Science and Technology of Weft and Warp Knitting
Prof. Dr. Bipin Kumar
Department of Textile Technology
Indian Institute of Technology - Delhi

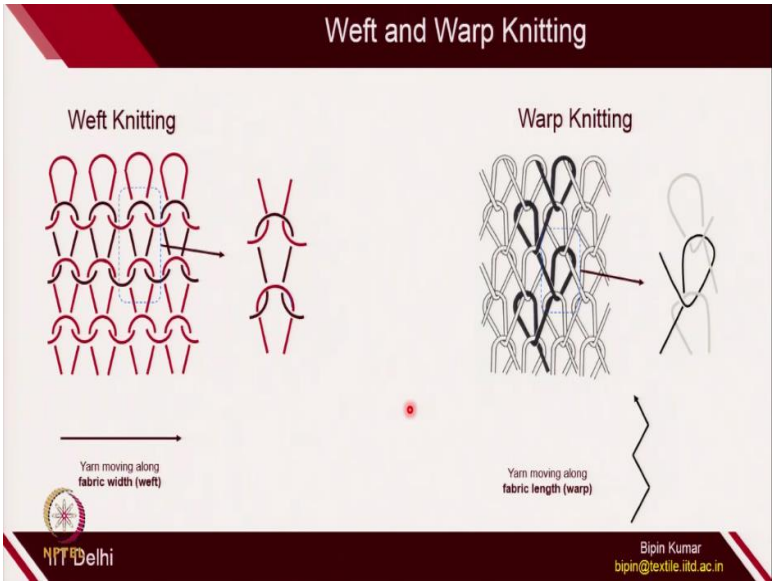
Module - 12
Lecture - 48
Weft and Warp Knitting - Summary

Welcome participants. Now, we are moving to last week in this series. In this particular week, my emphasis will be on, to help you understand the potential of knitting, both weft and warp knitting in different technical applications. You have seen how complicated this knitting is. We started the entire course with learning the science, engineering, design, as well as technologies.

So, before we move on to different technical application of knitting, I expect you to please summarize everything. Because there are, the syllabus is completely broad in both weft and warp knitting. You have seen, we covered almost 7 weeks completely on weft knitting and 5 weeks on warp knitting. So, in this particular lecture, before I move on to show you different technical application of knitting, I am going to summarize whatever we have covered so far, in 11 weeks.

Once you have the complete understanding of knitting, then I expect you to explore this knowledge and apply this knitting principle in other applications. So, let's move on to the summary part.

(Refer Slide Time: 01:41)



We have seen like weft and warp knitting are completely different in the way they are being formed. Both create loops, but the formation and the principle of knitting is different in weft as well as warp knitting. In weft knitting, you have seen the movement of yarn was along the fabric width, which is actually called weft in case of weaving. So, that's why we call this as a weft knitting, where the yarn movement is from left to right or right to left, along fabric width directions.

The beauty of this particular knitting is, because the formation of loops in such a way that each loops get equal tension from its neighboring loops. If you see the sinkers of which is connecting a particular loop with the left and right loops, they are in equal and opposite directions. Because of that, the symmetry is formed. And you will see mostly stable loops in case weft knitting.

Here also, if you see the movement of yarn, you can connect the loops of the same course. If you see particular loop, they are connected with other loops in the same course. And it is holding the loops of top and bottom by its head and feet. While in case of warp knitting, the principle is completely different. To create a warp knitting, you need multiple ends of the yarn.

And each end of the yarn will be making loops in either 1 or 2 columns. So, if you see the formation of loops in a warp knitting, the warps move in different columns. And if you see the sinker part, actually, each loop is connected with different courses; which is not the case with weft knitting. In this, each loop is connected with neighboring loops with sinker loops.

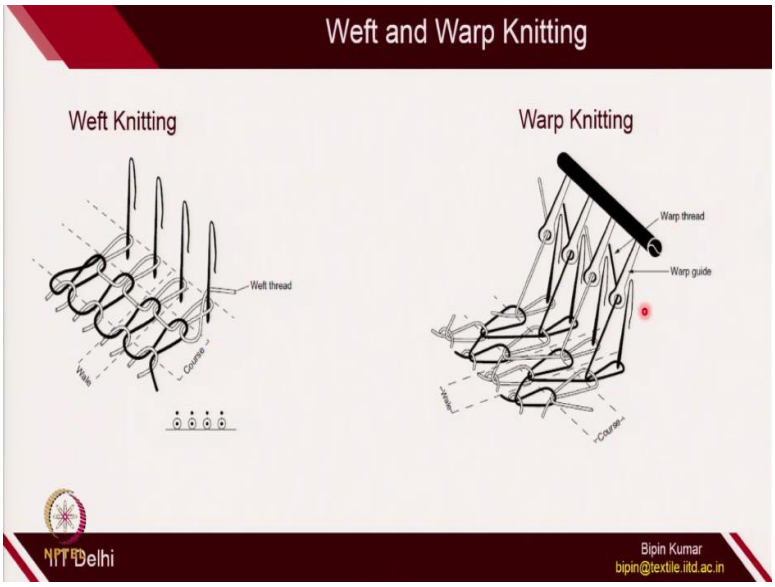
But in case of warp knitting, if you see this particular loop, one sinker loop is connecting with the loops in top course and the other sinker part is connecting the loops with the bottom course.

So, because of that, the sinker direction is completely different. This is why the tension in the loop is not equal. And you expect these loops to be bent in certain directions. So, in this way, weft and warp knitting are fundamentally different in many aspects. And we have seen in many lectures, how they are formed using different technologies. In warp knitting, the movement of yarn is actually in the length direction, which is called the warp.

That's why it is called warp knitting. These 2 types of fabrics produced in knitting has different characteristics, different behaviors. That's why they are recommended to be used in different applications. Especially, if you see the weft knitting, they are mostly preferred in garments. While warp knitting is mostly used in technical applications. Warp knitting usually have some importance in garments also, especially in lingerie and in intimate apparels.

But weft knitting is mostly popular in t-shirts, sweaters, woolens. So, this is how they are fundamentally different, not only in terms of their structure, but also in terms of their application potential.

(Refer Slide Time: 05:14)



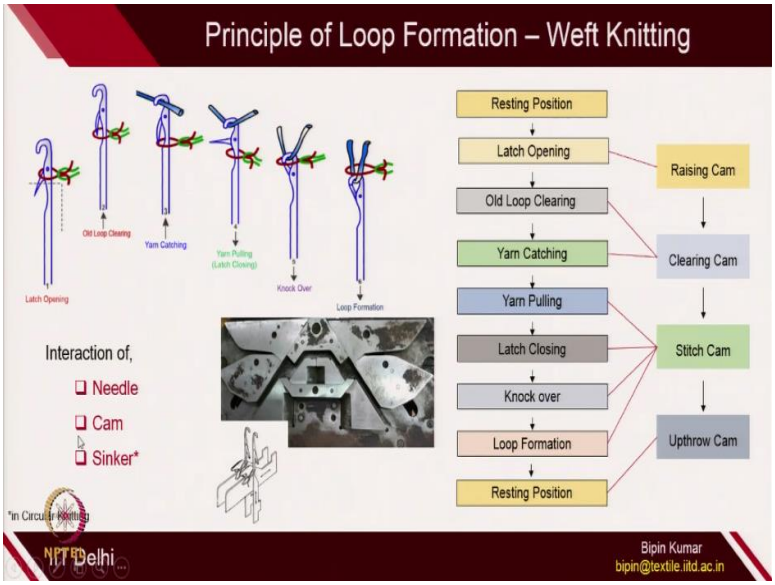
We have also seen the production principle of these weft and warp knitting. So, usually, in weft knitting, the loops are formed by series of needles which is placed on the bed. And the yarn is provided to each needle in a sequence order. While, in case of warp knitting, the

situation is completely different. Here also, the loops are formed by different needles, but the yarn is supplied to each needle at the same time with the help of warp guide. Okay.

