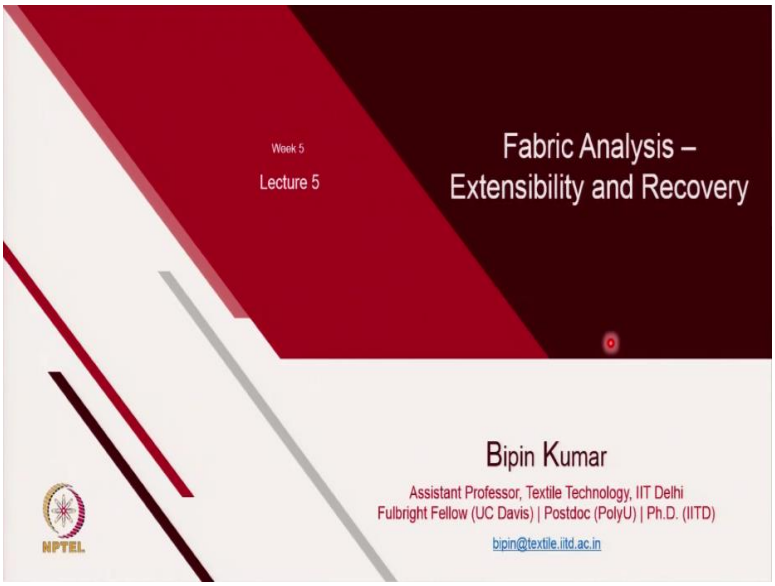
Science and Technology of Weft and Warp Knitting
Prof. Dr. Bipin Kumar
Department of Textile Technology
Indian Institute of Technology - Delhi

Module - 5
Lecture - 24
Fabric Analysis - Extensibility and Recovery

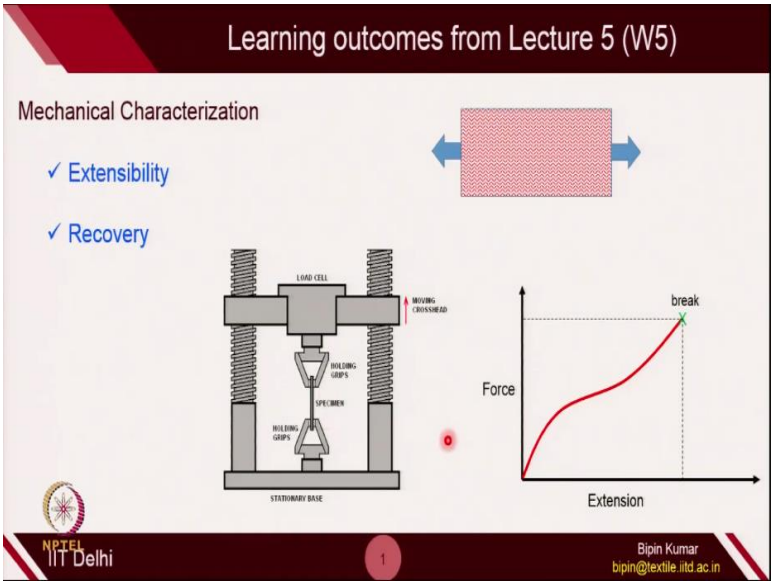
(Refer Slide Time: 00:17)



Welcome participants, to lecture number 5 in this particular week. So, in this week, we are already analyzing and designing different fabric structures on single bed machine and double bed machines. Two key fabric properties which I am going to describe in this particular lecture are extensibility and recovery. So, you have seen some of the key structural properties, as well as shrinkage properties in the previous lectures.

These two property of knitted fabric is extremely important from application point of view. So, whenever you design any particular fabric on any knitting technologies, you should have fair idea and understanding about the fabric response in terms of extensibility and recovery. Let's try to understand, first these two terms; and why they are important; and how we can control these properties of fabric by controlling the stitch type or length.

(Refer Slide Time: 01:22)

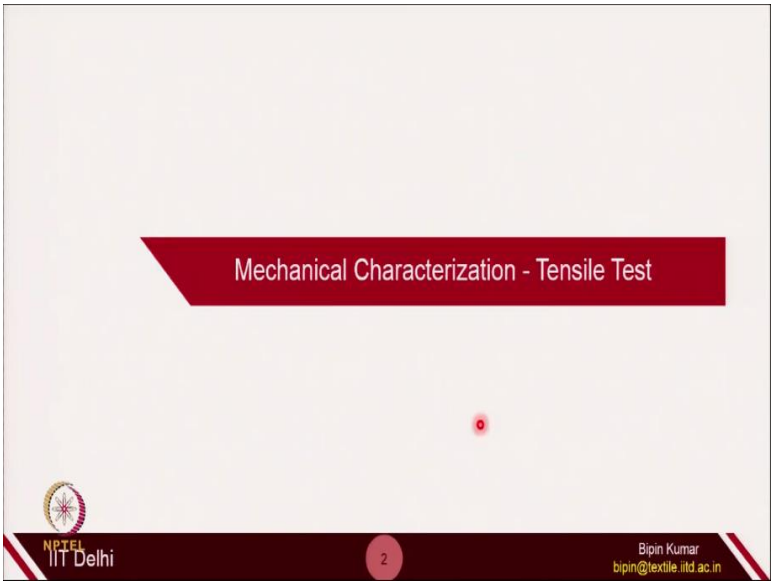


In this lecture, we will first understand 2 key properties, extensibility and recovery. We will see how different types of loops, tuck, float, affect these type of properties. If you see, both of these properties, it belongs to mechanical characterizations, because it will depends on the application of force on the fabric structure. So, if you apply a force in the fabric structure, it will deform.

So, in, through this properties, we will try to analyze, how the fabric will response in presence of load; and how the fabric will response when you remove the load. So, the useful instrument which we use in this characterization are the simple tensile tester or Instron, where we fix the specimens with 2 jaws; and we pull the specimen from other side. So, and we get these type of diagram.

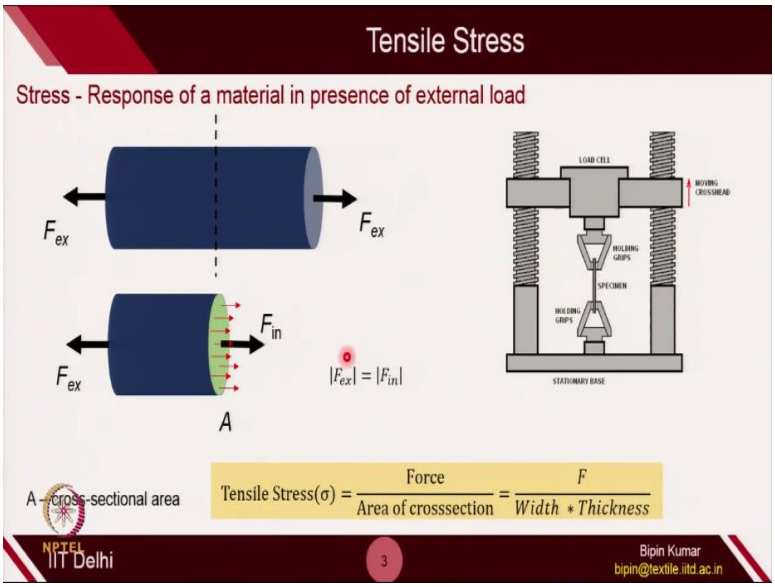
So, I, these are the very common diagram, when you go for testing of any material; not just textile material, but for any materials. If you try to analyze the response of the material in presence of load, you just fix the material between 2 specimens and you get the force and extension diagram.

