Science and Technology of Weft and Warp Knitting
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Module - 3
Lecture - 11
Single Bed Weft Knitting - Fabric Curling

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Welcome participants. Now, we are going to move in week 3. And today is the first lecture of week 3. The topic for this particular lecture is Single Bed Weft Knitting. And especially, in single bed weft knitting, we are going to discuss more about fabric curling. So, if you see last week, we covered lot of technologies related to single bed weft knitting. Now, we are going to analyze the behavior of fabric that we produced on single bed weft knitting machine. Before we move, let's have a quick recap of what we have covered in last week; week number 2.

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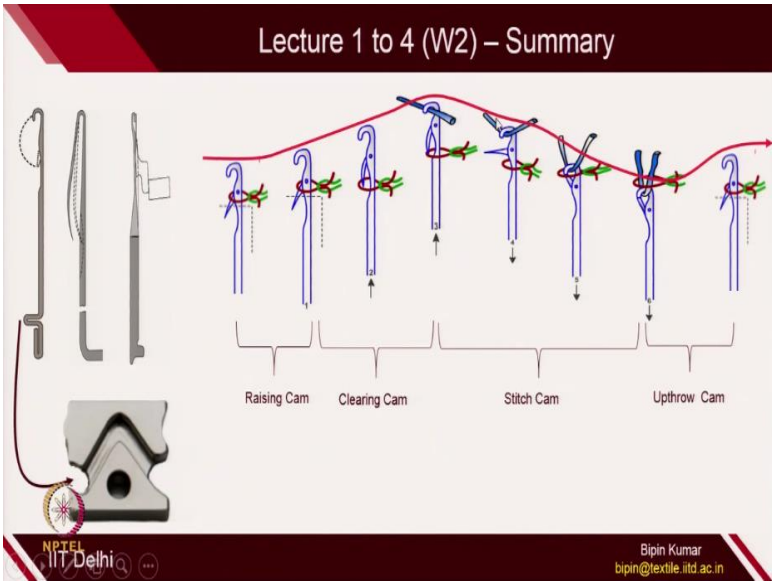

We covered the functioning of needles. We introduced you the needle. Needle is the heart of knitting. It actually helps in loop formation. The needle does some kind of reciprocative movements to do the knitting process. We have already covered this in details. For the needle to do this kind of knitting function, it has to interact with some kind of cam track. The butt of the needle actually follows the track of the cam.

Because of that, it does some kind of reciprocative movement on the bed. And due to which it can clear the old loop; it can catch the yarn; it can bend the yarn; and finally, knock the old loop from the needle. So, this is the basic principle of knitting formation by needle. We also have checked the functioning of other 2 types of needle, which was the beard needle and the compound needle; although, these 2 are not that much popular in weft knitting.

So, we restrict our discussion with the latch needle only. During this process of interaction of butt with the cam, the cam has to be specifically designed in such a way that it creates some kind of track. And to creates this track, the cam has to arranged by using raising cam, clearing cam, stitching cam and upthrow cam; so that, each of these cam interacts with the butt in a specifically time, so that they can do the knitting function. We have already discussed this in week number 2.

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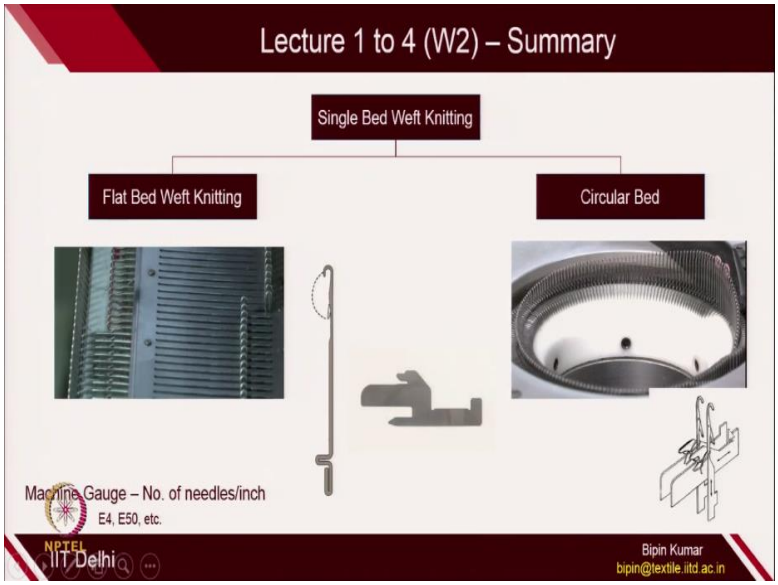

Also, we covered some of the technological machines related to single bed weft knitting. We covered 2 types of machines. One is flat bed weft knitting, where needles are placed on a flat bed in the tricks. And the other one was circular bed, where the needles was placed on the trick created on a cylindrical platform. Machine gauge is also one of the important parameter which decides how closely the needles are placed on the bed.

So, number of needles per inch is defined as the machine gauge which can be denoted as E4 or E50. E4 means 4 needles per inch, E50 means 50 needles per inch. So, naturally when you have more number of needles per unit length, the fabric that will be produced on the machine will be very, very finer. So, machine gauge determines important fabric density. Apart from needle, we also introduced you the sinker element which is primarily most important part in case of circular knitting.

We have seen how sinker and needle interacts together on the machine during knitting zone. And they, sinker actively participates in loop formation. So, it is not only the needle, but you, sometimes you need additional element depending on what type of technologies you are using for making fabric. Sinker is mostly useful in knocking the fabric, holding the fabric, creating loop while the needle descends downward. So, there are lot of functions which sinker provides when it is there on the machine.

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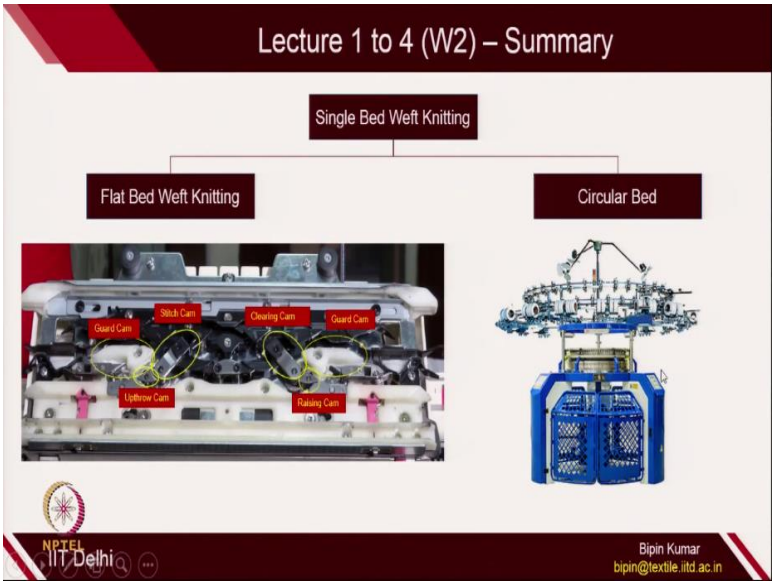

Apart from that, we have also given you the demo of how the cam track is created on flat bed weft knitting. There are lot of different cams starting from raising cam, then clearing cam, stitching cam, upthrow cam; and then, there are some guard cam. In circular bed, we given more emphasis on multi-feeder machines, because of very higher productivity, because here lot of cams was placed on the periphery of cylindrical wall.

So, the needle is always in some kind of knitting function. So, all the needles are making multiple loops in one rotation. So, this is why the production on circular bed is very, very higher.

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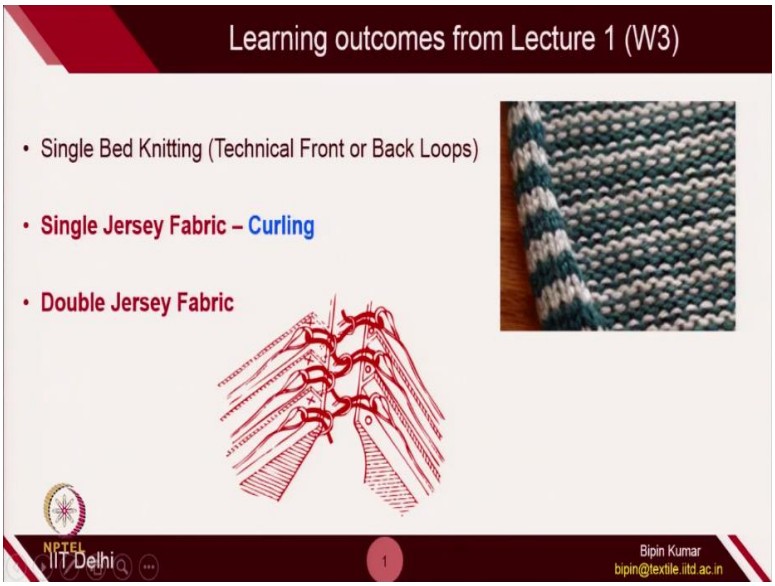

So now, let's move to this particular lecture series of week 3. In this lecture, first of all, we are going to introduce you the fabric features that we produced on single bed knitting; what is its

problem and what is its benefit. The first thing we are going to do is like, to understand what type of loops does the machine creates; whether it is the technical front or back loops when you are making the fabric on the machine.