So, these are individual guides. So, each guides actually provides the yarn to each individual needles at the same time. So, that's why the production of warp knitting is much, much faster compared to weft knitting. Because in weft knitting, the sequence of loop formations in a order. While in case of warp knitting, all the loops in a course, are formed at the same time. While in the weft knitting, the loops in a course are formed either one at a time.

So, either from left to right direction or right to left directions. Because, the feeder provides the yarn in a sequence order to each individual needle. While in case of warp knitting, guides provide the yarn to each needle at the same time. So, production capacity of warp knitting technologies is much, much faster compared to weft knitting.

(Refer Slide Time: 06:41)



We have also seen the principle of loop formation. In terms of principle of loop formations both in weft and warp knitting, its remain almost same, because we actually use the needle in the formation of loop. Because, to form a new loops, the old loops must come out from the latch and head part. And then the new yarn should be cached on. And old loop should be knocked out from the needle.

So, this is the principle of loop formation in weft knitting. To do this function, the needle can interacts with the cams. So, we have seen the principle of cams also. The path has been created. And the needle butt actually follows the path of the cams. And due to which the

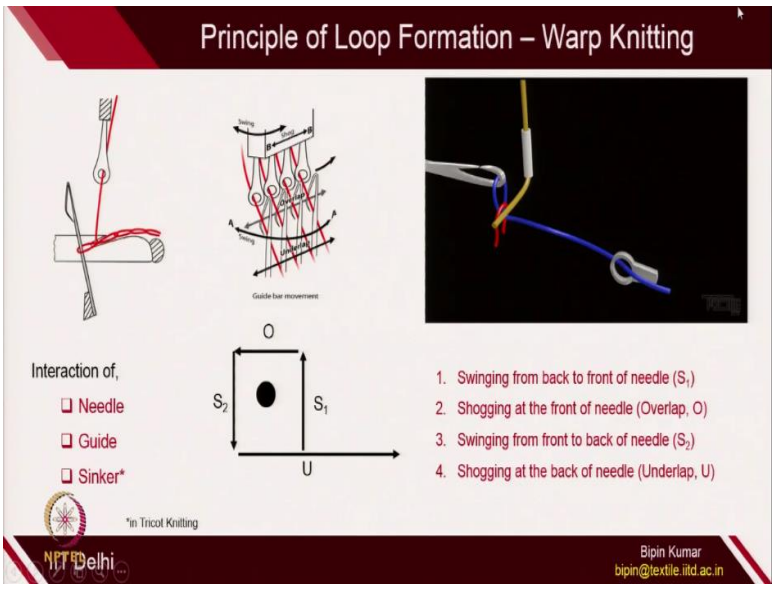
loops are being generated. So, the sequence is like this. So, which also, we have seen. So, the needle starts from the resting position.

Then, the latch gets open, because the needle butts interact with the raising cam. After that, the old loop is cleared. You can see it here. So, old loop is getting cleared. And this is due to clearing cam. Yarn is also catched after that. After yarn is catched, the needle starts moving downward or inside the bed with the help of a stitch cam. So, once the needle butt interacts with the stitch cam; this is the stitch cam.

It actually pulls the yarn, latch gets open and the loops get knocked out from the needle, especially the old loop; and the new loops get formed here, which is shown in the figure. After the formation of loop, it interacts with the upthrow cam and goes back to its original resting position. So, needle cam are the fundamental elements in loop formation in weft knitting.

And the sequence of loop formation must be followed in this way. Otherwise, the new loop formation will be impossible. In some machines, especially in circular knitting machine, we have seen also the importance of sinkers, how it helps in holding the loops. It actually helps in providing support surface for loop formation. It also provides support surface for knocking. So, in some machine, sinkers also become an integral part of loop formation. So, that's why, needle, cam and sinker; these are the 3 principle elements in loop formation in weft knitting.

(Refer Slide Time: 09:23)



If you see warp knitting; in warp knitting also, these 3 elements work together, especially needle, guide and sinker. Especially in sinker, the tricot, the machine's sinker's role is very, very important. So, we have seen how the guide bar does the swinging and shogging motion and provides the yarn. And all those sequence of loop formation remains same as it was there in weft knitting.

The old loop was clear. And then, the guide bar actually provides the yarn to the needle with the help of swinging and shogging motion. And then, old loop is knocked out from the surface. And the loop is formed. So, in the loop formation of warp knitting, what is more important for us is to understand the swinging and shogging motion of this guide. So, the guide is actually attached with the bar.

And this bar actually swings from the back side to the front side. And also, it moves laterally in the direction of needle bar to provide yarn to the needle. So, swinging motion from back to front of the needle. So, this is the swinging motion, first swinging motion. And then, shogging motion on the front side of the needle, which is called overlap. Then, another swinging motions, the swinging from front to back side of the needle.

And once the yarn is being supplied to the needle on the front side, now the guide bar switches its position from one needle to other needle. So, this is the 4 types of motions which each guide bars does during the loop formation in warp knitting. And you get yarn supply for each individual needles. **(Video Starts: 11:08)** So, here also, you can see, the yarns, the old loops actually comes out.

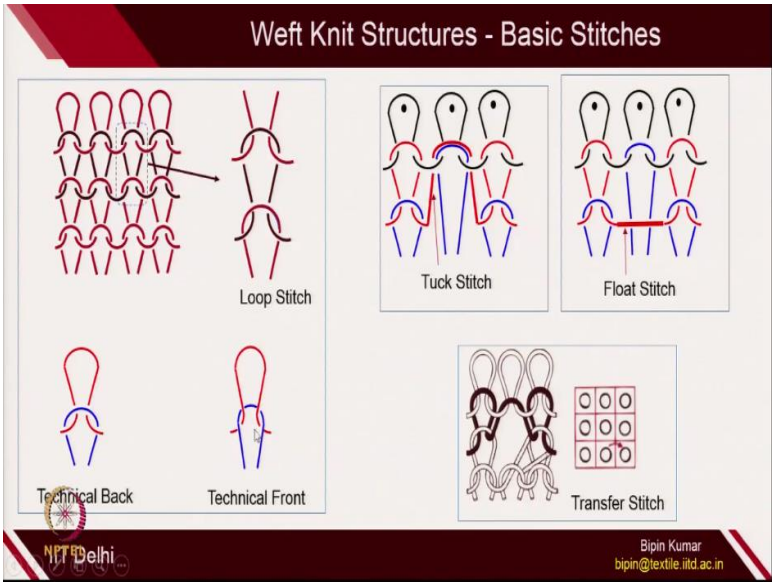
And then, guide bar supplies the needles in this way. And then, old loop is actually knocked out from the surface of the needle. So, this is important in loop formation in warp knitting. And we have seen how important is to understand the swinging and shogging motion. So, all the engineering designs of a warp knitted structures is generated if you understand the importance of overlap and underlap, as well as swinging motion. So, we have given sufficient time on understanding the overlap and underlap in warp knitting technologies. **(Video Ends: 11:48)**

(Refer Slide Time: 11:49)

In weft and warp knitting, we have seen so many different types of fabric structures. So, there was some design principles which was involved. So, I expect you to understand some of the basic design principle which is actually being used continuously for designing different types of knitting. That is the beauty of knitting. Even with the same machine, you can generate 100 types of design and 1000 types of structures, depending on if you understand these design principles.

So, if you see the weft knitted structure, you need to understand the importance of loop stitch; where you have one either technical back side you are forming the loops or technical front sides you are forming the loop.

