitting also just like in weft knitting, warp knitting structure also very complicated structures can be designed and in next 3 to 4 weeks, we are going to cover these type of complicated structures similarly in weft knitting we have seen cable, aran. We have seen bulging, we have seen rib designs, we have seen jacquard designs. Similarly, here also we can create many type of structures.

And these structures can be classified into one bar structures, two bar structures, multi-bar structures, 3-D structures that I will be slowly unfolding you and trying to explain these types of structures. At this moment, I have a few unique structures with me and hopefully in coming weeks, I will be trying to explain all of these structures and their technologies. So, let me show you some of these structures.

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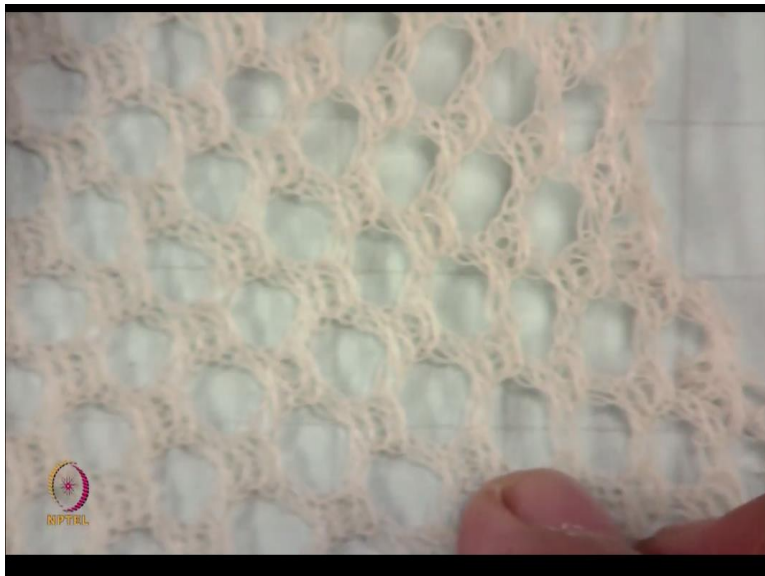**(Refer Slide Time: 27:09)**

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This is the structure I just showed you, so here one structures and the other structures you can see it here okay and third structures which is very useful is again for mesh fabric. This is also used in mosquito nets. This is mosquito net fabrics.
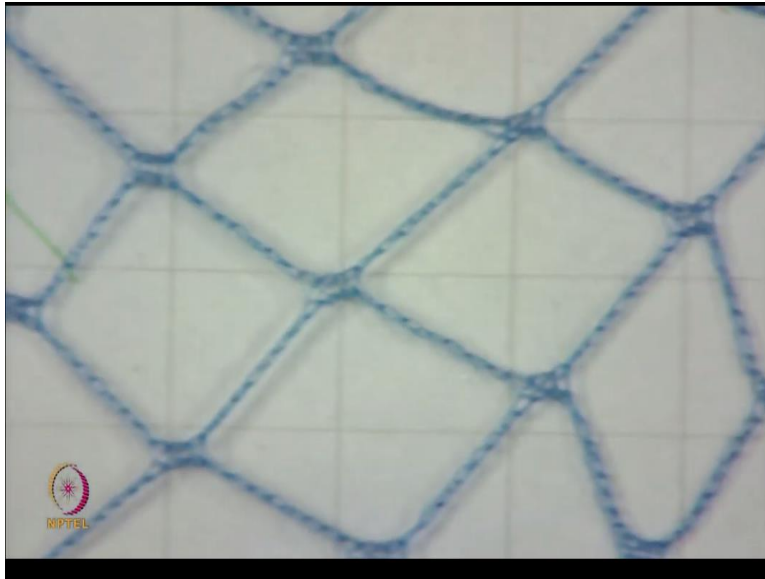
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We also have in supermarkets you might have seen this type of mesh fabrics where you keep onions and potatoes, so this is again a mesh fabric, very bigger mesh size, so you can see the mesh size is much bigger.

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You can again have a very unique structure with me, so you can see it here. So, again here you can see the mesh size is also different and also density of the loops are also different.

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We can also go for much higher mesh size depending on the application. So, usually you can see here the porosity of the fabric can be controlled. So, you can see the 2 fabrics I am showing you.