Apart from that, we are going to introduce you 2 important terms related to knitting; one is single jersey fabric and double jersey fabrics. First of all, we will give you the idea of what is the problem with single jersey fabrics and why we call this as single jersey fabric. Curling is one of the big problem of single jersey fabrics, which ultimately leads to the development of double jersey fabrics.

And to create double jersey fabrics, we need double bed or 2 sets of needles on 2 different beds. If you understand why there is a problem of using single jersey fabrics, then you come to know about why there was a development of 2 beds to create double jersey fabric. So, all of these small topics, we are going to cover in this particular lecture. But we will focus more on the curling behavior of the fabric which is related to single jersey fabric.

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Let's move to the first part, the single bed knitting. So, whatever bed we have learned in week 2, whether it is a flat bed or circular bed, we first need to understand whether these machines are making technical front or back loops.

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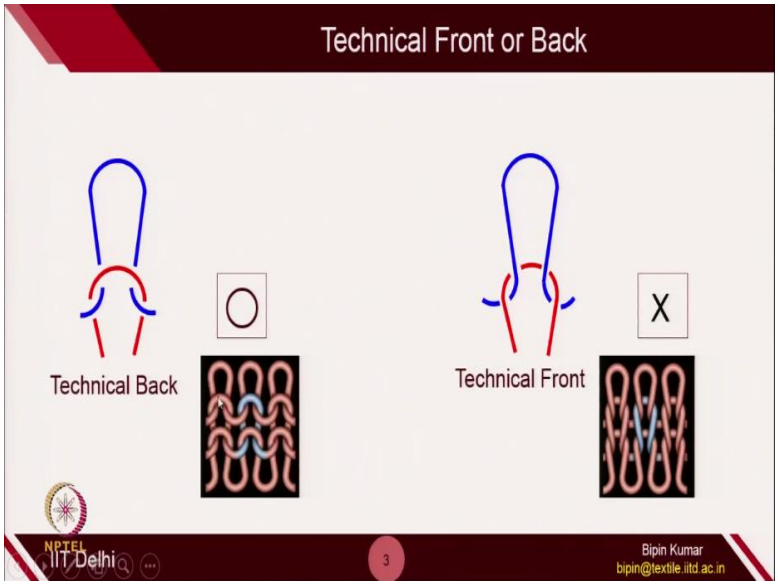

Just have a quick recap from week 1. I have already introduced you 2 technical terms, which is technical back and technical front. So, technical back is the loop which is created on the back side of the old loop. So, if you see the blue one, it is created on the back side of the old loop which is the red one. So, the yarn is pulled from the front side to the back side. So, that's why it is technical back.

In case of technical front loops, you can see the blue one is pulled towards the front side of red loop. So, these are the fabric features. So, if you see the technical back side loops on the surface, you can only able to see the head and sinker part. And in case of technical front side of the fabric, you can only see the legs part of the loop. And technical back, we can denote by just having circle in a box.

And technical front, we can define as cross in a box. So, these 2 types of loops are always there on the fabric. It depends on how we are looking on the fabric surface. So, let's see how these loops are created while we are standing in front of the machine.

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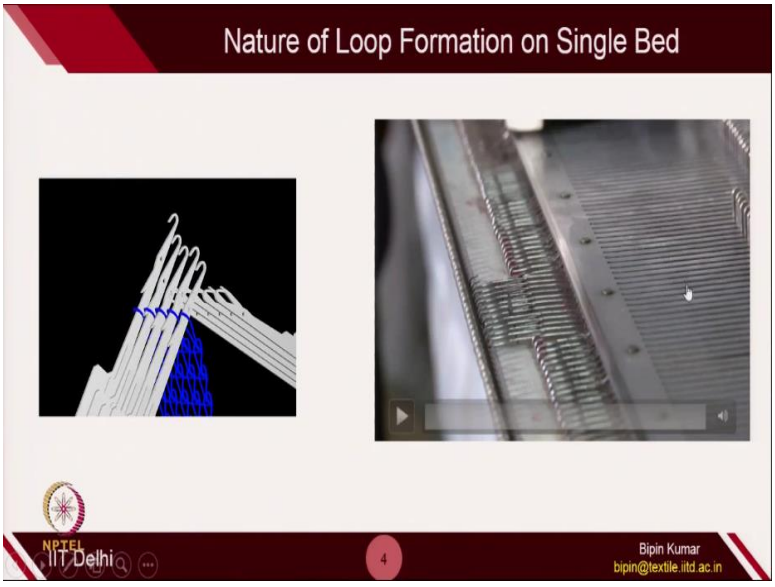

So, if you see the flat bed machine, I have already shown you **(Video Starts: 07:59)** how the needles do the reciprocative movements on the bed. So, when you run the cam jacket on the bed, the needles hit with the cam track and they do some kind of reciprocative movements. The key takeaway from this point is, the nature of movement of all needle on this particular bed are same. So, the amount of reciprocative movement and the direction of reciprocative movement for all the needles is same. First, it comes out then goes inside the bed.

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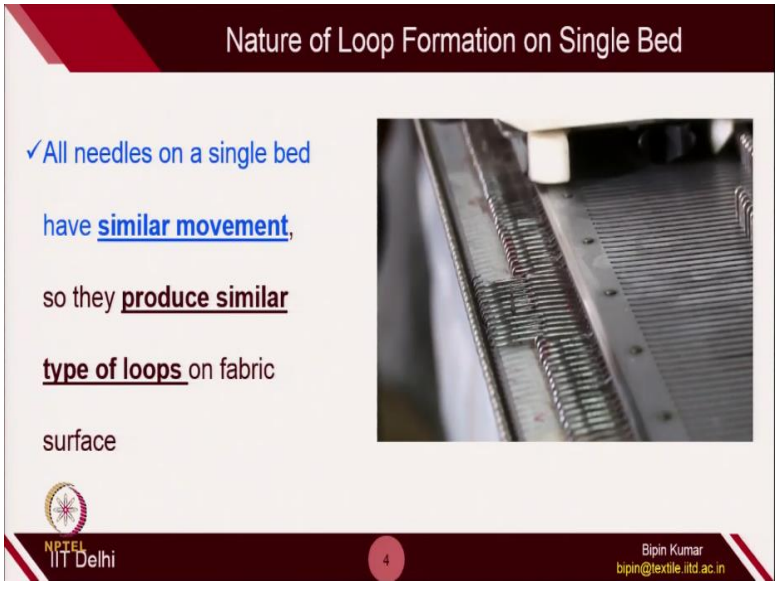

So, all needles on a single bed have similar type of movements. So, naturally, they have, they all have similar type of movements. So, they can either pull the loop to one side or maybe they can pull the loop to the front side or back side, depending on, on which position we are standing. So, on a single bed, we can only produce similar types of loop in 1 cycle. **(Video Ends: 09:04)**

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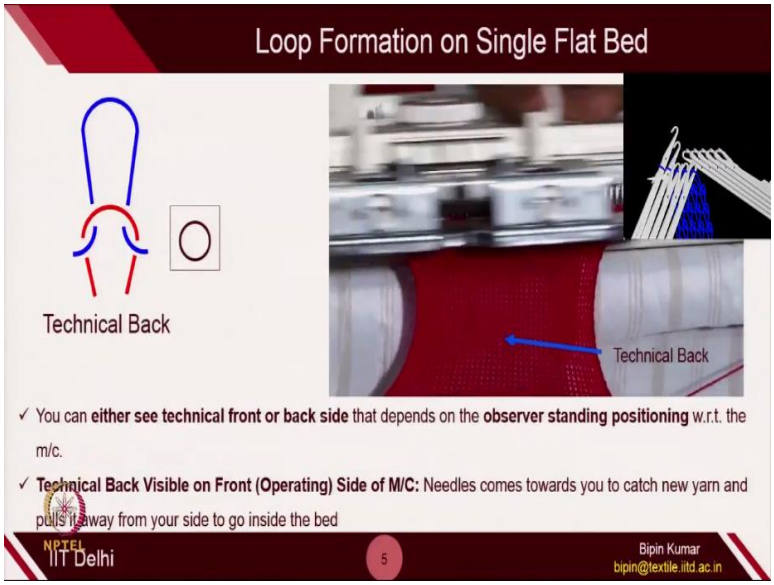

If you see the running condition of this machine; so here, **(Video Starts: 09:09)** you can see, we are running the cam jacket from left to right and right to left. So, naturally the needles is coming towards you, catching the yarn and it is going on the back side. So, if you carefully observe the movement of needle, if you stand in front of me in machine; let's suppose, if you stand here, the needle is coming towards you; it is catching yarn from the feeder; and then, it is going back towards the bed.