(Refer Slide Time: 02:42)



We will now going to understand how we do this test. And especially from the context of knitted fabric; and how these properties are defined; and what are their role in real applications. So, let's first, basic understanding about some of the key terms which I might be using in this lecture.

(Refer Slide Time: 02:59)



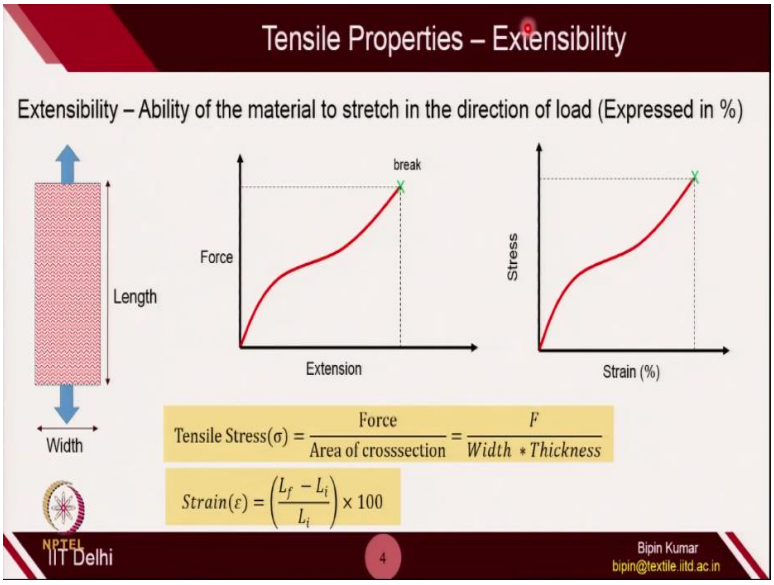
One of the key term is, tensile stress. Stress is a very common term. Usually, we keep using this word with force. But, just to let you know that these two terms force and stress are completely different. Actually, stress is nothing but the response of a material in presence of a load. So, no doubt, stress is related to load. But, in mechanics point of view, it has very significant role. So, when you apply any load to a material; for example, this is specimen in a cylindrical form.

And you are applying the load from the edges. For example, if you have pen and if we apply load, the material will try to resist. Because, the natural state of material is to remain it is in original position. But, with the help of force, you are actually extending the material. So, because of that, some internal resistance will develop inside the material. So, these internal resistance is nothing but the stress.

In simple terms, we defined stress as force per unit cross-sectional area. So, you have this cross-sectional area, over which you are applying force. So,
Tensile stress = force/area of cross sections. Herein, we have for the fabric, we can have width and thickness. But in case of this particular specimen here, the cross-sectional area is circular. So, we can simply take the area of cross section.

So, area of cross section from fabric point of view, it will depend on width and thickness. But for this particular material, it is just the area of circle. How do we get this tensile stress? So, basically, we fix the specimen between 2 jaws of the machine. And the upper jaw is fixed with the load cell. And then, we will pull the material from one side, keeping the other side fixed. So, this side is fixed.

And the other side, we pull it with the help of lever. And the specimen is fixed here. So, this is the length of the specimen which is fixed here; lower jaws; and this is the upper jaws. So, when you pull, the here is the load cell which will measure the amount of load. And there is the extensometer which is present, which will measure the extension in the specimen. So, with this, we get the diagram like this.
(Refer Slide Time: 05:28)



So, force versus extension. So, when you apply more and more force, you will expect more amount of extension. And eventually, you will realize the fabric will or the material will break. So, if you see the terms extensibility in very crude way, we can define the extensibility as a material ability to stretch in the direction of load. So, whenever we apply force, it is just the material ability to extend in the direction of force.

That is in simple terms, that is the definition of extensibility. So, you have the fabric, this is the length of the fabric and this is the width of the fabric. And we are applying the load through the jaws on the machine. I have already demonstrated that machine features. So, you, when you fix the fabric sample on the machine, you can pull from one side and the other side is fixed. And you can find out the stress, force by area of cross section.

So, here, the area of cross section is rectangular, which is not visible, because we are looking at the top plane. So, area of cross section for this specimen is **width*thickness**, because width is there; and thickness is the thickness of the material. So, area of cross sections is a small rectangle through which the force is applied. And, if the other part is the strain, which is nothing but the change in length per unit original length.

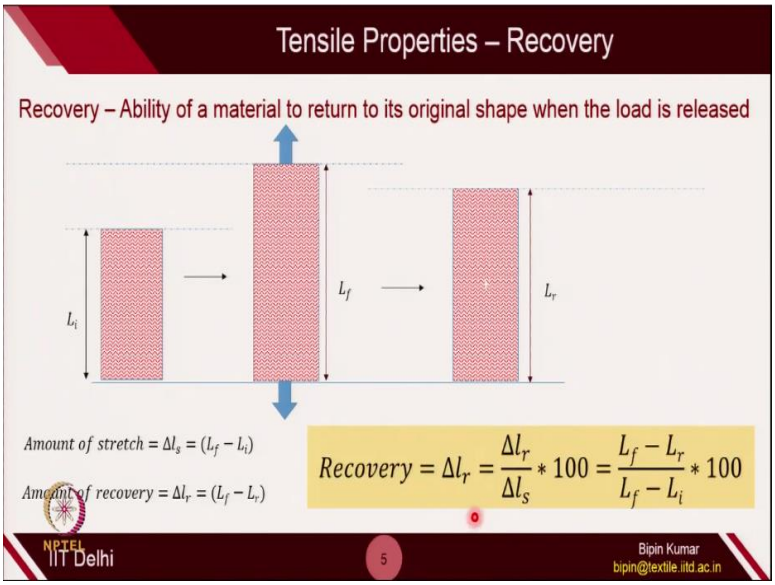
So, Li is the initial length, Lf is the final length. So, **distance of final - initial**, after the application of load; we get the amount of deformation. So,
strain=amount of deformation/original length. We define this term as a strain. So, we can convert these graphs in form of stress and strain. So, if you see the literatures, we usually convert force into stress, which is given by this formula.

And we convert extension; extension, the unit is usually in mm; it is the unit of distance. But we take the relative extension with respect to original length. So, if you divide it by original length, then we get it strain. So, this is the most popular one, we use it in mechanics. And extensibility if you see, it is the ability of the material to stretch. So, we express this in percentage.

So, when you apply certain amount of force or stress, we will see how much the fabric extends. So, for example, if you apply 10 kilonewton of force, you will see, what is the change in length per unit original length. So basically, it is nothing but a kind of a strain at a particular load. So, extensibility, no doubt, it will depend on lot of fabric structural parameters, especially the loop length, the kind of stitches, the kind of yarn you are using in the fabric material.