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So, in one fabric your mesh size is bigger and in other fabric you can see the mesh size is very smaller, which you cannot even able to look at. So, the structural capability of warp knitted structure is also tremendous and again it will depend on the engineer capability.

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So, this is you can see everywhere this has different varieties, different colors. So, these are the structures which I am going to cover in the class and you will have more understanding on warp knitting technologies. So, let's see again the principle of warp knit structure. So, these are the complicated structure which I am going to cover it.

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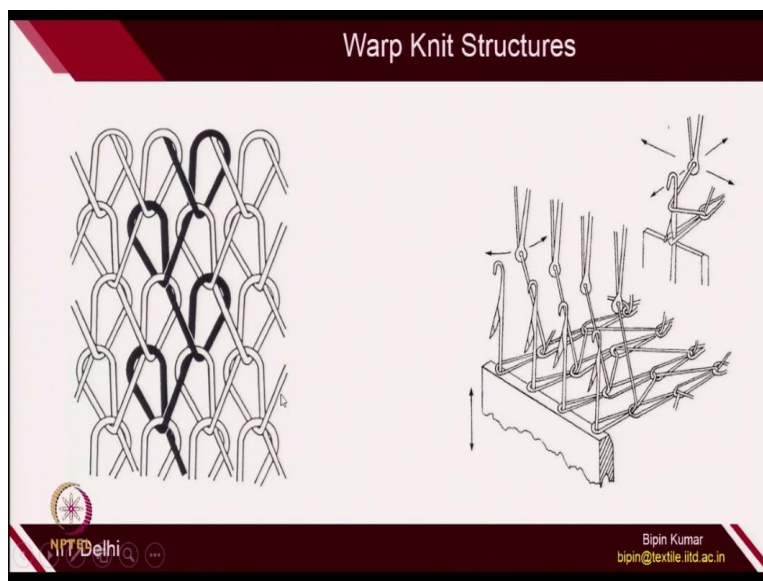
Again, I already mentioned you for making a warp knitted structure, the role of guide is very important because each guide is providing yarn to each needle and this guide bars actually shift position in alternating courses to provide yarn to different needles in alternating courses. So, this is how you create this type of loops in a warp knitted structures.

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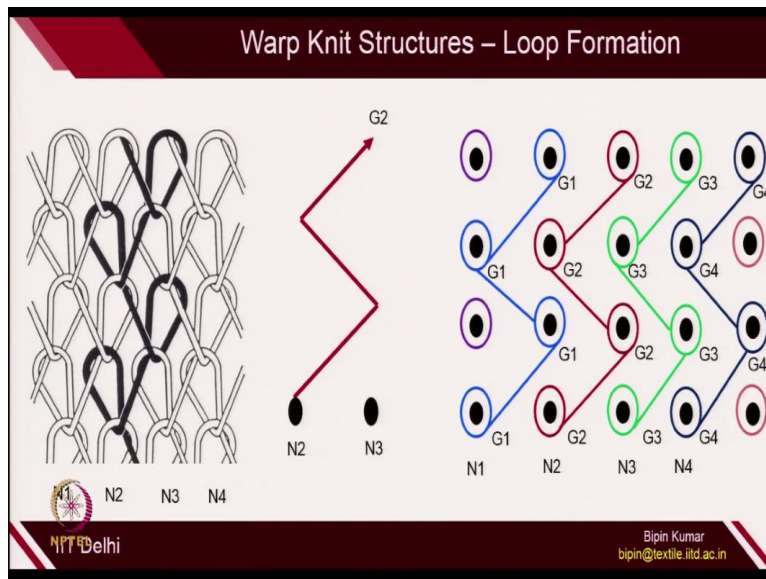
So, again if you want more detailed descriptions, I can show you here, so here there are 4 needles N1, N2, N3, N4 and there are other needles in the same machine. So, if you want to create the first course, so this is your first course, so imagine there are 4 guides, which are providing yarns to these needles and you created 4 loops. So, these are guide number 1, guide number 2, guide number 3 and guide number 4.