(Refer Slide Time: 12:30)

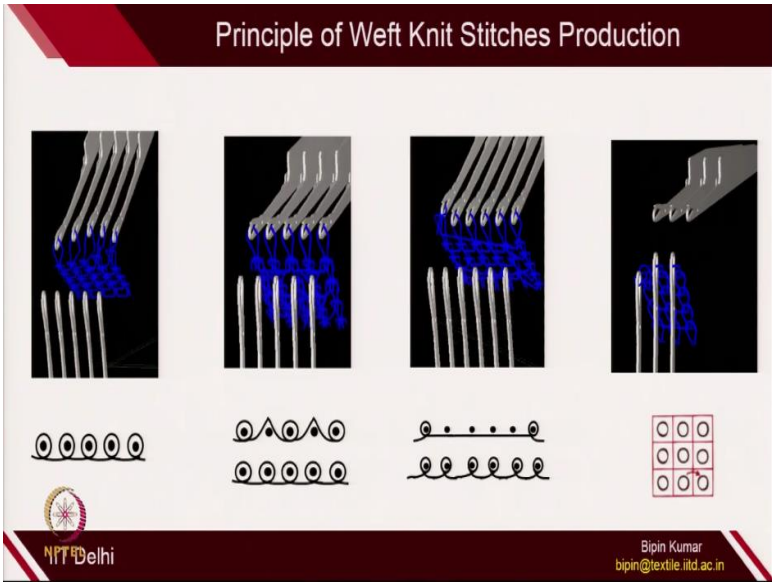


The other stitch which is also important is the tuck stitch, which is associated with the held loop. And this tuck stitch, which is actually the legs are open, because the there is no old loop which is there to hold the new loops. Because of that, the legs of the loops get open up. So, that is called tuck stitch. The another one is the miss stitch or the float stitch, which is also very, very important.

Here, the needle does not catch the yarn, new yarn. And it, and still holds the old yarn. So, because of that, the yarn remains floating in place of that needle. So, this is the float stitch, which we have seen in the videos also. And finally, the transfer stitch. So, in transfer stitch, you actually transfer the loops of one column to adjacent columns with the help of transfer function on the machines.

These are the 4 principles of stitches, which is used anywhere in weft knitted structure. So, whatever weft knitted structure which you are looking in the market, will must have either of these 4 types of stitches: loop, tuck, float and transfer.

(Refer Slide Time: 13:44)



So, here is the animation also. You can understand how these are created on the machines. The first one, the simplest one is the loops continuously being formed on each needles of the bed. That is called loop stitch. **(Video Starts: 13:56)** So, you can see, all the needles are doing clearing, knocking, catching. So, this is how you create loops. In case of tuck, the needles do the catching, but it does not clear the old loop.

So, this is the sequence of tuck formation. So here, the first course, the loops are being formed. In the second course, these 2 needles. So, second and fourth needle, they do not release the loops. And this is how you created a tuck structure. Similarly, if you see the float, the needle holds the old loop and does not catches the new yarn. Because of that, the yarn remains floating in the back side of the needle.

So, this is how they are created. So, the first course, all loops are being created. In the second course, you can see, these 4 needles does not do anything. It just holding the old yarn and does not do the catching. Because of that, the yarns are remaining floating on the surface. So, this is the float stitch formation. And this is how you do the transfer stitch. So here, loop from one column is actually transferred either to the left side or right side of the column.

So, in some of the advanced machine, especially jacquard knitting machines, you have the capability of achieving loop, tuck, float, as well as transfer at each position of either front bed or back bed. So, that is the beauty of technologies today's. So, technologies has become advance nowadays. And you can generate tuck, float, transfer or complete loop at any location in the fabric structure. **(Video Ends: 15:43)** So, once you does that, you can generate different types of design.

(Refer Slide Time: 15:49)

And we have also seen many, many complicated designs and networks of the yarn movements in the fabric. We have seen cable. So, these are the formation of cables and Aran design. Pointelle: So, you can see these holes which are created on the fabric structure is because of the pointelles. Loop transfer is also helpful in actually pointelle design. Jacquard:

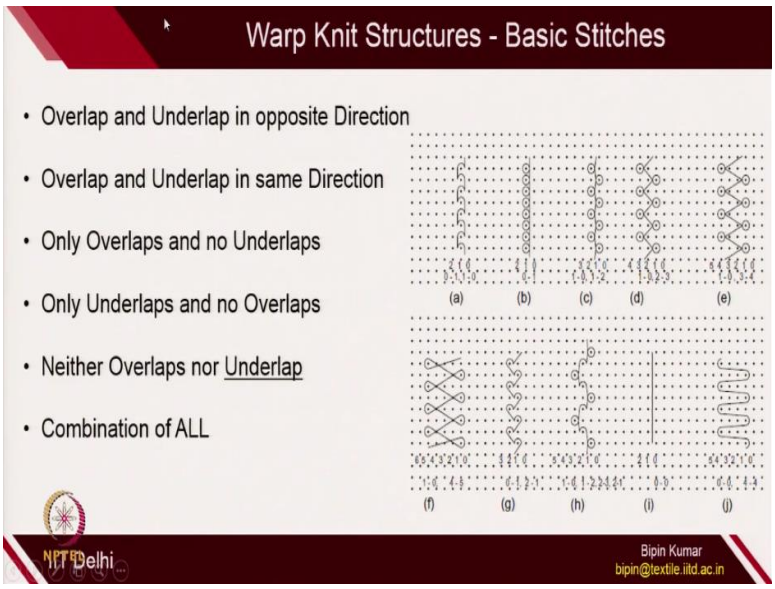
When you are playing with different types of colors of the yarn and if you want to intentionally hide certain yarns, you can go for jacquard designs.

We have seen rib, which is created by 2 beds where the loops are alternatively technical front and back in the course. Purl: Here the loops are technical front and back along the column. Narrowing and widening also we have seen, how it is important in collar designs. And wherever we want to give shaping, we use narrowing and widening. Partial knitting: We have seen how during the course, you can use 2 different types of yarns for making the loops partially.

We have seen bulging; we have seen link design; tuck design; float designs; cardigans; rib ripple; plain; baskets. So, these are just different generic names which is found in the literature and also in daily routines. But the importance of these designs comes from how you play with those 4 stitches, which is tuck, float and loop, as well as transfer. So, there are many other designs also available in the market, like PK, interlock, purl, garter, checkboard, reverse, stockinette, hurdle, seeds, moss, intarsia, fair isle.

If you simply understand the sequence of knitting actions, these designs will just be a name for you, because you are, actually you will be able to understand the principle of fabric formations. And once you understand the principle, you would be able to generate even more complicated designs, not only limited to only these type of designs. So, I expect you to please follow the design principles of weft knitting.

(Refer Slide Time: 18:02)



Similarly, if you see warp knitted structures, there are many basic stitches which actually comes from the overlap and underlap movements of guide bar. So, we have seen how you can control the overlap and underlap in opposite directions or same directions. You can also achieve only overlap but no underlaps with the help of guide bar movement. You can also achieve only underlaps and no overlaps.

So, in that case, the loops will not be formed. And only the floating yarns will be there at the back side of the fabric. Sometimes, we can also achieve neither overlaps and nor underlaps. So, that is also possible with the help of guide bar movement. And sometimes we use combination of all of these to generate a fabric structure. So, here is some of the lapping diagram.

So, here if you see, this is the pillar stitch. So here, actually there is no underlap, only overlaps are there. So, this is pillar stitch, open loops. So, here if you see this one, overlap and underlap are in opposite directions. So, this is closed pillar stitch. This one is actually overlap and underlaps are in opposite direction. This is called 1 cross 1 tricot, which is in opposite direction.

And this is here, we are producing closed loop. If you see this one, this is 2 cross 1 lap. So, here 2 pitch of underlap are there and 1 pitch of overlap is there. If you see here, this is actually 3 pitch of underlap and 1 pitch of overlap. If you see here, this is 4 pitch of underlap and 1 pitch of overlap. So, with the help of guide movements, it gives you the flexibility to control the shift of guide bar at the back side of the needle.