So, all those parameters, not only the material, but also the structural parameters of fabric will control this property, which is the extensibility. Now, let's go to the second property, recovery.

(Refer Slide Time: 08:39)



So, once you stretch the material, definitely you will realize; when you remove the load from the material, it will try to go back. So now, it will depend on the material that, whether it is going back to its original shape; yes or no. So, recovery is nothing but the material ability to return to its original shape when the load is released. So, here you can see, this is the original length of the material.

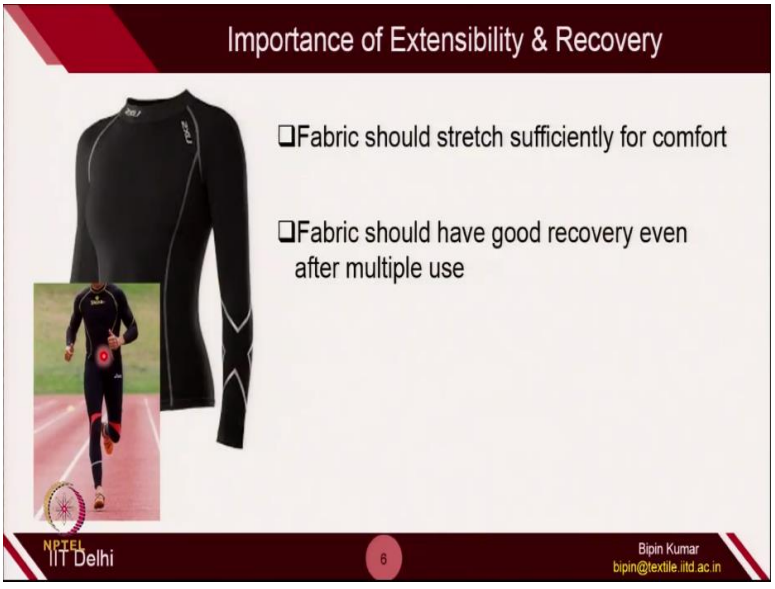
You apply load, certain load. And because of that, there will be deformation in the material. So, this is the, Lf is the final length of the material. And once you remove load from the material, the material will try to go back to its original position. So, original position is this, but in reality, you will realize the material will deform permanently. And it will never go back to its original initial length which is Li.

It will recover only to Lr. Depending on how much we have extended it and how much we have recovered, we define one parameter which is recovery parameters. For example, here, the amount of deformation we have given to this fabric material is (**Lf – Li**). So, amount of stretch, we have stretched this material **(final length - initial length)**. So, **Δl** stretch. And if you see how much the material has recovered.

So, this is the final length of the material after loading. And this is the final length of the material when you release the load. So, **(Lf – Lr)** is the amount of recovery. So, **ΔLr=amount of recovery**. So, **(deformed length - recovered length)**. Once you have these two quantity, you will simply take the ratio of these two; and you will get the recovery in the percentage.

So, recovery is defined as the amount of recovered length divided by amount of stretch length. So, this is expressed in the percentage. This can, the percentage especially in case of knitted fabric can go from 50 to 100. It will depend again on the material type, on the stitch type which is there in the structure and other key variables which is related to fabric behavior.

(Refer Slide Time: 10:52)



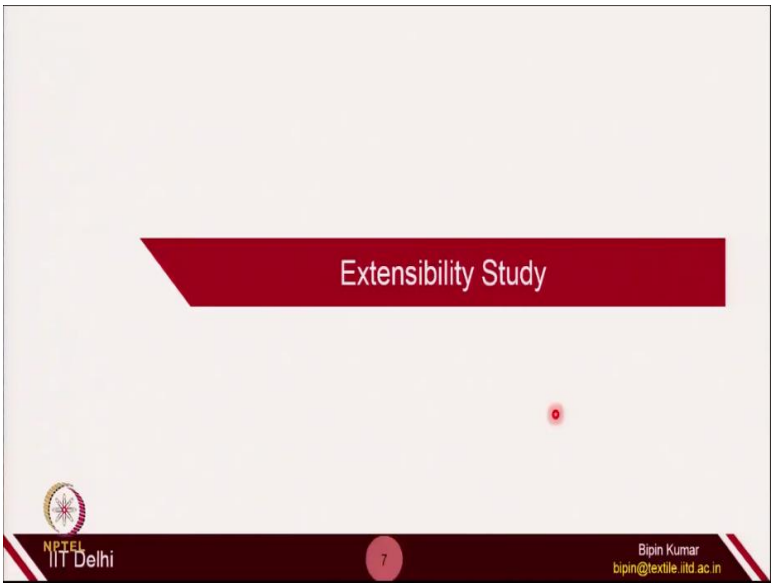
Again, if you see these 2 properties, especially extensibility and recovery, it is very, very important from the application point of view. Because, in reality we use these fabric for multiple times. And we have seen, especially in case of sports garment, knitted fabric is mostly used. And in sports garment, you might have seen the fabric is stretch in multiple directions. Okay.

So, sometimes it can stretch; it is always in loading, whenever we do any kind of hand movement. The first criteria like, is the extensibility, because fabric should stretch sufficiently. If the fabric is extremely tight, it will not provide you or add comfort to you during movement. So, we should have sufficient extensibility in the fabric, so that it can assist the movement. Also, the second thing which is important is the good recovery.

Because, you can see, whenever you play with the garment on your body, you are doing stretching multiple times. And the material has to recover back to its original shape. So, again, recovery become extremely key parameter. You don't want material to be too tight, because it will add discomfort. And also, you do not want that your material should lose its shape. Because, once the material become loose, it will of no use.

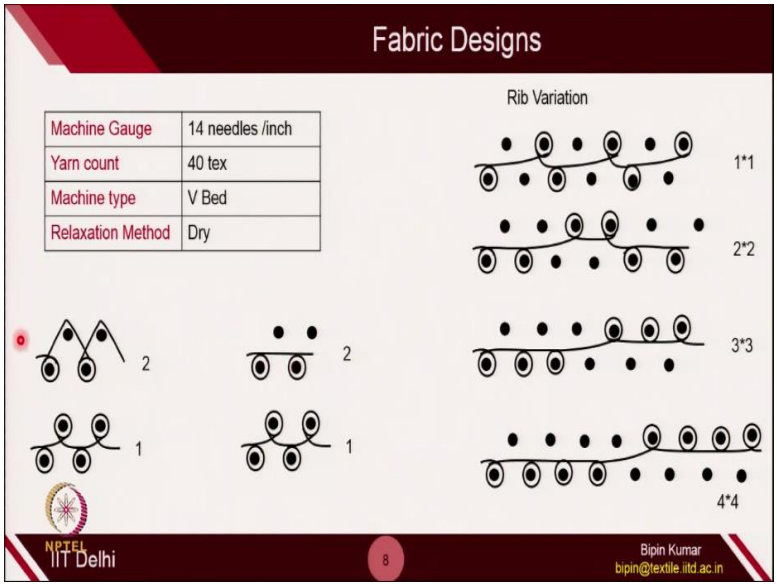
So, both extensibility and recovery is directly deciding the performance of the fabric in long use. So, that's why, these are the two key variables I believe, which should be extensibly explored in any knit structure before you go for application.

