Science and Technology of Weft and Warp Knitting
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Module - 1
Lecture - 1
Introduction to Knitting

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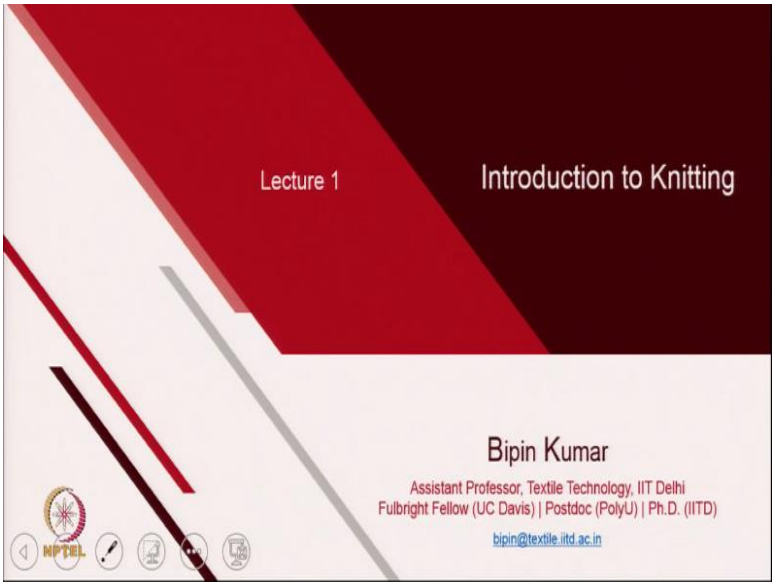

Good morning, participants. Welcome to this course on knitting. Myself Bipin Kumar; I am a assistant professor in Textile Technology Department at IIT, Delhi. Before I start introducing this course, let me introduce my team to you.

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For making this course, there was hard effort by so many members in my team, including Manjit Singh who is the Technical Superintendent at IIT, Delhi, in knitting section. We have Ashok also, who helped in making samples and providing some literatures. I also have huge support from my students, PhD students, Tuhin and Priyanka. We have a very strong support from NPTEL team, who helps in video editing, animations, shooting.

I am also highly obliged for company persons from different sections of the country, including Balasubramanian, Ramandeep, Pawan Sharma, who helped us giving me so many technologies related to knitting. And I also am, I would like to acknowledge some of my students who helps in making fabric samples, as well as making some photos and videos. So, let's go to this course. In this particular lecture, we are going to cover some basic topics on knitting. First of all, we would like to know, what do you mean by knitting?

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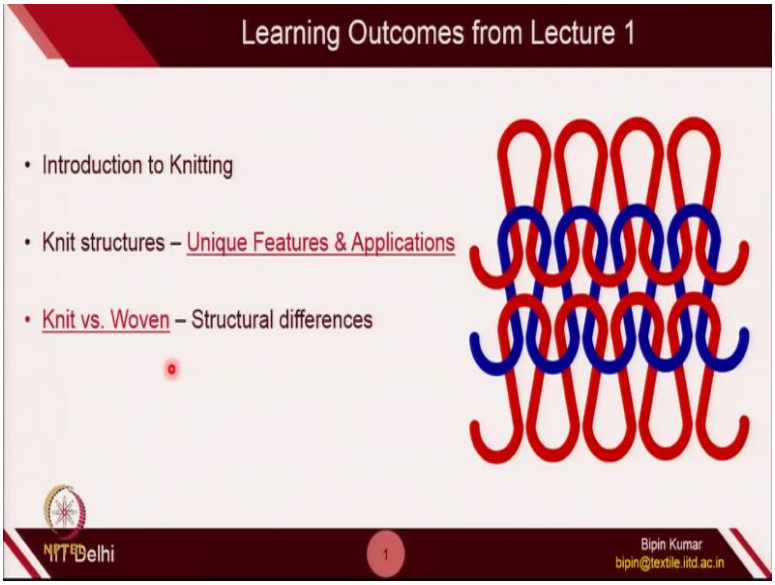

To understand the knitting, we need to also understand the structure of the knit. So, we will discuss about some of the unique features and applications of knit structures. At the end, we are going to compare knit versus woven structures, which is the most fundamental things. Because, once you understand these structures, you would be able to appreciate the knitting which is so important nowadays to design any sort of products; not only garments but also technical products related to different applications. So, let's go and see, what do you mean by knitting? Knitting is nothing but, just it is a process of converting yarn to fabric.