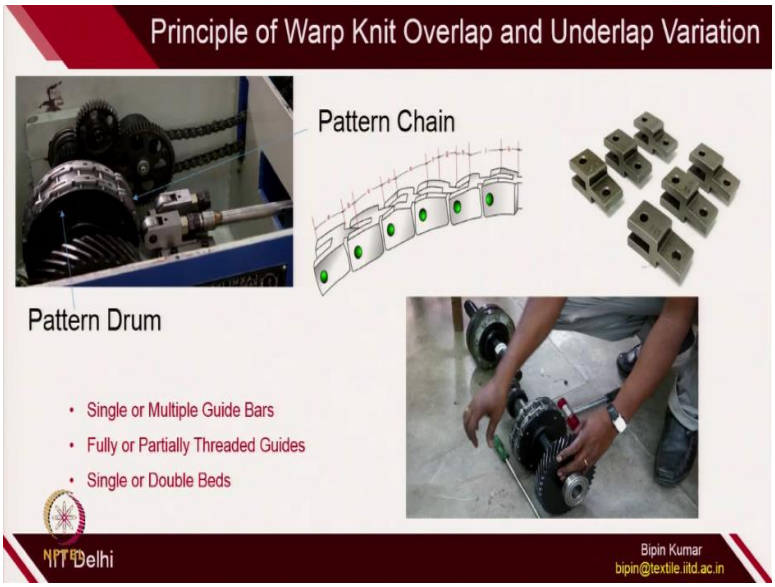
So, 1 pitch underlap, 2 pitch underlap, 3 pitch underlap, 4 pitch underlap. So, if you play with different underlap pitch, you will get different designs of the fabrics. And also, their properties will be different. Here also, if you see, both the overlaps and underlaps are in same directions. So, compared to this one, 1 cross 1 tricot, this is also 1 cross 1 tricot. But the loops are is open state; here, the loops are in closed state.

We have also seen the atlas designs, where the combination of open loops and closed loops, both are there. Sometimes, we can also achieve neither overlaps and nor underlaps. In this case, the yarn will just remain in a straight fashion. So, neither overlaps nor underlaps. So,

this is the condition. Sometimes, we can only achieve underlaps, no overlaps. So, only underlaps and no overlaps.

So, this is the conditions where we are achieving this. So, you can clearly see, it is just up to the imagination and the designer, how he wants to play with the guide bar movement. So, depending on the guide bar movements, you get different lapping plan. And hence, different types of fabrics will be generated, which will be having different properties.

(Refer Slide Time: 21:07)



Thus, the lapping plan for different guide bars; this is done with the help of either pattern drum or pattern disc. And pattern chains are generated with this, the help of different chain links, which is of different height. So, one, **(Video Starts: 21:27)** we generally do the sequence of these pattern chain links. And we create a pattern chain; and then we fix it on the pattern drum.

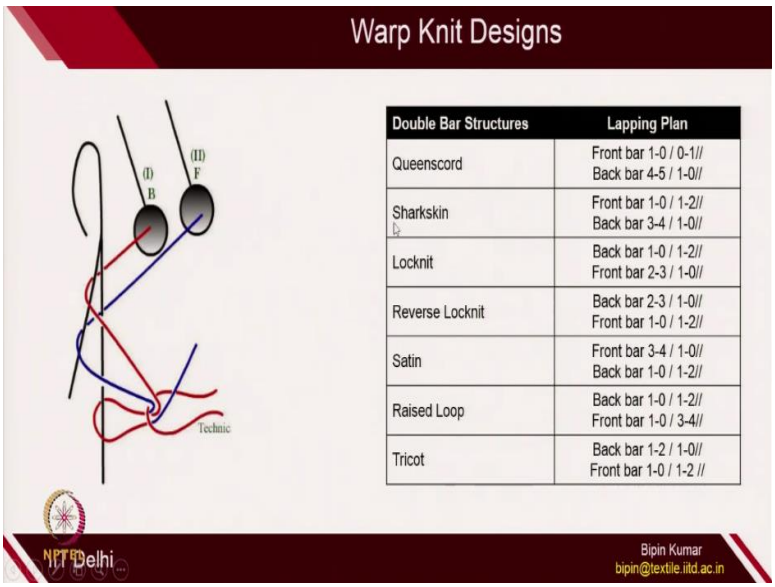
So, the follower actually follows the **(Video Ends: 21:38)** profile of this pattern chain. And in this way, we get different types of shogging motion, to generate different overlap and underlap distance for guide bar. **(Video Starts: 21:50)** So, this is how you can fix the pattern chain on pattern drum. And you can fix it on the machine, through which the guide bar gets different motion of overlap and underlap.

We have also seen, we can use single guide bar and multiple guide bar. So, here, 2 guide bar motions can be achieved, because they are 2 pattern chain. We can also go for fully and partially threaded guides for each guide bar. And we can also use **(Video Ends: 22:18)** single

or double beds of the machine in warp knitting. So, there are different technologies are there. And each technology has its own way of controlling the shogging and swinging motion; and using different types of guides and their bars, as well as different types of beds.

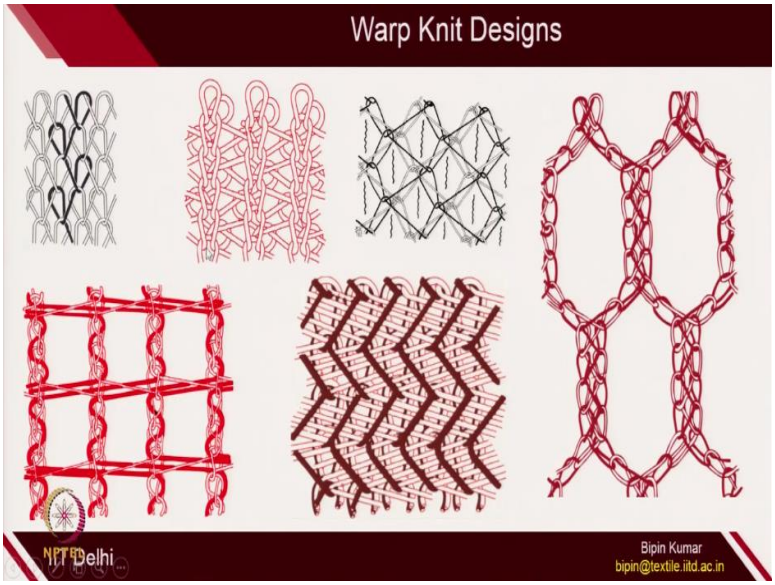
So, this is what we have already seen. We have seen so many technologies of warp knit, but the design principle actually depends on the overlap and underlap variations. So, in my opinion, whenever you see any warp knit technologies or warp knit structure or design, you only focus on the overlap and underlap sequence, because that is the key for analyzing any structure of warp knits. Rest other things are very, very simple.

(Refer Slide Time: 23:06)



So, we have seen in the market, usually 2 bar constructions are very, very important. And usually 70 to 80% of warp knit designs are basically created with the help of 2 guide bars which is providing yarn to the needles. And different types of generic names are given like queenscord, sharkskin, locknit, reverse locknit, satin, raised loop, tricot. All these designs, we have already seen in the previous lectures.

(Refer Slide Time: 23:36)



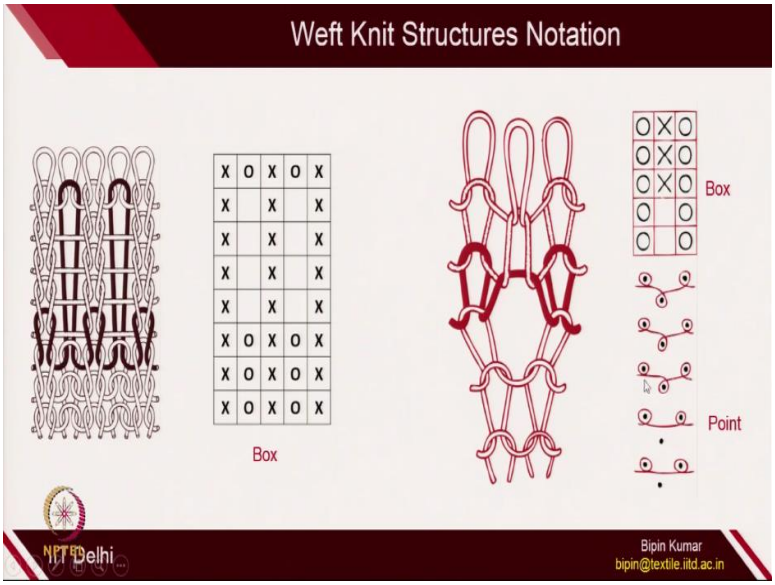
We have also seen many, many complicated design, especially the mesh designs, net designs. We have also seen inlays. We have also seen single bar construction, double bar constructions. We have seen how you can control the different amount of underlaps for front bar and guide bar to control properties. So, both weft knitting as well as warp knitting gives you the flexibility to play with different designs of the fabrics.