(Refer Slide Time: 12:34)



Here is again, I am giving you some behavior of some of the fabric designs which I prepared in the lab with help of my students. And how they respond when you are extending it in different directions? So, this is small case study practicals which we did it in the class.

(Refer Slide Time: 12:55)

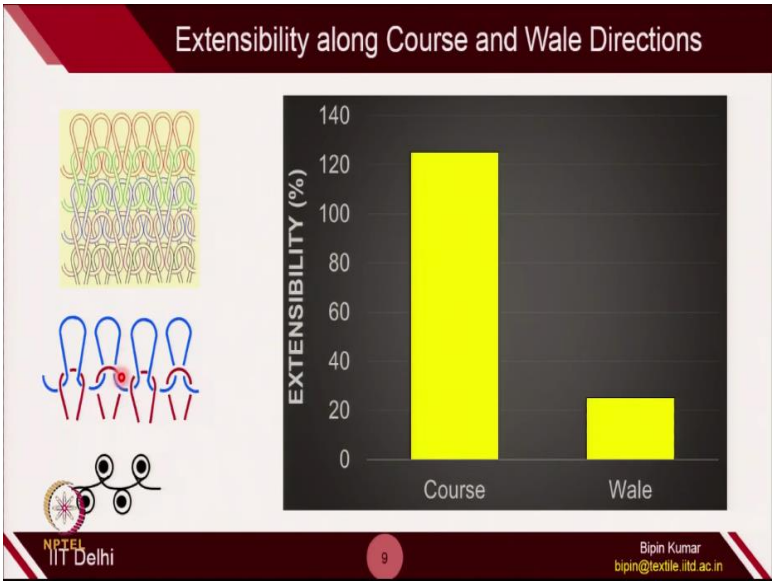


Again, these are the same fabrics which we created for the stretch or the shrinkage properties. If you remember the last lecture, where we were looking at the amount of shrinkage which the fabric is giving. So, again, we try to vary the rib variation. So, 1 cross 1, 2 cross 2, 3 cross 3, 4 cross 4. So, 1 cross 1 means, you are leaving 1 needles from both the beds. 2 cross 2, it means you are leaving 2 needles alternatively in each bed.

3 cross 3, you are leaving 3 needles alternatively in each bed. 4 cross 4; we designed till 10 cross 10. And also, we checked the variation in tuck and float. So, sometimes we created float in one of the bed. And in sometimes, we created tuck in one of the bed. And this is how we designed it. Again, the machine gauge on which we design this fabric was 40 needles per inch. The count was approximately 40 tex.

The machinery used was V-bed. And relaxation method, because, as you remember, relaxation is a key thing, because the moment you develop fabric on the machine, you better go for either dry relaxation or wet relaxation, to make sure the fabric remain dimensionally stable, before you, its use. So, we go for dry relaxation, keeping the fabric for at least 24 hours in normal room condition on a flat surface. So, let's see some of the results we observed.

(Refer Slide Time: 14:26)



So, extensibility; one thing we observed is, different extensibility behavior in course and wale directions. So, we tried for rib, simple rib fabric. So, loops on each needles, from front bed and back bed. So, this is the normal rib structure. We observed the extensibility, the amount of stretch ability of the fabric in course direction is much, much higher in the wale directions. So, this is obvious; I think, when you try to stretch in course direction, you can see, this is in loop shape.

So, the moment you try to stretch in course directions, this loop will try to open up. So, the leg which is in V shape, it will try to open up. So, you have more chances that this loops can open up. So, that's why, along the course, you will observe maximum strain; so, maximum extensibility. But if you try to pull the fabric in wale direction, it means, along a column; you can see, there is a very less chances of extensibility.

Because, after some time, the fabric will lock and the loop will not be able to open up the yarn. So, that's why, the, in the wale direction the extensibility you can observed is, will be very poor. So, I have these 2 small fabric samples with me, which I took from one of the fabric specimen. Both in course direction and wales direction, I can show you why the behavior is different.

So, let's see this 2 fabric samples. **(Video Starts: 16:06)** So again, this is the fabric samples we created in wale direction. I cut the fabric. So, you can see, this is along wale directions. So, the columns are along this. So, as per the standards, usually the specimen size is 15 - 20

centimeters and the gauge length is from 7.5 - 10 centimeters. So, if you try to stretch, you can see, the fabric is not stretching at all, in the wale direction.

So, you can see, I am applying too much force. I am applying too much force, but it is not stretching beyond this. So, hardly 20 - 30% extension or strain you can observe. But, if you see in course direction; so, this is along the course direction and this was along the wale direction. So, this was along the wale direction; this was along the course direction. So, in wale direction, you can see, the stretchability is very poor.

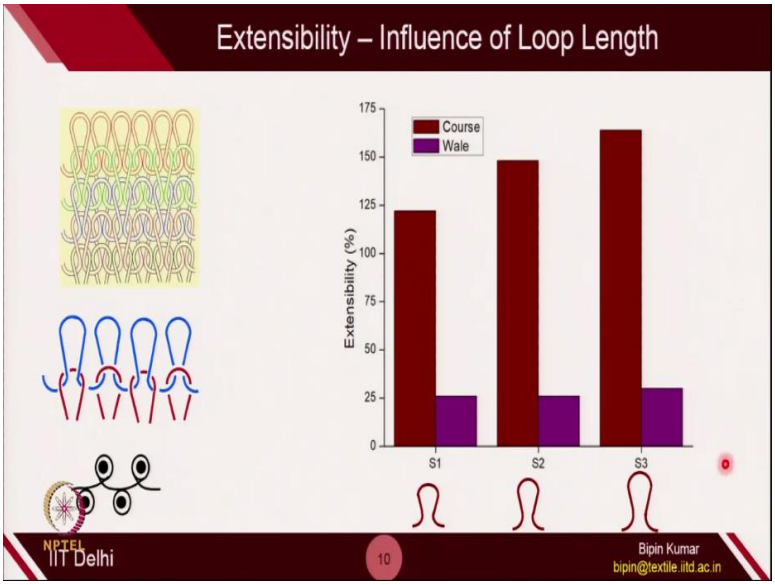
But in course direction, you can see how much you can stretch. So, definitely, you can see how the fabric is responding. From the application point of view, you have to carefully cut the fabric specimen, depending on which direction you want the fabric to extend and in which direction you want fabric to be little bit tight. So, that's again from the designer point of view. Or an engineer point of view also, you can control the properties.

So naturally, along wale direction, the property is different; along course direction, property will be different. If you go along diagonally, if you cut the fabric along diagonally, again you will have different behavior. So, that's knitting science. So, if you really want to achieve stretchability, exactly same in all directions, then you have to play with the structure carefully. So, let's see what will happen if you changes the loops or stitches inside this fabric.

So, what will happen to stretchability, whether it will increase or decrease? Similarly, in wale direction, whether it will increase or decrease. It will again depend on the stitch type, whether you are including loop, tuck or float. So, I am going to show you in couple of slides. **(Video Ends: 18:30)** So, let's go back again to the results part. So, again, you have seen that, in the course direction, the extensibility, you can see up to 120%, which I have already shown you.