So, naturally, if you try to analyze, it is catching the yarn on the other side of the fabric. And after catching, it is pulling that new yarn towards the back side. So, this surface which you are looking at, it is actually technical back side of the fabrics. So, depending on how you stand, you can easily see whether, the machine is creating technical front or back side when you are standing in front of machine.

For this particular machine, it is technical back side which is visible. When you are standing here and running the cam jacket, you are actually watching the technical back side. So, this is the technical back side of the fabric. And the reason being, because needle is coming towards you to catch the yarn. And then, after catching the yarn, it is taking that yarn and making the loop on the back side of the fabric. So, that's why, this surface is technical back side. **(Video Ends: 10:35)**

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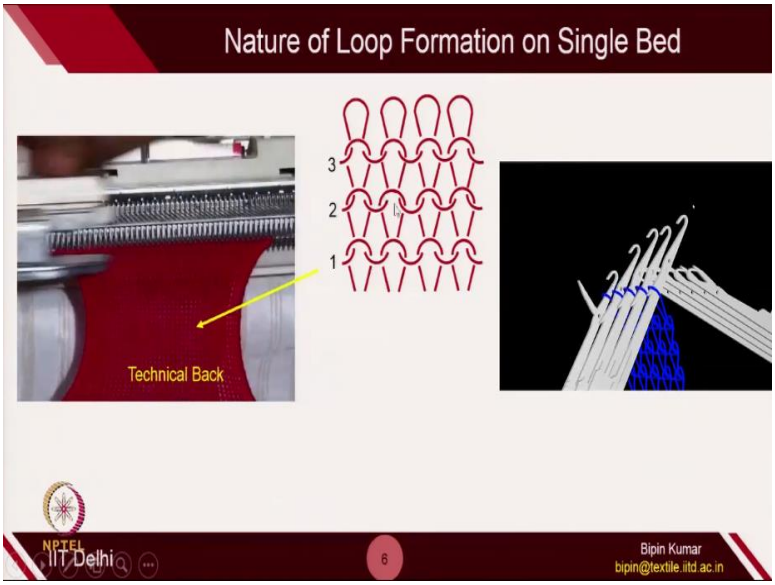

(Video Starts: 10:36) So, if you see this fabric on the machine, this is actually the loops which is being generated. If you take a snapshot, the loops will look like this. Okay. And I have also given you the symbol how you can represent this fabric. There are 3 courses. Let's suppose you have created and there are 4 columns.

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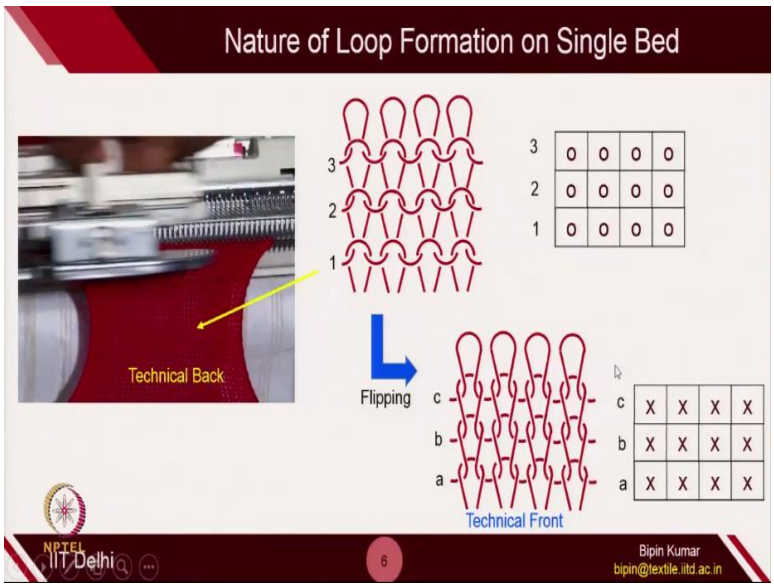

So, you can simply represent this fabric by circle in the boxes. So, each circle in 1 box represent 1 loop. So, so if you see this course, so, 1, 2, 3, 4. There are 4 loops and all are technical back loops. So, that's why, in all 4 columns, you have given 4 circles to represent 4 technical back loops. Similarly, if you see the second course; this is the second course. So, here again, the nature of loop is on the back side; so, 1, 2, 3 and 4.

So, 4 loops on the back side. This is how you denote the fabrics. But, if you flip this fabric on the other side, if you flip this fabrics; meaning, if you take the fabric and reverse it on the other surface, you will be actually looking the technical front side. So, if you just reverse the fabric which is not visible here, if you rotate this fabric by 180 degree, you will be able to see the other surface which is on the back side.

So, on the back side, actually all technical front loops are present. And we can denote these front loops by cross symbol. **(Video Ends: 12:09)** So, if you see this particular machine, it creates a kind of fabric in which there is either technical back on one surface or technical front on the opposite surface. So, this is the only type of fabrics which a single bed machine can produce.

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So, thus, this name single jersey fabrics comes in the picture. So, jersey usually indicates the knit fabrics. Jersey is another synonyms for knit fabrics. And single jersey means, the jersey which is created on single bed. So, a weft knit fabric that is produced on a single bed machine is called single jersey. The feature of the single jersey fabric is: you can either see technical back side, back loops on one side; and if you flip that fabric and look at other surface, you will be able to see technical front side.

So, this fabrics has either technical front or back on the surface. They do not have the combination of technical back and front on the same side. Either they have technical back completely on one side or technical front completely on one side. So, single bed machines;

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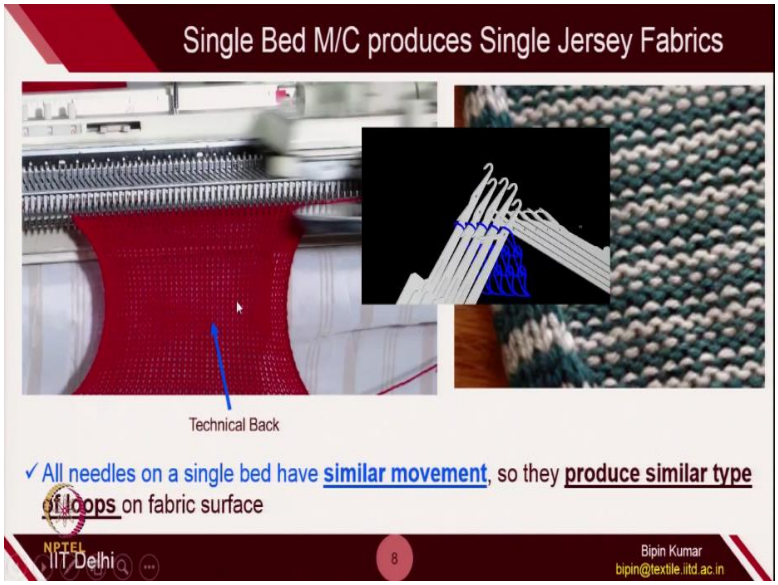
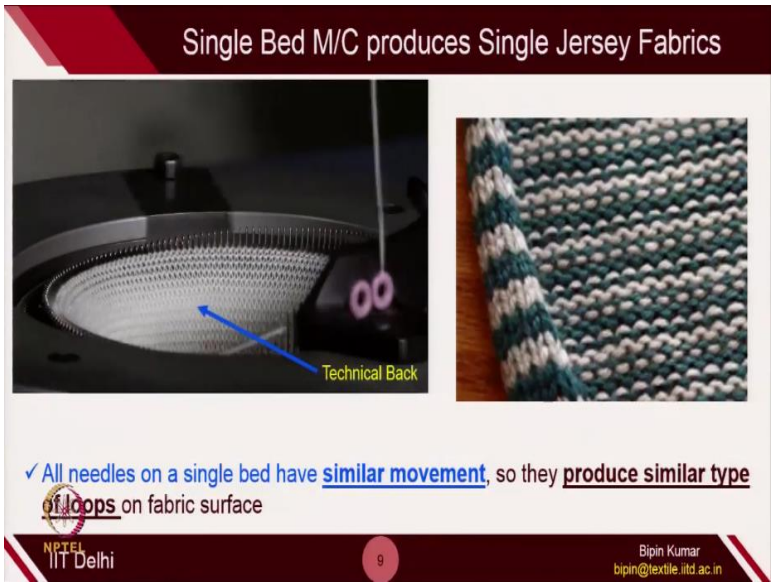


(Video Starts: 13:31) If you see the nature of this machine, the way the needles are placed, they can only pull the yarn on the back side. So naturally, all single bed machines can create only **(Video Ends: 13:42)** similar types of loops. So, they can only create single jersey fabrics. **(Refer Slide Time: 13:47)**



If you see circular knitting also, all the nature of movement of needles are same. They are pulling the yarn, going downward. So, again they produce similar types of loop on fabric surface. **(Video Starts: 13:59)** So, here you can see, all the needles are going up, catching the yarn from the feeder which is rotating and then taking that yarn on the bottom side, which is not visible here.