So, in my opinion, whether you are interested in weft knitting and warp knitting, you first need to understand the design principle and their science. And then you go for the technology aspects. We have also given you some indication of how you can analyze different types of structure. For analyzing different types of structure, design notations are very, very important.

(Refer Slide Time: 24:21)

So, I have given you some hints of how even very complicated loop structures can be denoted by simple designs. And notation followed throughout the world. Because, you have seen, the knit structure are very, very complicated. So, notation is very, very useful in analyzing these structures. So here, we have seen box and point diagram.

(Refer Slide Time: 24:45)



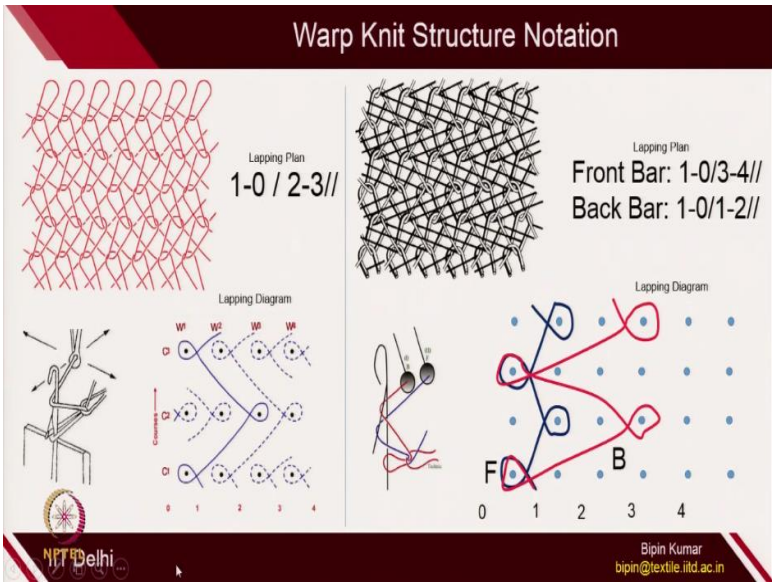
For example, if you see this particular fabric; so, box diagram. So this, instead of drawing the loops, you can simply draw the box notation. So, where a front loops can be denoted by X, back loops can be denoted by 0. Any float in the fabric structure can be denoted by blank box. And any tuck in the structure can be denoted by dot in the box. And if there is a transfer, you can simply put the arrow of that particular loop.

If it is transferred from left to right, you can put the right arrow. If to left direction, you can put the left arrow. So, all the 4 stitches which is important in knitting can be denoted with the help of box and point diagrams. So, here also, you can see, these are the box and point diagram. So, these are the point diagrams. So, where you actually see how the needles are placed on the machines.

Because sometimes, box diagram does not give the hint whether it is created on single bed or double bed, but point diagrams actually gives you the indications of how the needles are placed in realities and also whether it is a single bed fabric structure or double bed fabric structures, that can also be find out with the help of point diagrams. Also, the positioning of needles on each beds can be known, which is called gating.

So, whether it is a rib gating, then, both the sets of the needles are shifted by half pitch with relative to each other. If they are making interlock fabrics, then both the needles will be facing each others. So, this is how point notations are also very, very useful. Not only it gives you the indication of fabric, but also it gives you lot of understanding about the gating and needles arrangement of different beds which is used in fabric development.

(Refer Slide Time: 26:41)



If you see warp knit structures, warp knit structure notation is even more simpler than the weft knitted. Because here, although the fabric structure is very, very complicated, but if you carefully analyze the movement of each yarn, then you can relate that with the help of a lapping diagram and lapping plan. So, in lapping diagram, actually the movement of each yarn is actually given by the guide bar.

So, it is the guide which is used in notation of warp knit structure. So, the guide bar positions is placed with respect to the needles. So, usually the guide is placed in the space between 2 needles, so that guide bar position is denoted at 0, 1, 2, 3, 4, something like that. And depending on how the guide bar is shifting from one needle to other needles, that shifting is actually shown with the help of diagram or plan.

So, 1, 0 for example, here indicates the guide bar is shifting from first position to 0 position. So, this is the first position and this is the 0 position. So, if the dash is coming, basically it is doing overlap. So, it is shifting on the front side. Then, 0 to 2. So, 2 is again it is shifting from 0 position to 2 position. And oblique is there. So, which indicates the underlap. So, the shifting can be done on the front side and back side.

So, if it is done on the front side, that is overlap. If it is done on the back side, this is underlap. So, this is shown here. So, 1 dash 0 is overlap; 0 to 2 is underlap; and then 2 to 3 is again overlap. After 3, the same sequence is repeating for this particular structure. So, 1, 0, 2, 3. So, 3 to 1 is again underlap. So, this is how the notation is done. So, only for design repeat, you have to give the lapping plan and lapping diagram.

Automatically, each guides will be doing exactly the same factions. And such a complicated structure is generated. The same thing is happening in double bar notation also. Here, 2 sets of bars are used. You can see the black yarn and white yarn. So, there are 2 bars are used. So, for each bar, you have to give its lapping plan and lapping diagram. So, this is a double bar notation.

Similarly, if you go for 3 bar notations, you need 3 lapping plan and 3 lapping diagram. Similarly, if you go for 4 bar, 5 bar, 6 bar; depending on that, you need to give different lapping notation and lapping plan. If you go for 2 beds design, again the same sequence, you can give the movement of lapping plan and lapping diagram for each guide bar, when it is shifting from one needle bed to other needle bed.

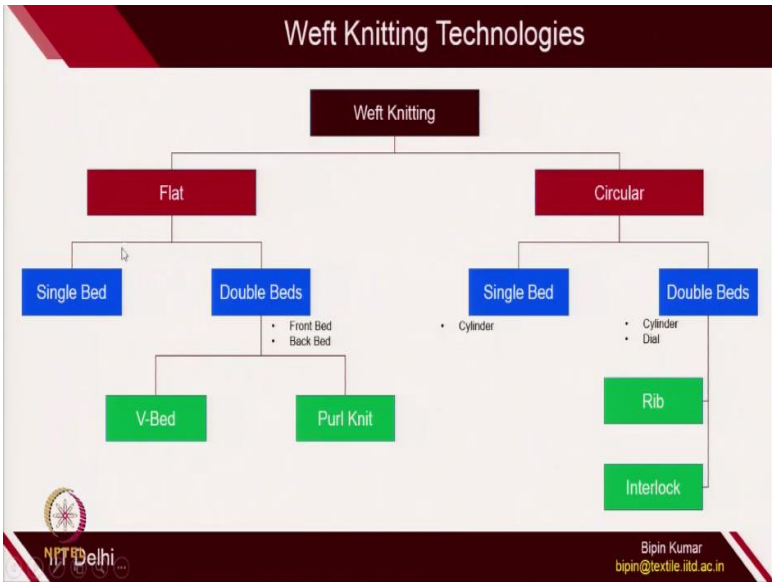
So, we have also seen how the 3d spacer fabric or pile fabric notation was done with the help of connecting guide bar which is shifting on 2 beds. So, definitely, warp knit structure is very, very complicated. But, if you just follow the lapping plan and lapping diagram, the structure looks very simple. So, once the design principle is and science is clear to you, you should then look for the different technologies which is available. So, in my opinion, different companies have come up with different types of patents in their fields. And technology is nothing but, it is actually helping the science and engineering.