So, just now I showed you the schematic of guides and needles. So, each guides are providing yarn to the needle and needles are making loop out of it. So, for example needle N1 guide number 1 is providing the yarn, needle N2 guide number 2 is providing the yarn, N3 guide number 3, N4 guide number 4. So, this you create these 4 loops here okay. So, this is the first course. Now, what about next course?

So, when this course is done, you are moving to next course. So, in the next course, what exactly is happening because you can see once the guide 1 provides yarn to needle 1, the same guide is not available with N1 in the next course or if you see needle number 2 guide number 2 is providing yarn here but in the second course, which is in this particular course, so this loop the guide which is carrying this yarn is actually G1.

So, after first course, each of this guide is shifting its position 1 pitch towards right, so G1 is now providing yarn to N2, G2 is providing yarn to N3, G3 to N4, G5 to N5 and so this is how the guide bar is shifting. So, the guide bar actually changes its position in second course. Again, if you go to third course, it is similar to the first course. So, again this guide bar go back to its original position.

So, this G1 is now providing yarn to needle number 1, G2 is now providing yarn to needle number 2, G3 to N3, so this is how you provide the needles and if you see for fourth course, again you are providing this guide bar is shifting positions. So, it is the guide which is very important, needles remains stationary; needles will just make the loops if any yarn is provided to it. So, in every course, the guide is changed so that's why the yarn is changed for that particular needle.

So, that's why in the same column, you are making you are making loops from different yarns because if you follow the same needle, first course G2, second course G1, again third course G2, fourth course G1. So, this is how for each needle guides are changed, yarns are changed so that's why in the same column different loops has been created and guide bar is shifting the position.

So, needle and guide become a key element in the formation of the fabric. Most of the warp knitted structures in fact all of the warp knitted structures, what is more important for you is to understand the movement of this guide bar. So, if you understand the movement of guide bars, the structures become very easy for you. So, some of the structure capability I am going to show you which is nothing but very easy.

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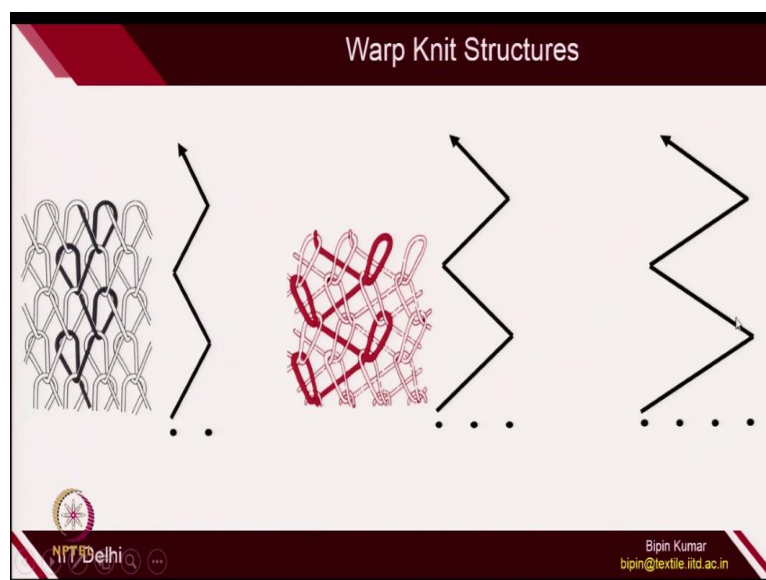
So, if the guide bar is shifting position from only to the alternative needles, then you create this type of structures where you can see it is the guide bar is shifting position from next needle. So, when the guide bar is shifting position for 2 pitch, so from first to third and then

going back to first, so then you get this type of structures. You can see each yarn is shifting from first column to third column.

So, this is possible only by guide bar. So, guide bar is free to move on the bed, left or right depending on what type of structures you can create. You can also switch up to 4 needles, 5 needles, 6 needles depending on what type of loops you want to create.