Along wales, it was around only 25%. So, and the main reason, you can easily observe the loop behavior. So, the moment, in the course direction, if you will try to stretch, these loops will simply open out, open up; and the yarn will try to achieve in a straight form. So, before the yarn itself is start deforming, the course will give you sufficient space for this loops to open up. And the yarn can become straight. So, that's why, in the course direction you observe very high amount of extensibility, compared to wale direction.

(Refer Slide Time: 19:16)

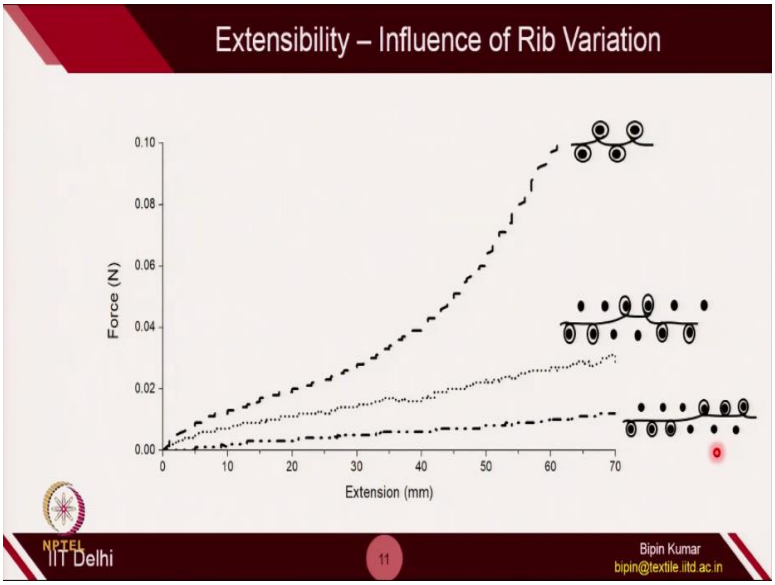


Now, let's look at the response of loop length. If you change the loop length; and you know how to change the loop length, by changing the stitch setting. So, if you change the loop length, you can see along the course direction, this red one is the course direction. So, along the course direction, the stretchability or extensibility is increasing. So, bigger length, obviously if you have bigger loop length, more chances that it can open up and the yarn has maximum space to cover during opening.

So, that's why, you can expect very high stretchability or extensibility in course direction. But, if you see in wale direction, not much change has been observed. Because again, no matter how much loop length you will increase along column, again if you try to stretch the fabric, the yarn will become tight very fast, because there is no chance for opening of the yarn, because the foot is locked.

So, you can see, this foot of each loop is locked. So, it cannot open up and the yarn cannot be in relatively straight position when you stretch this fabric in vertical direction. But again, if you see course direction, definitely you can observe the variations. So, you can control the fabric properties by changing loop length in course direction.

(Refer Slide Time: 20:45)



Now, let's see the influence of rib variation. Here, all needles was participating in loop formation. And here, 2 needles alternatively in front and back bed left. So, 2 front; and then 2 back bed was left; than 2 back loops; then 2 front was left. Again, 2 front loops. Here, 3 cross 3. So, you can see, when you have more number of loops, technical front and back simultaneously, you need to apply more force to achieve the extension.

So, but if you have more and more technical front loops along the course, followed by technical back loops. So, if you increase the number of technical front loops in the course, followed by multiple number of technical back loops, you will observe the fabric will become highly extensible. Because, you can see very less amount of force is required to extend the fabric up to 70 mm.

But to extend the fabric up to 70 mm, you can see how much force is required for rib fabric. So, for rib fabric, it is 0.1 newton, to extend up to 70 mm approximately. But for 3 cross 3 fabric, you can see here, only it is even less than 5 times force which is required for the normal 1 cross 1. So naturally, more technical front loops along the course, followed by technical back loops, results in more amount of extensibility.

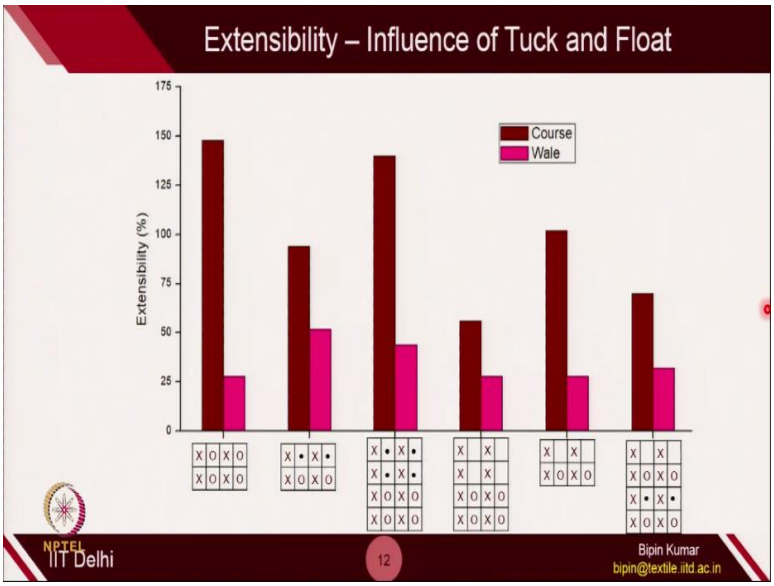
So, I have 2 samples with me, where you can clearly see the difference; how is it easy to deform the fabric when you have more number of technical front followed by technical back, compared to the **(Video Starts: 22:36)** simplest structure. So, let's see this fabric. So here, I have 10 cross 10. So, it means 10 front loops, followed by 10 back loops. So, you can see how easy. So, even by small force, you, I can deform this; very easy, I can deform this fabric.

Absolutely no force is required, it is a self-foldable structure. So, the moment you release the force, it will just self-fold. So, this is the beauty of this particular fabric. So, it's so extensible. We have not used any kind of elastomeric yarn in this fabric, but still, the fabric is so extensible, very easy to deform. But if you see 3 cross 3 fabrics; so, this is a 3 cross 3 fabric. So, you have 3 technical front or technical back.

We need to apply little bit force, more amount of force to deform this. So, you can see here, so I am, I am needing little bit more amount of force to stretch this fabric. But, and if you place 10 cross 10, it is very, very simple in stretching. **(Video Ends: 23:53)** So, that is the beauty of a knitted structure. So, playing with the rib, you can control the force and extension. So, this is how, you can see.

So, in case of higher number of technical front, followed by technical back, you will observe very less amount of force in deforming the fabric. So, naturally the extensibility of these type of fabric is much, much higher, if we keep the same level of force. Now, let's see the influence of tuck and float.

(Refer Slide Time: 24:25)



So, these are the basic symbol of the fabric. So, you have 1 cross 1 rib. So, you can see, in course direction, wale direction, the extensibility is different. When you have tuck in the second course and; this is the repeat unit. So, in the third course, again 1 cross 1 rib, then followed by one front loop and tuck and the back bed. So, this is basically a cardigan structure. So, you can see, the extensibility drastically go down in course direction.