(Refer Slide Time: 30:12)

Science and engineering is more, more important in terms of product development. Technology just accelerate the production capacity. So, different types of technologies are available in the market in both categories weft and warp knitting. And the list is very, very broad. So, in this particular series of lecture, I would not be able to cover many different technologies.

But in my opinion, once you have the understanding of science and design, probably technology is just the cakewalk for you. So, you keep looking for new technologies in the field; keep looking for their functions and their patenting principle; how they actually generate loops; and what are their capacities. So, in weft knitting, they are, different types of technologies are available.

(Refer Slide Time: 30:58)



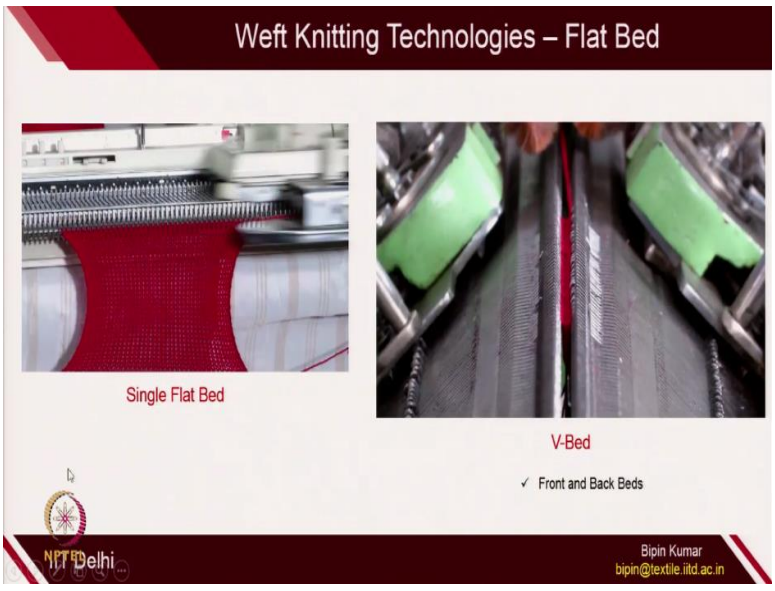
It could be flat knitting; it could be circular knitting. In flat knitting, we can go for single bed, double beds. In double beds, we can go for the V-bed, purl knitting structures. Nowadays, some companies have come up with 4 beds, which is called seamless garment manufacturing. So now, the knitting has advanced in such a way that the entire garments can be generated with the help of 4 beds.

So, there will be no need for stitching or cutting of the garment. You can simply you feed the yarn and the entire garment without any stitches will come out; and you can simply wear it. So, those type of machine capabilities are also coming in the market. And it has 4 beds. So, whatever I am listing is the basic one. Definitely, in different literature and different resources some other classifications might be given.

So, you should not get confused with those classifications. Rather, you should focus on the principle aspects; why they are classify in that way. So, every author and every researcher has their own opinion on classification of machines. In my opinion, in simple terms, when the needles are arranged on a flatbed then it is called flat category. When the needles are arranged on any circular beds, either on cylinder and dial, then it comes under circular categories.

So, sometimes we can have single bed where one cylinder is there. Sometimes we can have double beds, where 2 beds are there, either cylinder or dial. So, we have seen rib and interlock machines also in the practical.

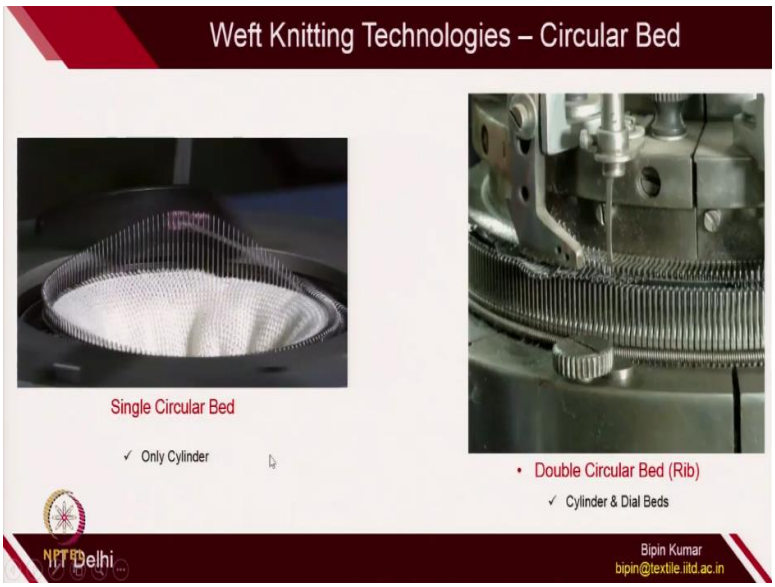
(Refer Slide Time: 32:38)



So, single and double bed flat knitting technologies, I have already demonstrated in the practical. If you come up with any nearby knitting machines, I request you to please go and learn these knitting. Because it is very, very useful and handy. And you will really enjoy doing knitting and making fabric development. So, this is the single bed. **(Video Starts: 33:02)**

And with the help of cam, you can generate the fabric in one go. This is the double bed, where 2 sets of the needles are arranged in a V-bed. And you can generate the fabric; and the fabric is pulled between the beds. **(Video Ends: 33:16)**

(Refer Slide Time: 33:17)

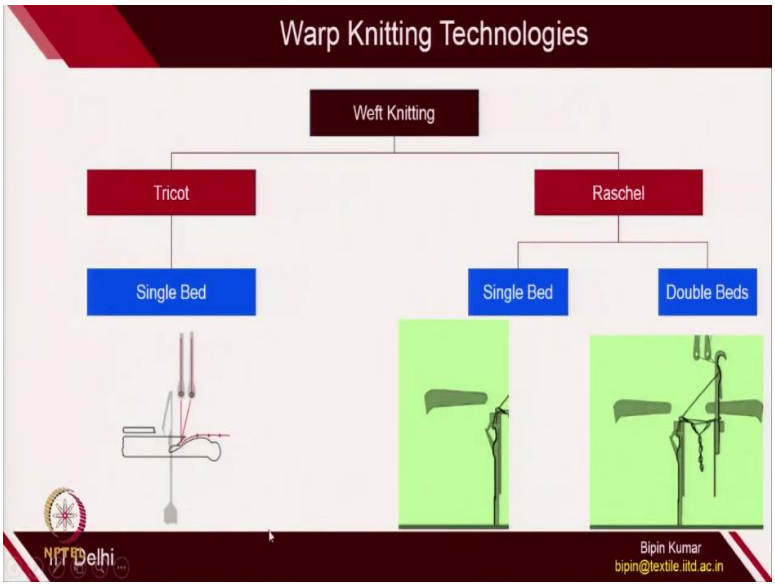


Similarly, you can have circular bed which is mostly automated. **(Video Starts: 33:21)** The production capacity is very, very faster, because it is not manual. And automatically with the help of gear system, the cam can be rotated on the cylinder; or cylinder can be rotated, cam can be fixed. So, this is the single circular bed. Here, there was double circular beds, especially rib setting.

So, here cylinder and dials are placed. So, cylinder in the vertical direction, dial in the radial directions. So, these are 4 types of technologies I demonstrated in the lab. Definitely, in the market you will find even different types of technologies. But the design principle and the science of loop formation remains same. **(Video Ends: 34:05)** What will be different is only the placement of the needles and what the different types of needles they might be using.

They might be using latch needle; they might be using beard needle; and they might be using compound needle. So, do not get confused, it is just the manipulation of different machine elements. And, but the principle of knitting remains same.