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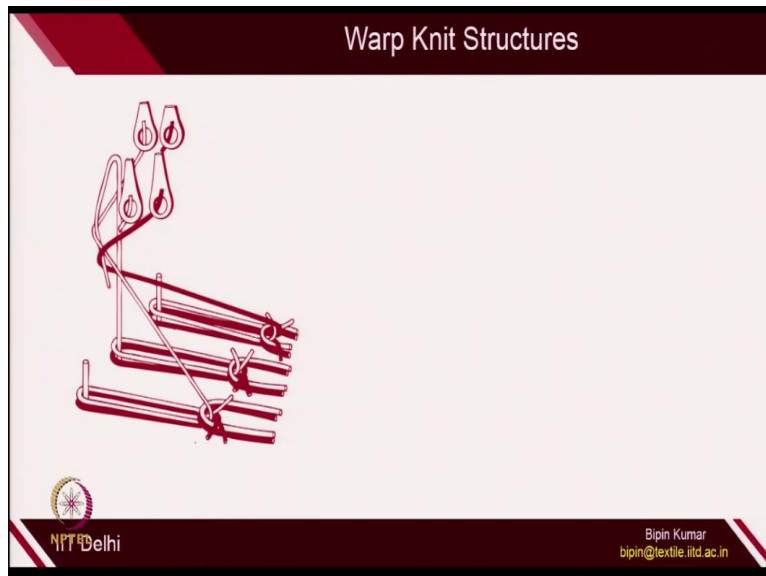
Sometimes, you can also provide 2 guides or 2 yarns to the same needles. So, once you provide 2 yarns to the same needles, naturally different structures will come. I have some of these structures with me. So, where you can easily see there are 2 loops in the same structures. So, let me show you those loops.

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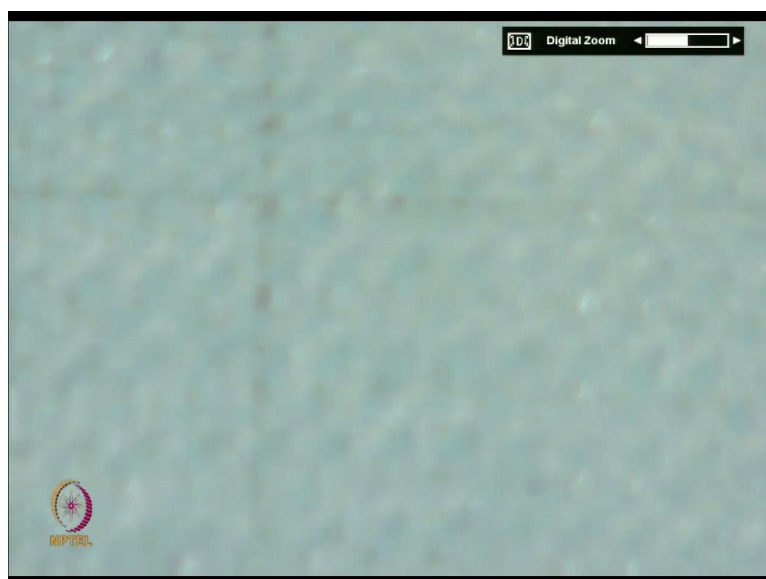
If you see some of these structures, so the video is not clear but here you can see it more number of loops are there because each needle is making 2 loops simultaneously in the same course.

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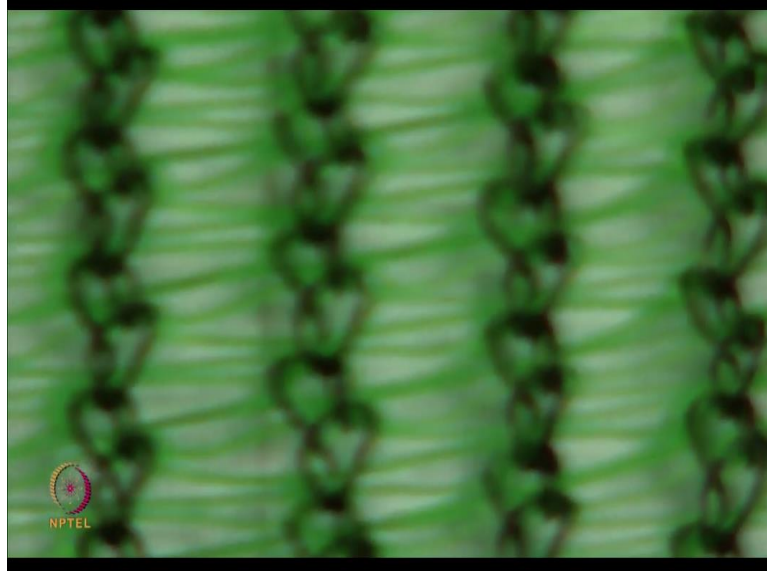
So, here also if you see, if you carefully see, so 1 loop is made from the black yarn and the other loop is made by the green yarn. So, 2 yarns are being catched at the same time, so in the same course. So, each needle is carrying 2 yarns simultaneously, so this is what this structure is showing to you.