So, in the course direction, you can see the extensibility go down. So, this is the difference. When you have more tuck, naturally the fabric will already become wider. So, if the fabric will become wider; so, the loops are already open up in tuck. So, once the loop is already open up, it has not too much chances to further open up the other loops. So, that's why the extensibility become reduced.

If you see in wale direction, the extensibility is increasing. So, here you can see, it is around 25%. But here, it is around 50%. The reason being, because you have seen like, whenever you have any tuck loop, it is always had the bigger held loop. So, whenever there is a bigger held loop, it will try to relax the fabric in wale directions. So, fabric will shrink in wale direction. So, naturally, you have more chances to extend in length direction.

So, that is the reason why you are having maximum amount of extensibility in wale direction, when you have tuck. When you increase the tuck simultaneously on the same needles. So here, the needle on the back bed, in this column; you can see, this needle is having 2 tuck simultaneously. So, once you have 2 tuck simultaneously, the extensibility will increase little bit.

In the wale direction, it will decrease comparatively with the 1 tuck structure. If you see the float. So, in float, you can, definitely you can see compared to the rib one, whenever you have floats in the structure, you have limited extensibility in the course. And the reason being, because you have seen in the float, the yarns are already in a straight position. So, once the yarn is already in a straight positions, there is a less chance for the extension of the yarn.

So, because the loops already open up, that's why the yarn is in, under straight condition. So, whenever you have more and more tuck, you can observe very poor extensibility in course directions. So, where, which you can see here. So here, the course direction, the extensibility is very, very poor. When you increase the amount of floats too much, the extensibility will go down.

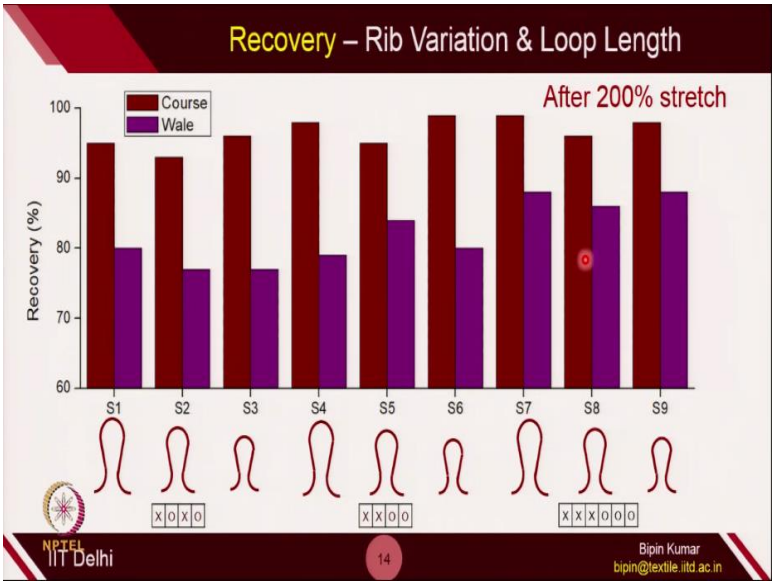
Whenever you have tuck and float simultaneously, again there will be some differences. It depends what type of stitches you are giving inside the fabric structure. And the fabric will respond according to that. And in the wale direction, almost if you see, the floats and rib,

almost similar. But course direction, definitely you can observe the major difference. So, this is the beauty of tuck and float stitches.

One key thing I want to mention here is, if you want to make sure the fabric is stretchable in all directions, almost similar amount. So, for example, if it is stretching 100% in wale direction, then it should also have the stretchability similar in course directions. So, the nearest fabric which is behaving like this is this one where you have 2 floats. So, here you can see the course and wales extensibility are slightly closer compared to other fabrics.

And this is the beauty, because you can engineer the number of floats and modulate the extensibility and make sure the fabric has uniform properties in all directions. So, that is the possibilities which knitting can provide. Let's go back to the other part, which is the recovery.

(Refer Slide Time: 28:38)



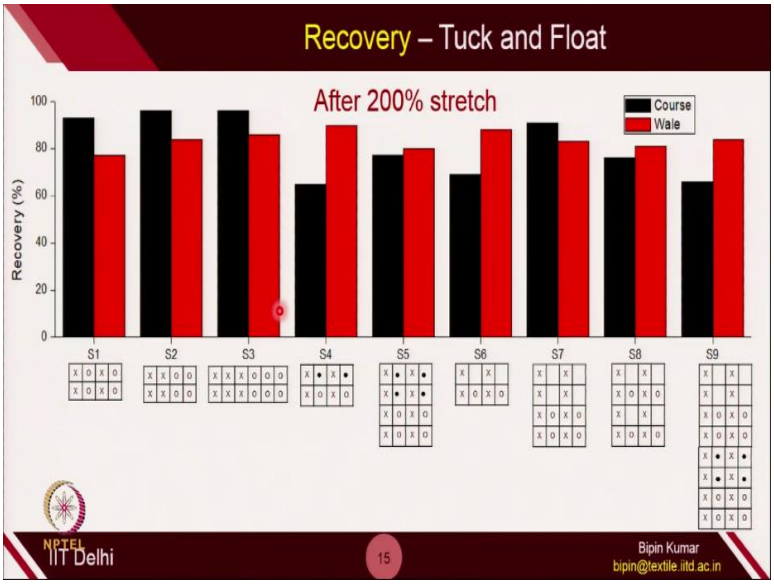
So, in recovery, again if you see rib variation and loop variations, I have not observed too much difference. Especially in course direction the recovery was much, much better. So, you can see here. After 200% extension, I observed almost 90 to 95% recovery of all the fabric samples which I already showed you. So, 1 cross 1, by changing 3 loop length. Here, 2 cross 2, changing loop length.

Here, 3 cross 3, changing loop length. So, these are the symbol of the fabric, each fabric. So, but in wale direction, the recovery was poor compared to course direction. The reason being, because, when you extend 200% stretch, it might be possible that the yarn itself might deform

and which cannot be recovered back. So, that is the key thing. So, but naturally in course direction, you can expect maximum recovery.

So, when you are putting any fabric panel on a garment and designing something, you need to make sure the directions in which you are using these panel. Because, if you design in such a way that it has maximum deformation in wale direction, then you will realize that the fabric will bag after some time, because it will permanently deform. So, these are some of the variations which I observed with some of the samples which we produced.

(Refer Slide Time: 30:08)



Tuck and float also, if you see, the similar type of response was there, but better than the rib one. So here, this is the rib variation. So, you can see, the recovery is very, very good in course direction. But in wale directions, the recovery was increasing when you have more technical front and back loops simultaneously. So, 3 cross 3 rib was better recovery properties compared to 1 cross 1 and 2 cross 2.

When you include tuck, so because of tuck, you can see the recovery become poor. You can see here clearly. So, this is very poor recovery in course directions, because the yarn will deform after 200% stretch. When you have 2 tuck simultaneously, again same thing is happening. Compared to rib, you have poor response. If you see float, again it has poor recovery in course direction compared to rib.