(Refer Slide Time: 34:29)

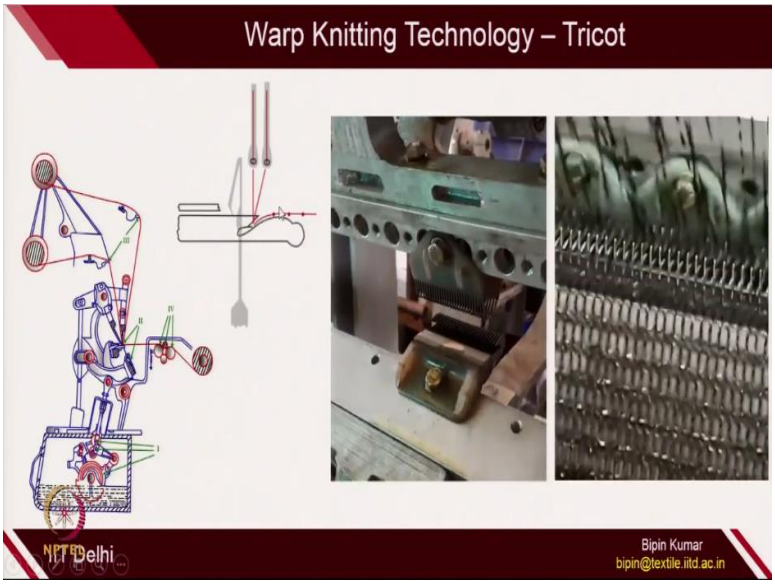


Similarly, in tricot category and raschel category. So, in tricot category, usually single bed are there. But nowadays, 2 bed tricot machines are coming, but I have not seen so far. Although I have found some literatures where 2 bed tricot machines are available. In tricot, the guide and the fabric formations, actually they make 90 degree with each other. So, this is how the sinker plays a very, very important role in fabric pulling and providing the support surface for knock over; and also catching the loops when the needles rise.

So, sinker plays a very, very important role in tricot. In raschel, actually, the sinker only helps in **(Video Starts: 35:17)** holding the loops when the needles are rising. Otherwise sinker does not provide any support surface for knock over. So, in raschel, this gives you the flexibility to play with 2 different beds of the loops. And if you carefully see **(Video Ends: 35:36)** the movement of yarns and the fabric, there are around 180 degree rotation.

So, technology wise tricot and raschels are completely different. Especially, raschels become very, very useful in the market. Because the sinker role is not there so much. And it is the trick plate in the bed which is used in pulling of the yarn to make the loops.

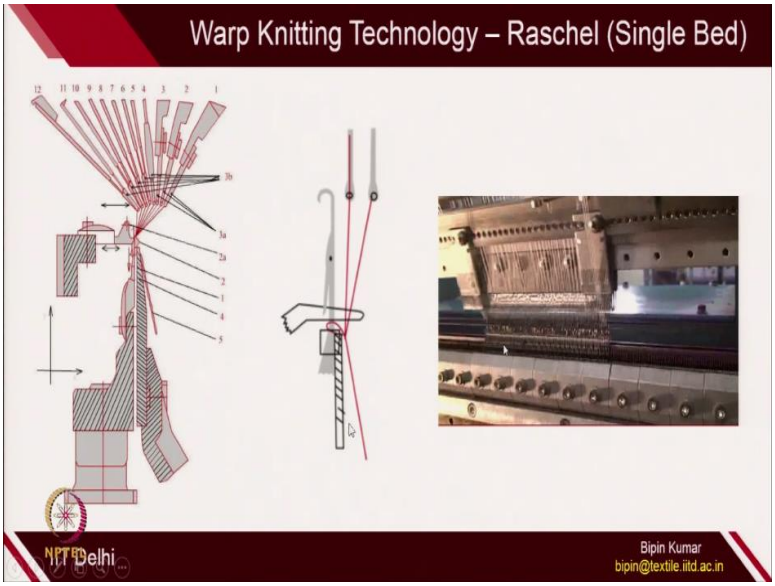
(Refer Slide Time: 36:10)



So, in tricot, I have shown you in the practical **(Video Starts: 36:12)** also; these 3 elements, needle, sinker and guides; they are placed on the machines and they do the relative movements with each other for the loop formations. Here is the actual formation of the fabric. You can see it here. It is very difficult to analyze the motion, if it is running at a very, very high speed.

Again, if you carefully see the path of the yarn which is supplied to the needle and the path of fabric; they are making around 90 degree. So, the yarn is supplied and the fabric is being pulled around 90 degree. So, this is the beauty of tricot. **(Video Ends: 36:56)**

(Refer Slide Time: 36:57)

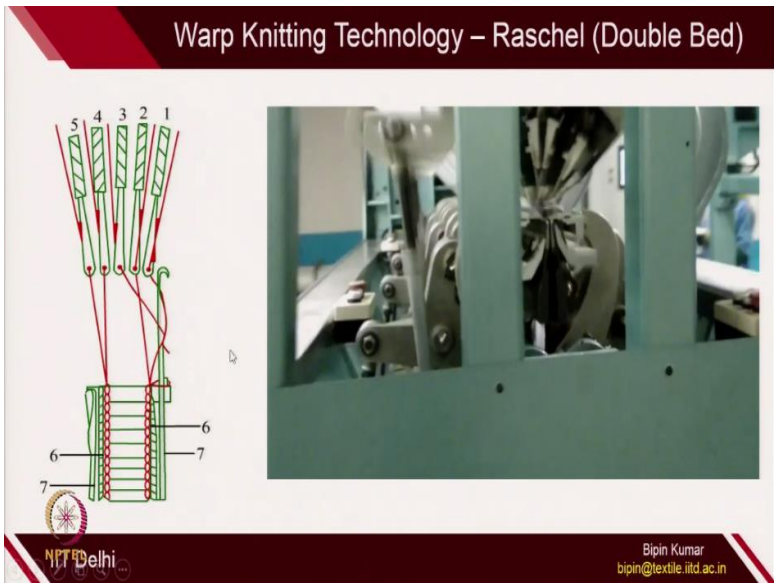


If you see the raschel, the yarn are supplied and the fabric is been pulled just beneath the bed of needle. And it is around 180 degree. **(Video Starts: 37:11)** So, definitely, different

tensions will be there in raschel. Usually, raschel machines are very, very faster compared to tricot machine. And in raschel, you can play with multiple guide bars, because that gives you the flexibility.

So, this is the raschel machine. And you have seen here, the role of sinker is only to hold the loops. It does not help in providing support surface for forming new loop or knocking old loop, because new loop is getting formed between the trick plates and the knock over surface is actually provided by the tricks which is there on the bed itself. So, this is how the raschel machine is completely different from **(Video Ends: 37:58)** tricot machine.

(Refer Slide Time: 37:59)



We have also seen the importance of double bed in formation of 3d spacer fabric or pile fabric. So, here you have multiple guide bars. And here, they are 2 sets of bed which is there. So, one needles will be making fabric from some of the guides. Other set of the needles from different beds will be making another fabric with different sets of guide. And there will be some connecting guides which will be connecting the fabrics of both the beds.

So, basically, they are 2 layers of the fabrics which is getting connected by the connecting layer. **(Video Starts: 38:34)** So, here you can see, there are 2 beds. And these are different types of guides. So, some guides are making fabric on either of the beds. And 1 guide or 2 guides will be there, which will be connecting the fabrics from both the beds. So, this is how raschel machine.

So, this type of arrangement will not be possible on tricot. So, that's why raschel is very, very important in technical applications, because that is gives you the capability. Because, there is no sinker elements involved, the fabric can be just pulled from the back side of the bed. And that is gives you lot of flexibility in **(Video Ends: 39:11)** fabric designing for complicated structure. So, 3-dimensional structures can be created on raschel double bed machine.

(Refer Slide Time: 39:22)

Technical application: So, so far you have seen the science of loop formation. You have seen the design aspects of different stitches in weft knitting and warp knitting. You have also seen different technologies which are available for different types of fabric formations in weft knitting and as well as in warp knitting. So, once you have the science engineering design and technology aspects, then you can look for the knitting in different technical applications.

So, in the next lecture, I will be giving you many case studies in which you can use the weft and warp knitted for applying it in a different technical fields. So, all of these technical applications are not just limited to only certain fields. Even you can also think for other technical application for these type of knit platform. So, in my opinion, the knitting just gives you a platform through which you can generate different types of products.