So, whatever surface you are looking, this is actually technical back side. So, the nature of needle that is placed on single bed, whether it is flat or circular, **(Video Ends: 14:23)** the nature

of moments of all needle remain same. So, that's why they produce similar types of fabrics or single jersey fabrics.

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Now, we come to next section of this lecture, which is curling in single jersey fabrics. Curling is one of the basic features which you can observe by looking to single jersey fabrics. So, whenever you see any single jersey fabrics and if it has open ends; so, if you, let's suppose, if you have a rectangular section of the fabric; if it has free ends, free edges, then you will always observe that the fabric is curling from the edges.

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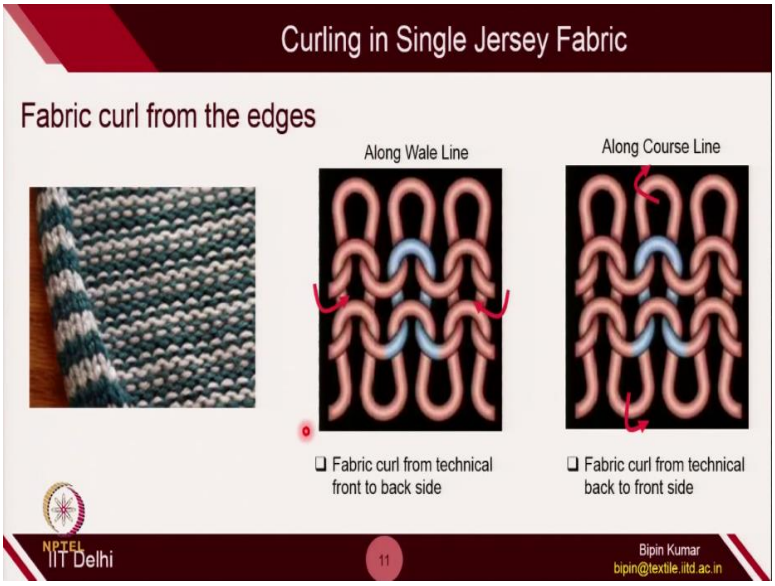

And in this particular section, we are going to understand why this particular fabric is doing the curling. This is one of the basic features due to which knitting fabric is entirely different from a woven one. When you make a woven fabric, when you cut the fabric, the fabric remain

stable on the platform. But when you work with a knitted fabric and especially with the single jersey fabric, the moment you will cut it from any sides; from the edges it will try to curl, it will try to bend, which you can see here.

It will never remain stationary like a flat surface. So, that is the curling features which most of the single jersey fabrics you can observe. And the beauty of this curling is, it has different nature along different surfaces. For example, if you have a free ends and if you will see along wale line; if you see this particular free edge and this particular free edge, the nature of curling will be completely different.

So, the fabric will try to curl from technical front to back side. So, from this photo also, you will be able to observe; if you see the photo; so, this is the technical back side of the fabric, but the curling directions, you can see, from this edge which is the free ends, the fabric is bending from technical front to back side. So, all the loops which is present on the left side of the fabric, they are actually bending towards back side. Okay.

But, if you will have observe along course direction, which is not visible here; I am going to show you the fabrics in a while; but on the course direction, all these top loops is actually trying to bend towards front side. So, along the edges, if you see the fabric; on one side it is bending towards back, but on the perpendicular side, it has opposite nature, it is bending towards front side.

This is one of the important feature in curling. Because of this, it is very difficult to work with these type of fabrics in cutting and sewing. Let's try to first understand why this curling is happening. Before moving to that, let's see the nature of this fabric and try to observe the direction of these motions. Along the wale line, the bending from front to back; and along the course line, bending from back to front.

Let's see the fabric itself. **(Video Starts: 17:47)** So, I am showing you the fabric. You can see, the fabric in relaxed condition, it is bend automatically, which is very strange. If you see any other fabrics, like woven fabric or many types of knitted fabrics, you will not observe this phenomenon. But in case of single jersey fabric, this type of behavior is always observed. So, the fabric will never remain in a open state, it is always in the curled state.

Now, try to see the direction in which it is curling. So, let me first zoom it, so that you can able to see which one is technical front side and which one is technical back side. So, you can see, this is the technical back side. Okay. And, the technical back side, because you can observe the head and sinker part. So, that's why this is technical back side. Okay. And, if you see the free edges, this is the free edges.

I am holding it right now, so that it can remain open state. I am holding this edge. And the moment I am releasing this particular edge, it is automatically bending towards the technical back side. So, this side is technical front side and this one is technical back side. So, along this side, it is the nature of bending is from technical front to technical back. So, along this side, the loops which is there on the left side of the fabric, they all try to bend from technical front side which is at the bottom side which is not visible; from the bottom side to the top side; and top side is your technical back. Okay.

So, the nature of bending is from technical front to back side. If you see the opposite side, this is again, the nature is bending from technical front side which is at the bottom side; from the bottom side to the top side. Okay. So, the nature is from; so, technical front side to back side. Okay. So, this is how it is bending. So, now let's try to observe the perpendicular sides. So, perpendicular sides means this one along course direction.

So, along course direction, this is the course direction. And if you try to open this fabric and try to observe this particular side, the nature is automatically in the opposite direction. So, you can see, in the relaxed state, the loops; so, in the relaxed state; if you see here, the nature of bending of this particular side is from technical back to front side. Because this is the technical front side and this is the technical back side which is at the bottom.

So, this side has opposite tendency compared to the perpendicular side. So, this side and this side, they have opposite nature of curling. Okay. And if you go at the bottom side also; again, if you relax the fabric, again the nature of bending is from technical back to front side. Okay. This is the front side and this is the technical back side. So, the nature of loop is bending from technical back to front side.

So, this is how this fabric behaves. And you can see, whenever I have to cut the fabric, how difficult it is, because the fabric is not stable. The moment I am releasing this fabric, it is always in some kind of bent form. So, making any clear cutting or sewing is extremely difficult due to

presence of curling. Now we are going to understand why this curling is happening and why this curling is different in 2 different sides. Okay.

Along the wale side it is different, the nature is different; and along the course side also the nature is different. So, let's understand why it is happening and why we need to create different types of knitted fabric. Okay. So, now let's see. **(Video Ends: 22:20)** So, just now we discussed, along the wale line, it is bending from front to back side; and along the course line, it is bending from back to front side. Now, let's see why it is happening.

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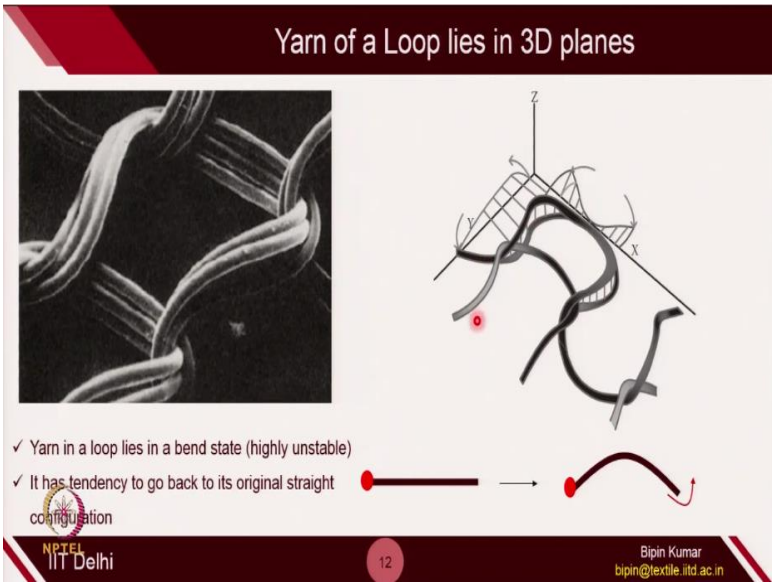

To understand this, you need to first understand like, whenever we create any loop by the yarn, it is either coming out from the old loop or either it is going inside the old loop. So, in this process, you can clearly see the yarn which is there inside the loop. It is not standing or sitting in a same plane. It is coming on the top of the plane also. So, the yarn part of a particular loops are always in the bend position. Okay.