The other stitches, the variation will be like this. So, it depends again, what type of fabric design you are making, you can selectively make your design of experiment. Either you can

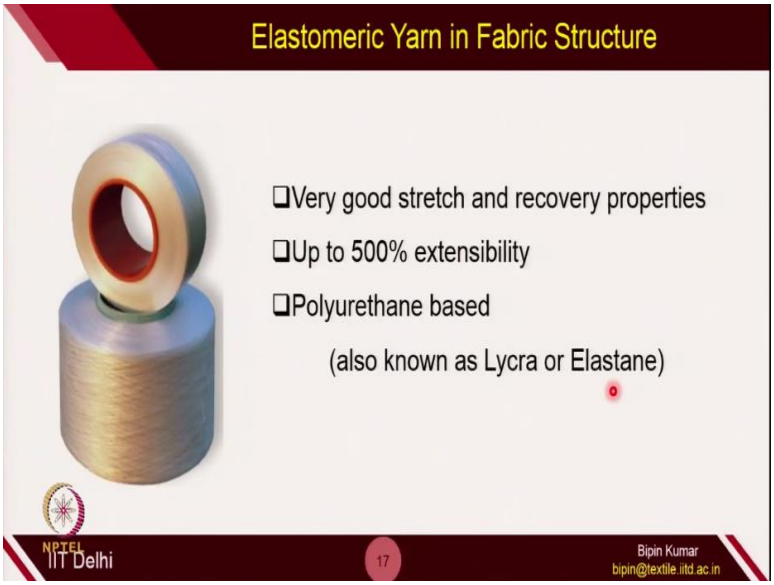
vary the rib type or whether you can varies the tuck alternatively; and float; and you can do these simple study to observe the fabric behavior. So, this is just for the understanding, so that more test you will do, the more you will understand about the fabric behavior, which is very, very important from product point of view.

(Refer Slide Time: 31:56)

So, we have seen the recovery and extensibility behavior. Now, let's see how we can improve the extensibility and recovery. Because, eventually in the product, we want 100% recovery. Because, we don't want that, we are using some t-shirts; and after 10 days or 20 days, we see that the t-shirt loses its recovery and permanently deform. So, these extensibility and recovery; we need to make sure the fabric has good extensibility as well as good recovery after multiple use.

To improve extensibility and recovery, definitely we have to look for the smart materials; or such, those material which has better properties in extensibility and recovery.

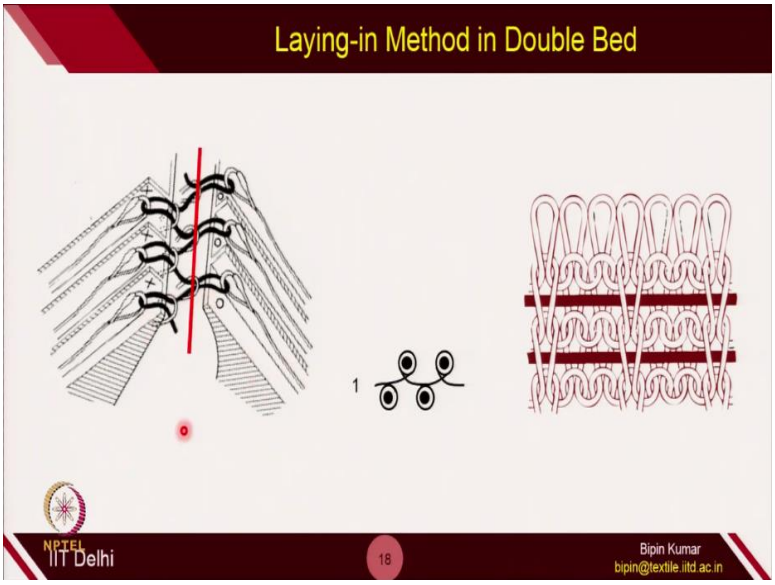
(Refer Slide Time: 32:47)



So, elastomeric yarns are quite popular in knitted structure. So, if you see your socks, sometimes pressure garments, even in your sports garments, many times, they include elastomeric yarn, intentionally in a fabric structure. The reason being, because the elastomeric yarn has very, very good stretch properties, as well as it has almost 100% recovery properties. And that is the beauty of this polymer, which is based on polyurethane.

So, if you take these yarn from the market; if you try to stretch it, you can extend up to 500%. This is commonly known as lycra or elastane. So, the yarn itself has very good stretch and recovery properties. So, if you use such type of yarn in the fabric, the fabric will automatically will become very good stretch and recovery property. So, but now the problem with these type of yarn is, it is very difficult to include these type of yarn in a knitted structure. So, that's why, there are some key method through which we can integrate these type of yarns in the fabric structure.

(Refer Slide Time: 34:00)



So, one of the key method is laying method in the double bed, when you are making the loops by simple yarn like cotton, polyester or wool; so, these, they are making yarns. And you can put the inlay as a floats. So, these inlay or the elastomeric yarn are not a part of the loop making process, but still, it will be there inside the fabric and it cannot come out very easily. So, how you can make this on a V-bed machine?

So, for example, here the front bed is making front loops, back bed is making back loops. And there are plenty of space here. You can see here. So, you can simply put the elastomeric yarn in between. You can go for the second course. And in this way, these elastomeric yarn will be locked within the loops itself. So, this is how, when you go for the second course after putting this elastomeric yarn, the elastomeric filament can be locked within the loops between technical front and back.

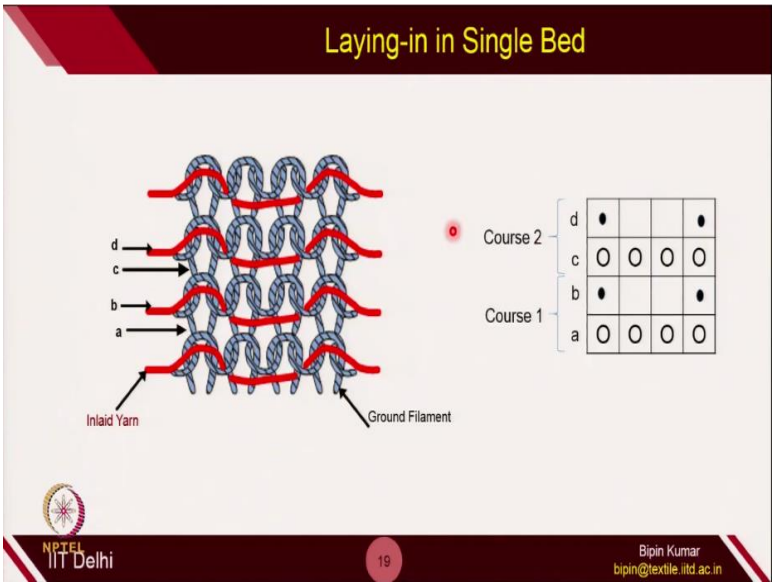
So, between the layers of technical front side and back side, you will see, elastomeric yarn is, will be floating. So, I have this fabric samples with me. So, you can see here, how the yarns will be floating. Although I have not used a **(Video Starts: 35:18)** elastomeric yarn, but I have used the other yarn. So, you can see the other yarn is hidden between technical front and back loop.

So, if you see from one side, this is a simple rib structure. And you can see, in the courses, you can see how the yarn is locked. So, you can see here, how the yarn; so you, this yellow one is basically, it's not the part of loop, it is not intermeshing, but still, it is locked inside the

structure. That is the beauty of knitting. You can interlock anything. So, from the both side, it looks similar.