(Refer Slide Time: 40:23)

So, for example, very recently, shoe uppers are picking the moment. And so, in the last 4 to 5 years, you might have seen many new industries who is making shoe uppers for the shoes are coming. And you can imagine every individual on the planet makes, use the shoes. Knitting is playing a very important role, not only in t-shirts, but also in shoes. So, this is the very prominence application of knitting. And there are lot of profit margin in this particular business. And many new companies are coming out in daily basis, who is making shoe uppers.

(Refer Slide Time: 40:59)

Other key performance of knitting is to apply it on a e-textiles. So, e-textile is also future. So, nowadays, health monitoring is also becoming very, very important in the market. And where, many sensors and actuators has to be integrated in the textiles. So, knitting is the only

platform I must say, because that has lot of flexibility; and also, the process is very simple. Because, if you see the weaving, there are lot of winding, warping, beating, sizing are there.

But in knitting, you just need one yarn; and you can do the fabric development. So, the machine can be easily modified in case of knitting, to integrate fibers or smart fibers or smart sensors in the fabric structures, which can be used for health monitoring. So, e-textile is very, very important in coming market. And it will be hardly 2 to 3 years from now, where you will see lot of e-textile products being used by common man.

Also, you have seen the knitting importance in sports. So, in sports also, you can design appropriate garments for particular sports like swims, for marathons, for footballs. So, different types of a sports garments can be engineered to give comfort to athletes as well as sports person. So, sports also is a very big field. And many big companies are using knitting as a platform for generating smart sports garment which is key for the performance of these athletes.

(Refer Slide Time: 42:44)

Knits are also being used in composites, especially profile composites knits are very, very useful, because it is gives you shear easy shear properties. And any shapes, complicated shapes can be generated with the help of composites, with the help of knit structures. Other big application of knitting is the cut resistant fabric, especially for protection. Knitting has a very good shear properties.

So, definitely cut resistance gloves are now a key parameters in many companies to protect the workers from harsh environment. So, cut resistance gloves are also having a big market where knitting is being used. And especially weft knitted structures are mostly used in cut resistance gloves.

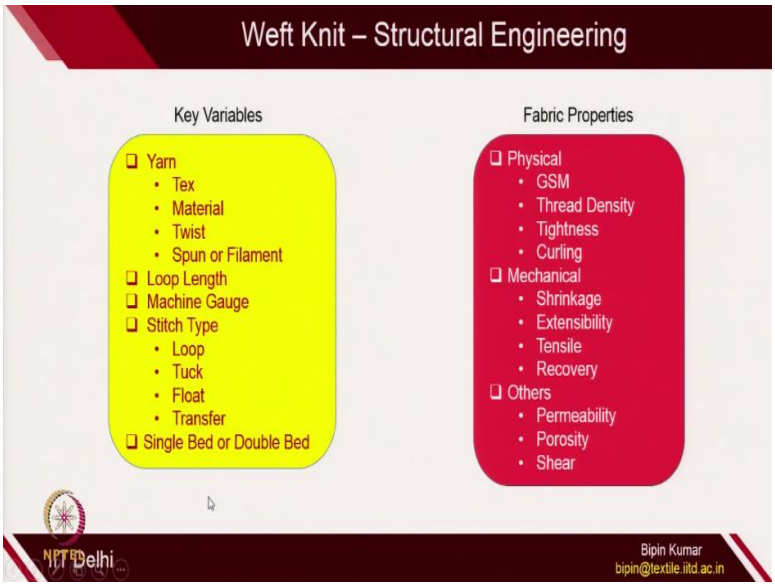
(Refer Slide Time: 43:33)

Other technical applications like mosquito nets, agro nets, packaging; where also you will find mostly warp knitted structure is used. So, in next class, I will be discussing lot of these technical applications. I have some products with me. I will show you how they have used different types of weft and warp knitting engineering for designing these type of fabrics. And they are really changing the course of this technical applications. Because they are not only benefited, but they have also opened a wide varieties of scope for applying knitting in many other fields.

(Refer Slide Time: 44:18)

So, what is the main important thing? Because, so far, in last 11 weeks, you have learned a lot of knitting. Now, the idea is how you will, you are going to use knitting in engineering and design.

(Refer Slide Time: 44:36)



So, that's why this particular week I kept as a example to show you how you can use knitting for designing different types of products. So, the core engineering principle for any designing of weft and warp knitted products is to understand the variables of knitting. Because, you have seen how the knitting variables is so important. Knit is gives you lot of variables, where you can change the yarn tex, material, twist, filaments.

You can also, with the help of machine, you can change the loop length of the fabric. You can control the thread density. You can control the gauge of the machine. You can also

generate different types of stitches: loop, tuck, float, transfer. You can use single bed or double needle beds for weft knit development. So, whatever variables, whenever you are going to change with the help of material as well as a structural part, you will get different types of fabric properties.

And here is the key. So, you need to first focus on the designing part. So, first you learn what are the different types of designs that are possible on knitting, whatever knitting machine you are using. And based on that, then you relate with this fabric properties. So, you change the design, you learn, you do the analysis of those fabric properties and get the understanding. Once those understanding is clear, then you can apply for different technical applications.

So, in weft knitting, especially loop length, gauge, stitch and number of beds. So, these are the key variables. Once you do that, usually the physical properties of the fabric like GSM, thread density, tightness, curling; mechanical properties like shrinkage, extensibility, tensile, recovery; other properties like permeability, porosity, shear, cut resistance, abrasion resistance.

They are many properties which is linked with these variables. So, in my opinion, before you go for technical applications, you need to first understand the relation of these variables with the fabric properties. And that is key to the engineering. So, in research of any knitted structures, you first have to do the designing and get some relationship.

Once you have these relationship clear in your mind; then, ideally speaking, whenever you go for any new technical applications, you will be clear about what type of design you will choose, what type of technologies you will choose, what type of materials you will choose; and then, you can able to also control those fabric properties. Similarly, in warp knitting also, there are a lot of key variables like:

What type of yarn material you are choosing: tex, twist, count. What gauge you are using: whether it is a 14 gauge, 20 gauge, 8 gauge. What are the stitch type you are using; how you are wearing the overlap and underlap. How many guide bar you are using: whether you are using single guide bar, multiple guide bar, like 2 bar, 3 bar, 6 bar. Guide bar threading: Whether you are used the full threading of each guides of a bar or you have used partial threading; especially for net structure, we are using partial threading.

Or whether you are using single bed or double needle bed. So, these are some of the key variables. Once you change any of these variables, definitely the physical properties, mechanical properties and other properties of warp knit will change. As a student, if you really want to learn knitting, I expect you to see the variations and understand the importance of these variables on controlling fabric properties.

So, the engineering of any technical products in the knitting, not only just required your understanding of knitting as well as your design aspects. How much; what type of different designs you can generate; what type of different technological understanding you have; what machines capabilities; what are the knowledge do you have in terms of availability of weft or warp knitting machines; what are the key variables are there for designing; what designs you can generate.

So, once all of these things are understand, then probably you can use those variables to design different fabrics. And then, you can analyze those fabric properties and get some relationship. So, this is the key aspects. In the next class, I will show you how you can use some of these key aspects for generating different types of technical products; and how you can also control their performance.

So, in many fields like medical; in agriculture; in wearables; in sports; in cut resistance; in cushioning; they are many applications. I am going to show it in the next class. So, with this, I am ending this particular lecture. I hope I have summarized this particular knitting domain in a just single lecture. But, as you have seen, knitting is not so simple. So, whenever you want to thoroughly understand it, I expect you to follow good literatures and good research papers.

And more important, you do the practice in the lab. Because until and unless if you will not make the fabric in the lab, all of these keywords will be just a keyword for you. You will not understand their importance. So, in my opinion, wherever you get chance to make any knit designs, please go and learn that. Because that is the key for engineering. So, with this, thank you very much. I catch you in the next class, where I will show you different technical products of knitting. Thank you.