They are available in all 3D planes. It is not just 2D plane where the yarn is just lying, it is also going in the third plane. Okay. So, if you see any yarn, any textile yarn, it always is, it is in natural state, it is always in straight conditions. But, when you make this yarn to bend into some unstable position, naturally the yarn will try to relax. Okay. So, at present, whenever we are creating loops, the yarn in the loop is in a bend state which is not in its natural states, because in natural condition, yarn all yarns are in a straight configuration.

But inside this particular fabric, we are forcing this yarn to bend in a certain fashion to create a loop. So, and this bending state is highly unstable state. And once any object is in highly unstable state, naturally, it will automatically try to moves into a stable state, because this kind of configuration is not supported by the law of physics itself. So naturally, the yarn which is not supposed to stand in a bend state, it has always the tendency to go back to its original state.

And what is the original state? Which is the straight configuration. You can also understand by simple example. Let's suppose, if we take any rod. From one side, if you bend it, if you, from one side if you bend it; and if the road is elastic, the moment you release the force, it will always try to go back to its original straight configuration. It will allow you bending, but you have to hold it so that the yarn can be in the bend form.

But the moment you release it, this force from other side, it will always try to go back to its original state. So, the nature of this yarn is always to recover from the bending state. So, in the loop also, in each plane, the nature of yarn are in different bending states, sometimes it is bending in a concave order or sometimes it is bending in a convex order. So, we need to first; for example, if you see here, the this part of yarn is bending in some other fashion and the head part of the yarn is bending in some other fashion.

So, if we understand how these bendings in a different plane is happened, we can able to observe what is it behavior during its rotation. To observe this, we need to first look at the projection of the bending of these yarns, of this different segments of this particular loops into 3 different planes, so that we will be able to see, in which plane how the yarn is actually bent.

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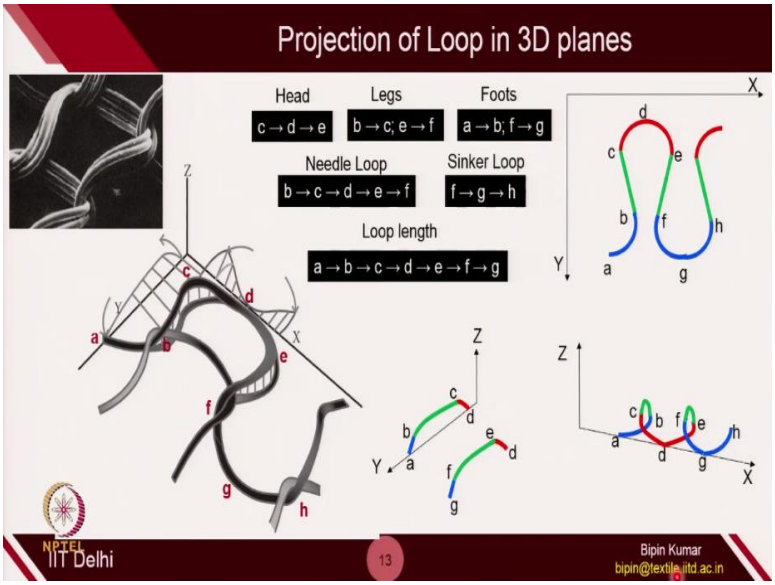

This is the actual loop and you can see the yarn is bend in different configuration. Okay. Let's try to see the bending in different segment of this particular loop. So, you can see, this is the particular loop. Let's define some of the segments of this loop. We have already defined leg, head, needle part, sinker part and loop part. Let's try to differentiate each of these segments. So, we start from this ends, which is the a point; and from a to b, b to c, d, e, f, g and h. Okay.

So, we are actually covering the entire loop and now we are going to make a different loops here altogether. So, each of these segments, we can define it. We already know this definitions. So, from a to b part, if you see, this is the foot part of the loop, a to b. And from b to c, if you see b to c, this is nothing but the leg part of the loop. After that, from c, d, e, you can say, this is the head part of the loop. Okay.

And again, e to f is the leg part; e to f is leg part. So, there are 2 legs, 1 head and 2 foot in a entire loop. We have also defined needle loop and sinker loop. So, needle loop is nothing but, we start from the leg section, cover the head section; and then we cover the second leg section. So, from b, c, d, e and f; these are needle section. And this particular section is f, g, h. This is nothing but the sinker loop. Okay.

We have already defined these terms in first week also. And also, we have introduced this during sinker movement. And if you try to see the entire loop length, we start from a and we end at g. Okay. So, a, b, c, d, e. So, we start from a and we straight away go to g. So, in the entire length, this yarn is an different state. So, from a to b, it is rising in some other way. From b to c, it is doing another kind of bending nature.

From c to e, it is again having different kind of bending nature. So, to understand this, let's project these yarns into 3 different planes. If you know coordinate geometry, we can have 3 planes. So, here I am showing you 3 axis. One is the x-axis, you can see here, this is the x-axis. This is the z-axis which is on the top side of the fabric. And this is the y-axis. So, the fabric is actually lying on a x-y plane, but yarn is actually moving in z direction as well.

So, let's try to project each of these segments of a loop in each of these planes. So, we start from the most easiest one which is the x-y plane on which the fabric is placed; the horizontal surface on which the fabric is placed. So, x-y plane. So, in x-y plane, if you see from the top, the projection of each yarn will look like this. So, the yarn will actually looks like a perfect loop.

And this is what we have already introduced you. So, if you look from the top and the fabric is placed on the surface, if you try to project, each yarn will make a perfect loop. Okay. So, from a, b, c, d, e, f and g. So, you can easily denote. So, a to b, b to c, c, d, e, f, g, h. So, f g h is the sinker part; c d e is the head part. So, c d e is the head part f g h is the sinker part. So, this is the most simple one.

And in knitting, you might have seen these type of diagram everywhere in research paper as well as in books. But, let's try to project in 2 different other planes; the x, x-z plane and x-y plane. So, first look at this y-z plane. So, now, we try to see the projection in y-z plane. So, in y-z plane, if you see the movement of this segment of yarn, a to b, it is actually rising. Because you can see the movement of yarn has to go up, because the yarn is pulled from the back side of the fabric to the front side, because we are making technical front loop.

So naturally, from a to b, we are going upward. a is the point where z is 0 and we are going upward. So, a to b. After a, we are moving to c part. So, if you carefully see the point c, when we are going to create a new loop after this one, the c part has to be bend by the next new loops. So naturally, from b to c part. You can see from here. So, b is here and c is somewhere here.

So, from b to c, you can see, this yarn is still going up and then going down. So, it is going up in z direction and then going down. Okay. So, this is the projected part of the leg segment. So, the leg segment is not straight, not in the same plane itself, but rather it is going and then going

down. So, you can see from this figure also, it is, from this point which is somewhere bottom and then it is rising and then it start going descend, because the head part is going down of this particular loops.

So, from b to c. After c, you can see the d is further at the bottom most position. So, d is somewhere here at this point, which is at lower height than c point. So, naturally, we are going from c to d. So, this is what is the projection of this segment; so, from a to d on this particular plane. Okay. Now, if you start from d to e, if you carefully see a to d, these are exactly mirror image of d e f g.

So, the projection of d e f g on this plane will remain same, because they are just identical. Only the x coordinate is changing, but d e f g, the x and y coordinate will remain same according to a b c d. So, we can simply project the d e f g segments on the same plane. It will actually look like exactly same. So, d e f g. So, this is the projection on z-y plane. Okay. Now see the projection in the last plane which is z-x plane.

This is the most complicated one. In z-x plane, if you try to see the segments from a to b, naturally x is changing. You can see here, a to b, x coordinate is changing. Also, from a to b, z coordinate is changing. So, this is how it will look. So, from a to b, x coordinate is changing and z coordinate is also changing. After that, it is going from b point to c point. So, if you see b to c; so, c is on the left side of x.

So, if you see, c is actually on the left side of the b. The c has to be somewhere here. But, we have also seen here, from b to c, the z is increasing and then it is decreasing as well. So, it will look like this; somewhere it is, first the z is increasing and then z is decreasing and then we reach c point. Okay. So, this is the leg part, the projection of the leg part on z-x plane. Once we reach c, we are going to d point.

So in, C is naturally at the higher most position. And then we are going to d which is the bottom most position. So, in here, from c to d both, if you see here, c to d, x is increasing, x coordinate is increasing because we are going towards right, as well as the z is decreasing. So, from c to d, z is decreasing and x is increasing. So, this is the projection of a b and c d. Okay. a b and c d, these segments is identical to d e f g.