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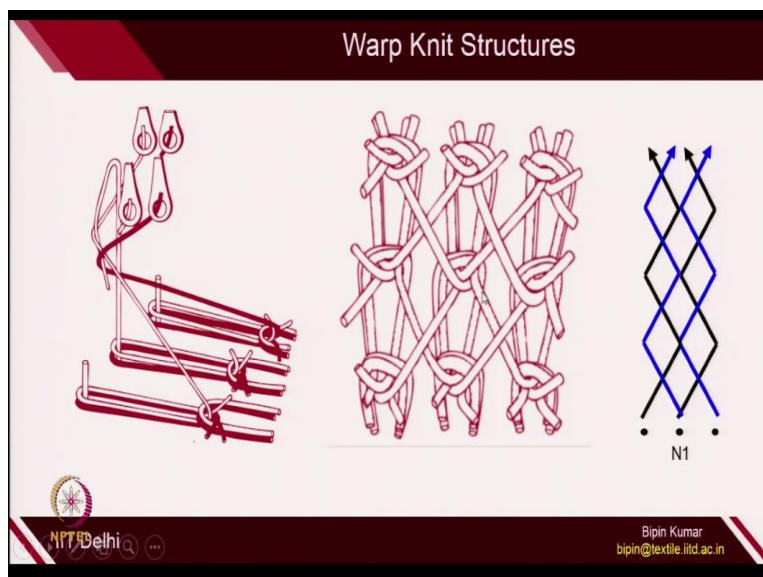
So, each needle is carrying 2 yarns. So, once there is 2 yarns, the needle is making 2 loops at a time and you can get other complicated structures. So, each needles you can see there is a blue yarn and black yarn. So, every course there are 2 yarns are intersecting and they are

making loops. So, here if you see each loop, actually there are 2 yarns have been present. So, one is fed from the left side, the other one is fed from the right side. So, the 2 guide bar is going in the same needle. So, this is how and from the figure also this should be clear to you.

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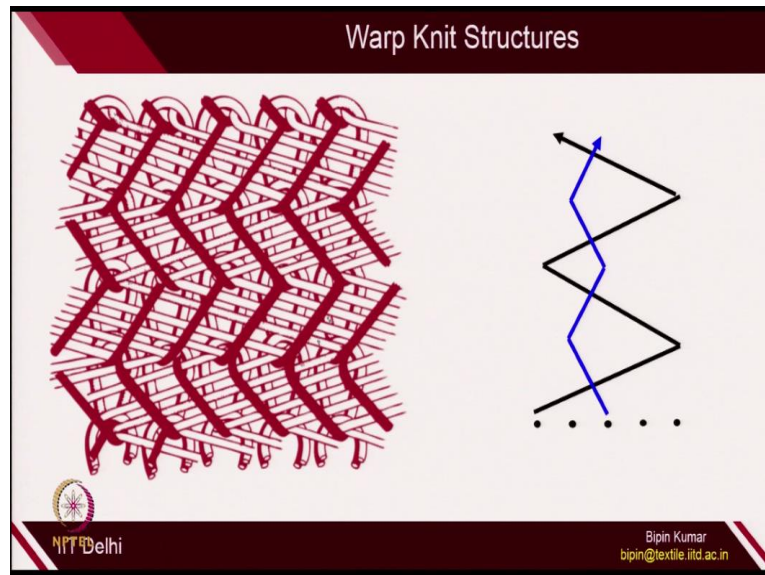
Other structure is like obviously when you have 2 guide bars, naturally you can play its movements, so 1 guide bar will be doing 1 shift, so here if you see the red yarn, it is shifting from first column to second column and if you see the other white yarn, it is shifting from first column to fourth column. This is how it is doing, so it is shifting one pitch and the other one is shifting 4 pitch and you are getting this type of structures.