And the reason being, because **(Video Ends: 36:02)** you have fed this yarn between technical front and back loops on the machine. And this, in this way, technical front and back loops will combine and hold this yarn and not release.

(Refer Slide Time: 36:20)

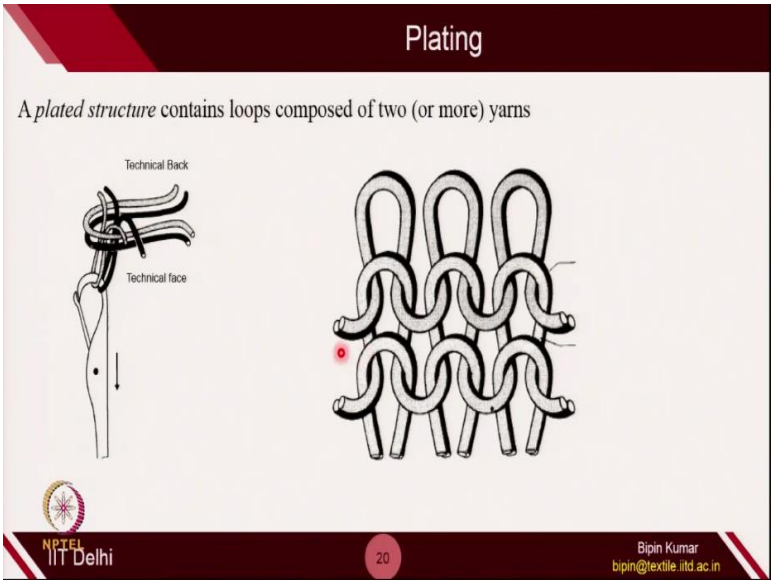


The other thing, on a single bed, if you want to put these type of inlayed yarn, it is difficult. So, that's why, you need to go for tuck and floats. So, you can put the inlay as a tuck and float. So, here, basically you have to go for 2 feeds. So, in course number 1, the feed 1, all needles will be knitting. And in feed 2, some of the needles will be making tuck and the other needles will be doing float.

So, of the same bed. So, this is how the course 1 will be designed. So, here a and b is course number 1. So, if you see a, it is making loops in the first feed. And the b, this is tuck; and then 2 float; and then tuck. If you go for second course, which is c and d; 2 yarns are feed. So, in the first yarn, when it was feed, it is making technical back. But, if you see d, it is again tuck, 2 floats; and then tuck, 2 floats; and then tuck.

So, this is how you do it in a single bed. Because, in single bed, it is not, there is only one type of loops. So, naturally, then we have to make sure the inlay yarns can go in a tuck way. So, this approach can be used for single bed laying process.

(Refer Slide Time: 37:44)



The other way, the most simplest one is the plating, where you just combine 2 yarns. And 2 different yarns will be feed simultaneously. And the needle will be making loops. So, this process is called plating, where the loops consist of 2 or more yarn. So, you can see, each loop has 2 yarns. And each yarn will be participating in the loop formation. So, the black and white yarns.

So, each loop is made from black and white yarn. So, you can mix lycra with normal filament and make the fabric highly stretchable and highly recoverable at the same times. There are other way also, like you can also play with the design of yarn itself. You can go for core spun yarn. There are different types of yarn where you can actually generate elastomeric filament itself and mix with a synthetic filament.

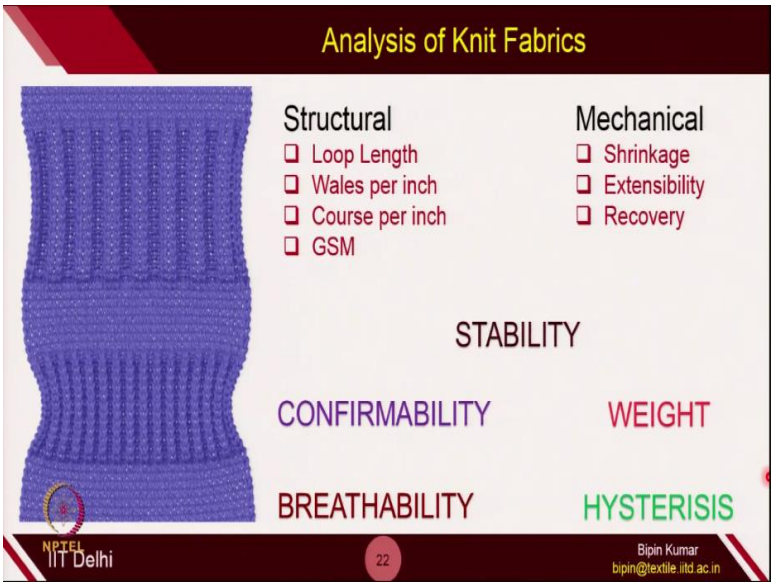
And then go for knitting. So, that is also one of the method like core spinning, where you have lycra in the core and other filament at the sheath. So, you can use those type of yarn to make elastomeric fabrics, which is highly stretchable and recoverable.

(Refer Slide Time: 39:00)

So, with this I am going to summarize this particular week. Because, this week, I believe it will be too hectic for you. The reason being, because we have covered so many designs and so many testings. The main reason for doing this design and analysis was, because, you just don't focus only on the design aspect, but also you try to understand the science of knit structure.

Because, science is extremely important, because the, if you understand more and more about loop behavior, you can design your product and optimize its properties, as per your requirements.

(Refer Slide Time: 39:39)



Overall, we have seen, we can control the loop length; how we control the wales and course per inch; how we can control the GSM. So, all these structural characteristics. We have also

seen 3 mechanical characteristics. One is shrinkage, the fabric shrinks once you take out from the machine. Fabric extensibility, how much you can stretch at a particular load. And recovery, how well the fabric can go back to its original position.

So, these 3 mechanical properties and structural properties the must whenever you go for any design. I have also shown you how the appearance of the fabric will also change when you have different stitches on the machine. So, with this, when you have the fair understanding of aesthetics, design, structure and mechanic, you can think for product. You can also design fabric with good breathability.

You can also design fabric with the desired weight configuration. You can also design fabric which is more stable. We can, you can also think for a fabric which conforms with the body perfectly. You can also minimize the hysteresis, so that repeated response can be observed. So, it all depends on how well you learn the characterization. So, I expect all of you, whenever you get chance, you focus on structural characterization and mechanical characterization; and try to link with the product properties; and try to think what you actually want to achieve to knit designs.

So, with this, I am stopping here, this particular week. In coming weeks, we will go even very complicated designs of knitting. So, whatever designs you have seen so far, it is just the simplest one, which is why popular in the market. But apart from that, there are many other designs are there, like cable design, pointle design. You have many others possibilities are there in knitting.

Apart from that, we will also learn a new kind of knitting process where you can individually select needles of each bed. Also, we will learn about some new techniques like racking of the bed, through which you can design even more complicated loop structures. So, stay tuned. If you get time to do the practice. I expect all of you to please do little bit of practicals related to knit structures. And stay tuned. Once again, thank you very much.