You can repeat this entire projection somewhere here. So, from d to e, again it will be rising because e is at higher most position and z is increasing and x is increasing. Both is increasing. f is on the left side of e. From e to f, first z is increasing and then it is decreasing. So, from e to f, z is increasing and then decreasing. And it is on the left side of e. So, and after that, from f to g, again this part which is the mirror image of a to b. Okay.

a to b and f to g are similar. This is how we completed the entire loop. From g to h, if you further go ahead, it will look like this. So, this is how the projection of loop is done in 3 different planes. So, the most simple one to understand is this one and the most difficult is this one. But the beauty of this projection is, now you can see how the yarn is actually bend inside the fabric. It is not that simple.

Only the yarn is bent in the form of perfect loop, but also, it is bent in z direction. And due to which it has different nature of recovery. And this is why the fabric curling is different in different sides. So, let's see why the nature of wale curling and course curling is different from the edges.

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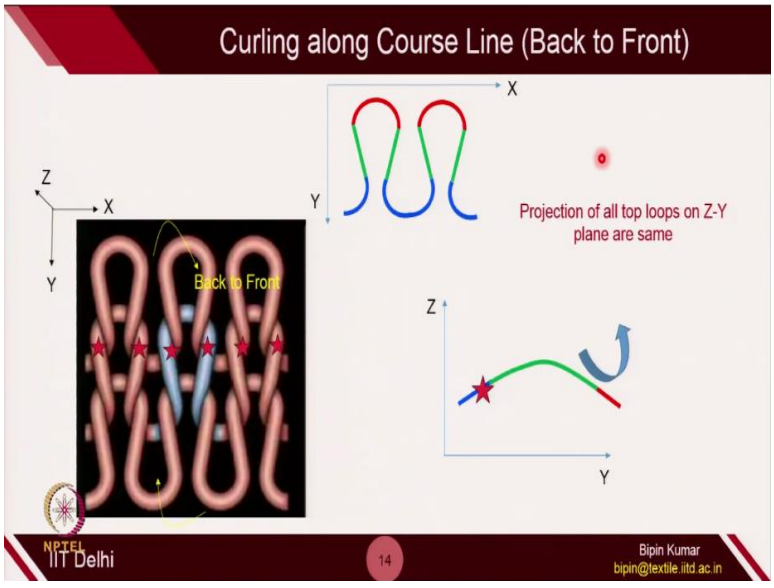

So, this is the fabric where you have 3 planes and the fabric is placed in x-y plane, which is the plane of the PPT you can say. And z is outside this screen. We have already seen the projection in x-y plane which is perfect, it is the most simple one. So, if you see the loops here, it will look like this. You can keep continuing depending on how many loops are there. And let's try to see the projection of course line.

So, course lines means, we start to see the projection of each of these loops. So, first loop, second loop, third loop. So, all the projections, we try to see in z-y plane. So, in z-y plane, each of these leg segments, starting from the feet part and then going towards at this point, the projection will look like same. We have already seen this here. You can see here, the projection actually are exactly like this.

So, in z-y plane, the projection of a b c d is like this, this is what I am showing you here. So, this is basically the projection of a b c d; one feet and one leg. Okay. So, one feet, one leg; this leg and this feet, they also have the mirror image. So, the projection will be identical to this. Again, if you see this particular feet and leg, the projection will again be the same. So, projection of all loops, all top loops on z-y plane, it remains same. Okay.

So, projection of all loops, 1, 2, 3; they are actually having same projection on y-z plane. Now, let's see where we are holding this fabric. So, basically, if you see each of these loops, we are holding somewhere here. So, at this point, the old loop is holding its feet and leg part. Okay. So, if you see this loops, we are holding here. And this loop, we are holding here. So, we are holding each of these legs at this intersection points: 1, 2, 3, 4.

So, all loops are actually hold at each of these points. So, if you hold at these points and the other point which is here is free. So, this point is free. Just I mentioned in couple of slides before, if you bend the yarn and if you hold from one side and if other side is free, it will try to recover its straight section. So, once it will try to recover its straight section; so, what is the nature of bending then?

So, the nature of bending will be naturally anti-clockwise. Okay. So, all these loops will try to bend in anti-clockwise directions, because the ends are free. So here, we are not holding it. So, all these leg segments, especially the green part, these green parts; all these leg segments will try to bend anti-clockwise. So, if all these leg segments try to bend anti-clockwise, it means it will try to come towards you, come towards the viewer.

So, this is the front side. So, naturally, bending is towards the back to front. So, it is coming towards the front sides, because the ends are free. So, this is why on the top edge, along the course line, the nature of bending is from back to front, because legs are dominating the bending. Now, let's see the nature of bending in, along wale line.

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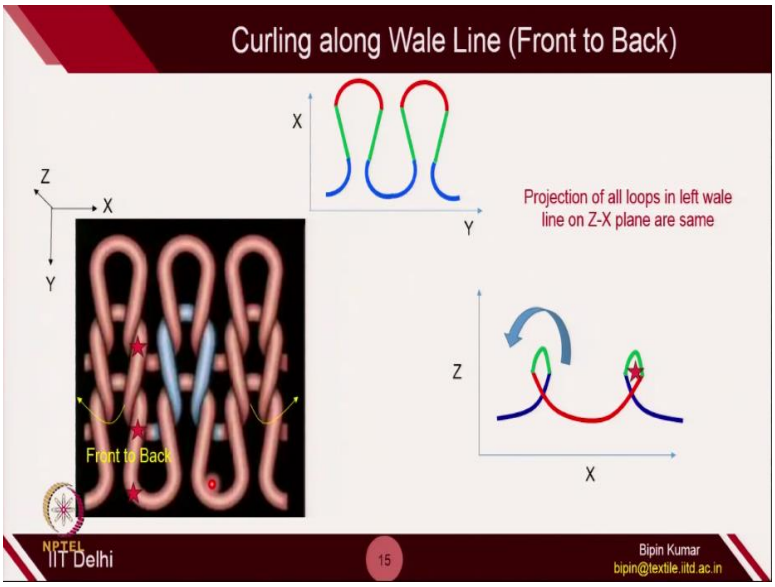

So, wale line, this is the wale line. So, what is happening here? So, we have already seen the nature of bending is from technical back to front side. Let's see the projection first. And then, we will observe what is exactly happening here. So, this is the front side of the fabric. So, the projection is like this. We have already seen this projection. Okay. So, if you hold the fabric; so, for each of these loops; if you see each of these loops: 1, 2, 3; along this line, along this wale line, if you see 1, 2, 3 loops and try to see the projection on z-x plane, they all will have identical projection.

And we have already seen this projection features in couple of slides before. So, this will be the nature of projection in z-x plane of each of these loops. If you see here, each of these loops, especially at this point on the right side of loop, we are holding it, because we have the fabric on the right side. But on the left side, we don't have any fabrics. So, on the right side, where there is a leg and the feet part, here, especially at this location, leg and the feet part, we are holding the fabric, because the loops are holding it.

But on the other side, since there is no extra column on the left side, because this is the free ends. So, this part is free. Okay. This part is free to perform its action. So, naturally, if you see, the yarn is bend in this way. So, once the yarn is bend in this fashion, what will be the nature of curling? The curling will be, it will try to open up; it will try to become straight; it will again become anti-clockwise direction.

And if it will go anti-clockwise direction; so, naturally, it will go inside towards the back side of the fabric. So, the nature of curling will be from front to back side. So, this is how the curling in a single jersey fabric is different along the wale line and course line. Now comes to the problem. Because of this fabric curling and because of this unstable behavior of this single jersey, fabric ends become highly unstable.

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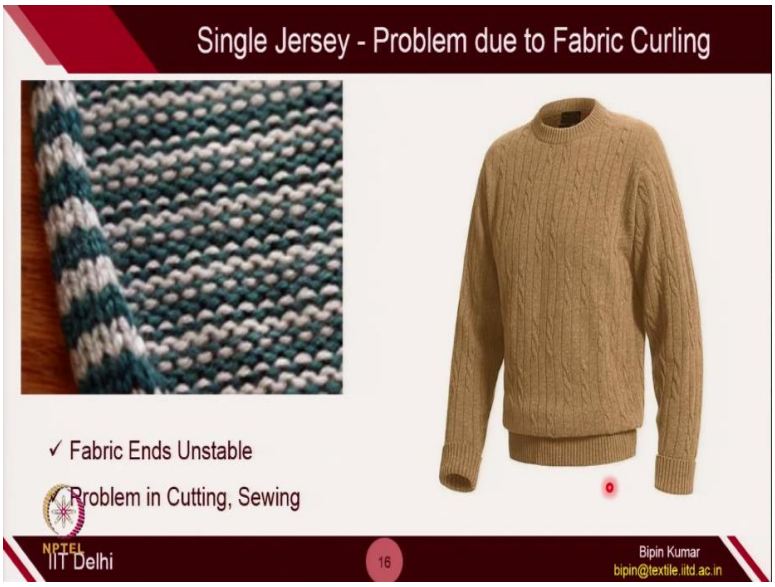

And we always have the problem of cutting and sewing. So, this is why we need to look for some other alternatives through which we can minimize these kinds of problems. If you see any sweaters and if you try to observe the fabric at the ends, especially at the collar, at the end segments, at the end of hand segments, the nature of these fabrics is not single jersey. It is something different.