So, although these structures looks very complicated but its again it entirely depends on how many guides you are using and how those guides are moving in the fabric structure and how the loops are being made, that is the only difference in the warp knitting technologies.

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Warp Knit Structures
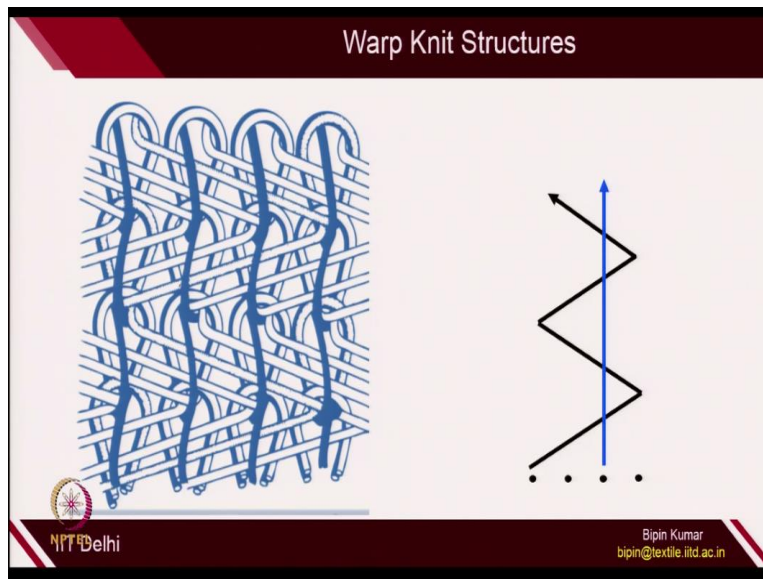
Sometimes, you can also feed 1 yarn where the guides are only giving yarn to that particular needles and other guide bar is switching. So, this is also possible. I have this particular fabric with me, so where you can, so this fabric which I am showing you. So, here you can see this, the black one, the guide bar is providing yarn to only 1 needle and the green one the guides are switching from 1 column to other column.

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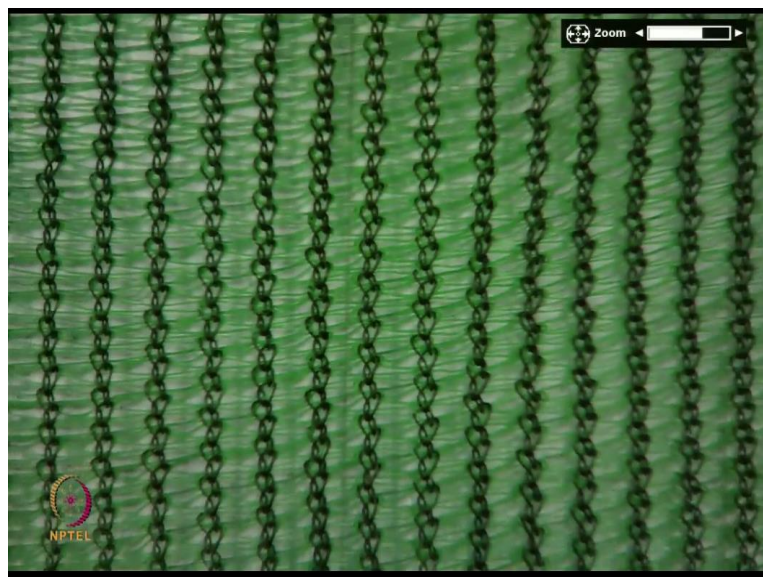
So, this is how these structures will look. So, the schematic which I just showed you in the previous slide is exactly the same. So, 1 guide bar is just providing yarns to 1 needle and other guide bar which is carrying the green yarns, they are switching from 1 column to other column. So this is the structure. So, with this I hope you can imagine how this structure is so different, how warp knitting is so different, where they are used and in the next class I am going to go more deep on making the loop using warp knitting machine.

So, I will show you the machine, I will show you the guide, I will show you the needles, how they move, how the loops are being formed, how the yarn is actually being supplied to the needle with the help of guides, so how they are placed on the machines. So, that I will be covering in the next class, so with this thank you very much for the listening.