And the main reason is, because we have to make sure the fabric at the ends remain stable. Otherwise, it will curl and it will not look good aesthetically on the wearer. So, single jersey is one of the biggest problem. This is why we need to look for other fabric structure or we need to look for other fabric technologies, especially in knitting, so that we can minimize the problem of curling.

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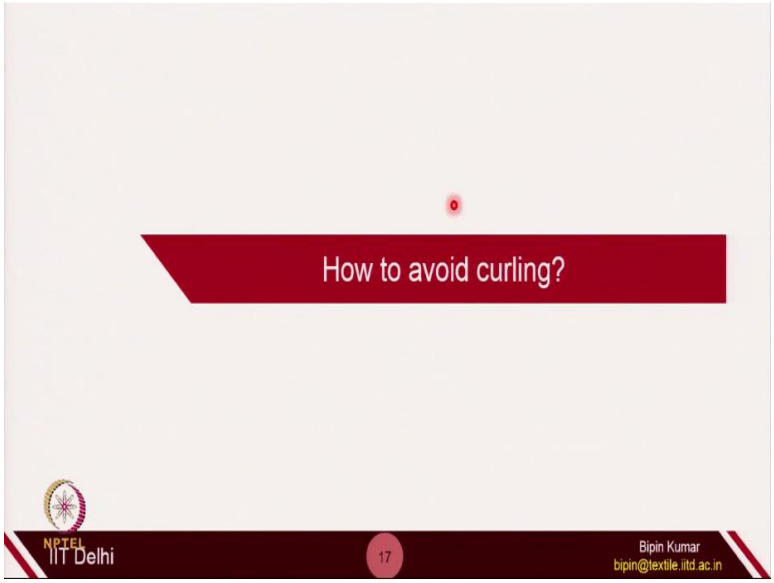

Now, let's see how to avoid curling.

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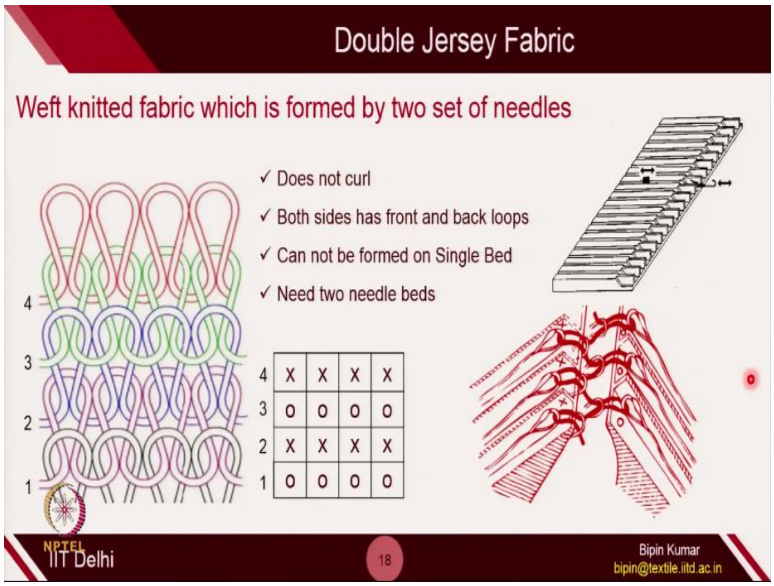

To avoid curling, we have another category of fabric in knitting which is called double jersey fabrics. So, double jersey fabric is nothing but a fabric which is formed by 2 sets of needles. So, if you see single jersey fabric, it is produced by one set of needle and all needles are placed on 1 bed. But now, we are moving to double jersey fabrics. And in double jersey fabrics, we have 2 sets of needles.

And so, since it has 2 sets of needles, so that's why it requires 2 bed. The beauty of these type of fabric is, it does not curl from any sides. And both sides has both front and back loops. So, let's see this particular schematic of this fabric and try to see how the loops look like. So, it has

4 courses. So, one is the pink one, the bottom one. And then blue one; then green one; and then red one.

I have already demonstrated this. So, for the first one, if you see, it is going on the back side. So, all are back loops. So, on the first course, if you observe the yarn, they all are going on the back side. So, these are technical back loops. Now, if you see the movement of the purple one, they are, all are coming on the front side. Okay. Now, when you see the green one, they all are going on the back side.

And then, again red one coming front side. So, on the fabric surface, in each course or in multiple courses, you can find both technical front as well as technical back loops. Okay. So, both side has front and back loops. And this is the fundamental difference of double jersey fabrics with respect to single jersey fabric. So, if you see the notation of single jersey fabrics, either is, it is totally cross across all the columns, all the boxes or it is totally 0.

But in a double jersey fabric, you will must see both technically front and back loops on the same side. And this is how, fundamentally it is different. So, if you have technical front and back loops on the same side of the fabric, it cannot be naturally produced by a single bed. Because in single bed, since the movement of all the needles are same; so, you can either produce technical front or technical back.

You cannot produce, like half needles producing technical front and half is producing technical back, because the nature is almost same. So, it is not possible. So, double jersey fabric cannot be formed by single bed knitting. So, this is why we need to come with a new type of technologies where some set of needles will be making technical front and some set of needles will be making technical back simultaneously.

And this is possible when we are dealing with 2 beds, 2 needle beds. So, in this entire week, we are going to focus on double needle bed machines, so double bed machine. So, single bed, which was the prime target in the week 2. Now, in this week, we are going to move on the double bed. So, we have 2 beds and 2 sets of needles on each side. And they will be doing opposite actions.

So, on one side, if they are producing technical back, then other side will be making technical front. So, this is how it works. So, a fabric which is produced on double bed is called double jersey fabrics.

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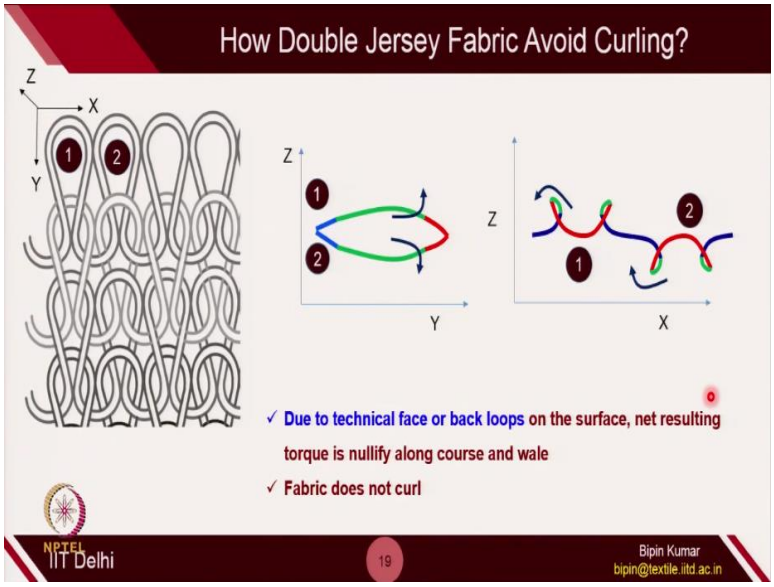

Now, let's look at the, some key features of double jersey fabrics. So, first of all, double jersey fabric does not curl. So first, let's see this fabric; and then, we will let you know, why this is not curling. **(Video Starts: 48:48)** Okay. So, now let's see, I am presenting you a double jersey fabric. This is your double jersey fabric and this is your single jersey fabric. So, you can see, how from the edges it is more stable compared to single jersey fabrics.

So, this is the fundamental difference. If you carefully see this double jersey fabric and if you compare it with single jersey; so, on the surface, if you try to see, you can only see the technical front side, because only the legs are visible. So, you can see here, similar nature of this fabric. So, this is the single bed machine fabric and this is the double bed machine fabric. So, nature is same. So, technical front.

But you cannot able to observe any technical back. If you flip this and try to observe again, it will again look like a technical front side. So, there is no technical back loops, you can see here. But what exactly is happening is that, when you stretch little bit, you can see there is another loops which is created inside. So, if you see, these 2 columns, they are actually not connected.

So virtually, there is extra column which is in between these 2 columns. And this is happening on the other side also. So, if you try to see what is inside, you can easily find the head part. You can see here. So, this is the curved section. Okay. So, if you open it, you can easily see the head and sinker part. So, between 2 columns which is technical front, there is technical back hidden on the back side. Okay.

So, although on the surface, it does not look like this, but in reality, the technical back and technical front is present on each side of the surface. But in visibility state, only technical front is visible, technical back is actually hidden between 2 technical front. Okay. **(Video Ends: 51:24)** How this having technical front and technical back on the same side, you can actually minimize the curling.

So, here I am showing you one of a simple fabric, double jersey fabric. So here, this loop is technical front loops and the next loop is technical back loop. So, let's first see the projection of these 2 loops. So, this is the first loop in z-y plane, in z-y plane, the projection of this leg will be like this, which we have already done this in couple of slides before. And the projection of this loop is like this.

And the nature of this loop is to bend in anti-clockwise fashion. Now, let's see the loop number 2. If you see the projection of this loop, the yarn is actually bend in opposite direction, because it is going inside. So, the yarn is bend in opposite direction. And the nature of curling will be naturally this side. So, once you release this fabric, this yarn segment will have anti-clockwise direction of curling and this one having clockwise direction or curling.

So, actually they compete with each other. And because this is symmetric, so eventually, no yarn is able to bend and no loop is able to bend. So, this entire loops along the course remain stable. So, this side remains stable which you have already seen the actual fabric feature. Now, let's see the z-x plane of loop 1. So, it is technical front side. So, this is how we make the z-x projection of technical front loops.

Now, after that, if you try to project this second loops, it is going on the back side. So, you can just flip it down. And this will be the projection of technical back loop. So, naturally, if you try to see the curling behavior of this loop and this loop along y-axis, this loop will try to bend anti-clockwise and this will try to bend clockwise. Okay. So again, these 2 loops; so, this

column and the entire this column, along wale, has different nature of bending; and due to which it will cancel out the effect.

So, due to technical back and front loop on the fabric surface, net resulting torque or net behavior of curling is nullified along course as well as wale direction. This is why double jersey fabric does not curls, gives you more stability. So, fabric does not curl. So, this is the fundamental difference between double jersey and single jersey fabrics.

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So, if, now if you see the sweater design, if you see, mostly this collar, neck and especially the end segments of this garment, they all are made from double jersey fabrics to make this structure stable. So, this is the reason why we need to have different types of technologies in knitting, so that we can create single jersey as well as double jersey fabrics.

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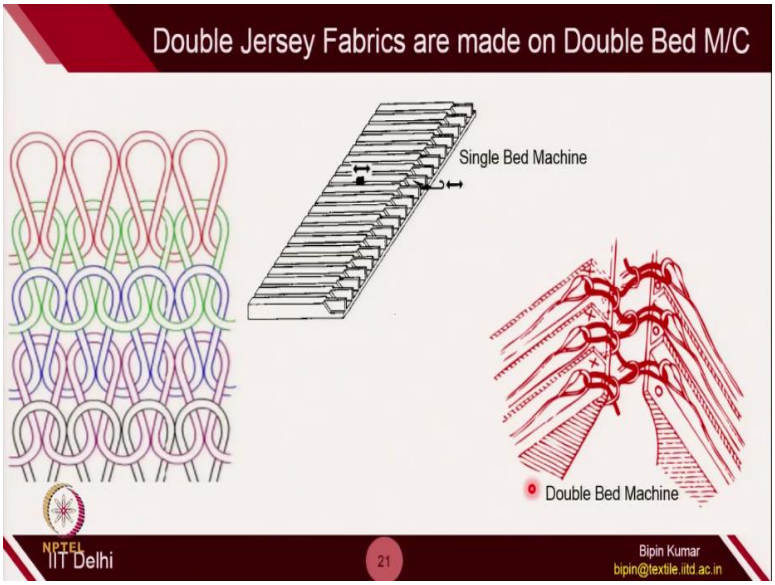

Double jersey fabrics can only be made on double bed, because on a single bed, since it has, similar type of needle movement, so it cannot produce double jersey fabrics. That's why we need 2 beds with 2 sets of needles performing in opposite directions. So, in this way, we can create technical front as well as technical back loops. So, this comes, this is why a new set of technological development starts happening in knitting, because we are creating more stable fabrics and double bed machines starts coming in the market.

Now, the reality is, most of the knitting machines are made up of double bed, especially V-bed machines, where 2 sets of needle beds are there and needles are performing different actions. So, in next couple of lectures, especially in this week, we are going to see the technologies related to this type of beds, this type of knitting. And we will try to understand the orientation is; also in circular bed also, we had 2 beds doing the same thing and the reason is to improve a stability of the fabrics. So, the entire week will be devoted to double bed technologies weft knitting.

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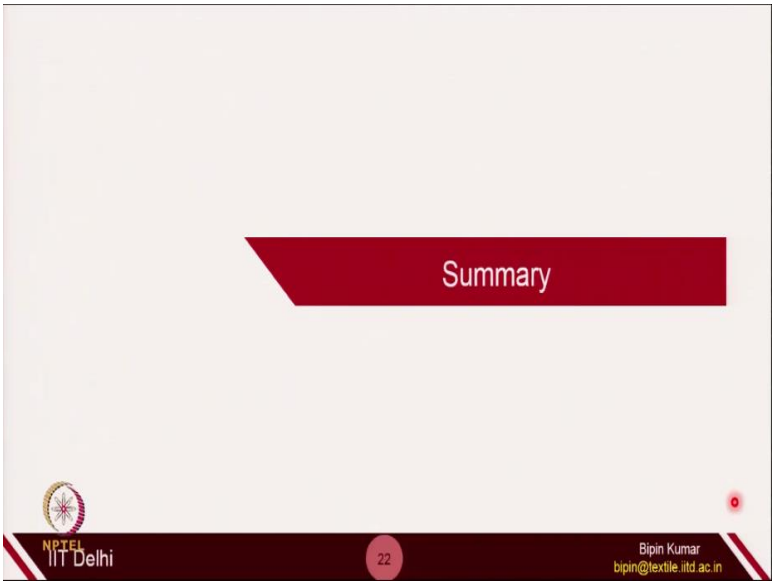

So now, I am going to summarize what we learned in this particular lecture. Naturally, we started with single jersey feature, the fabric features, it actually curls from the edges. And we make single jersey fabrics with a single bed machines.

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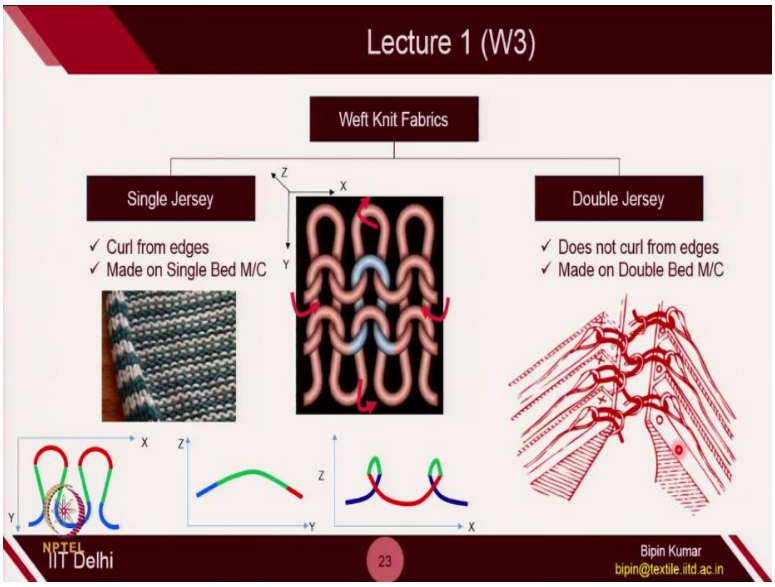

And we have also seen the curling nature in detail. How from the top side and especially along the course side, it bends from technical back to front. And along the wale side, it is bending from front to back side. So, the nature of curling is different. And you can able to analyze this nature of curling by taking the projection of each loops along 3 planes. And then, you can able to differentiate the nature of curling.

To avoid this curling, we need to produce double jersey fabrics which does not curl from edges. I have shown you the fabric samples as well. And to make these type of fabrics, we can only

make by double bed machines, because, then only we can have different sets of needles operating different functions. In double bed machines, we have 2 sets of needles. So, in next couple of lectures, we are going to understand technologies related to double bed.

So, I hope the point of the development from single jersey machines to double jersey machines would be clear to you. Let's catch in the next lecture, where I am going to show you most, some of the technological machines related to double bed. Thank you very much. Thank you very much for listening. Thank you.