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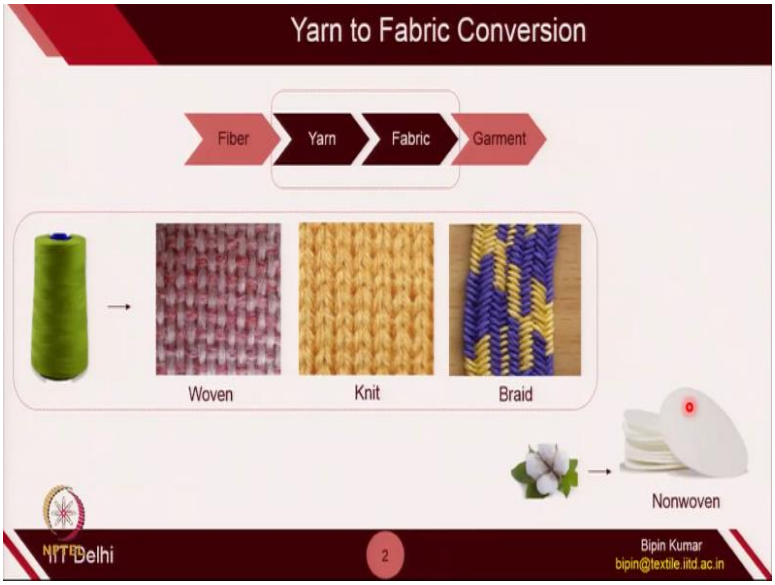

So, when we talk about yarn to fabric conversion, we have basic 4 processes in textile, where we convert fiber to yarn, yarn to fabric and fabric to garment. Knitting basically relates of conversion of yarn to fabrics. So, when you talk about conversion of yarn to fabric, we have different means by which a single individual yarn can be converted to different types of fabric structure. And knit is one of that structure.

So, you have the yarn which you make from the fibers; fiber to yarn. This yarn, later with the help of different fabric making technologies, you convert into different fabric structure. And some of them are: woven, knitted and braided. We also have one fabric technologies which is quite popular in 21st centuries, which is called nonwoven. So, nonwoven is also very important. Now it is, because it just skip the yarn formation.

So, you take the fiber and directly you convert to the fabric. So, you take the fiber and directly converting here to the fabric. So, this is why this is not actually called as a fabric. We call it nonwoven because we do not include yarn as a process of fabric formation. Rather we just take the fiber and convert into the fabric. So, these are the 4 fundamentals of fabric structures which is used in textile engineering. And knit is one of that structures. So, in this entire course, we are going to discuss about this particular structure, its technologies, its properties and its applications.

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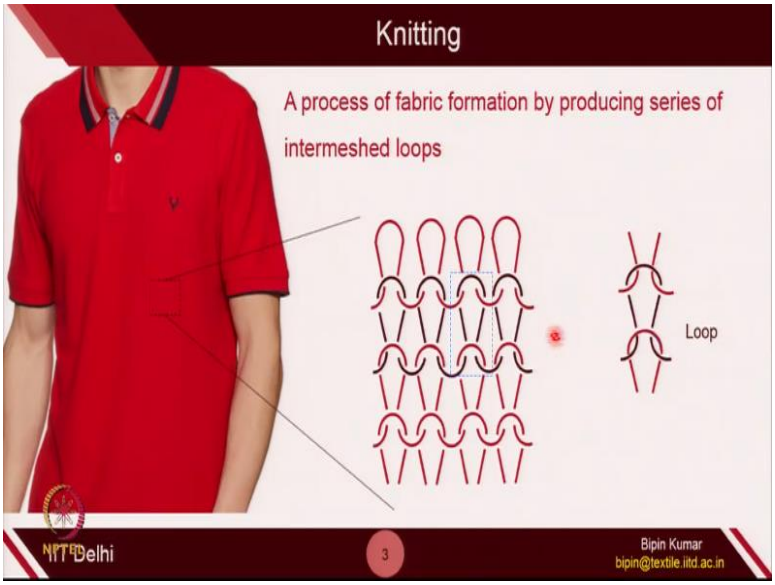

Let's, let's go and see, what do you actually mean by knitting? Most of us, we are quite used to of using t-shirts in daily routines. So, if you carefully see this t-shirt by microscope, you will realize that yarns in this fabric structures moves in the form of loops. So, knitting is nothing but a production of series of loops which are connected together. So, knitting is just a process of fabric formation by producing series of intermeshed loops.

What do you mean by intermeshed loops? Let's see one of the loop carefully. So, you have this loop. So, in reality, if you take any yarn, it is generally in straight form. But in the loop you can see the movement of yarn is in the bent form. So, to keep the yarn in the bent form, it need is support. And that support is provided by other loops. So, if you see this particular loop which is shown here, it is supported at the bottom and at the top.

So, you can see the upper loop and the bottom loop, they are actually supporting this loop in that particular shape. So, this is called intermeshing. So here, you have the loop which is intermeshed with neighboring loops, especially at the top and bottom in the same column. So, knitting is just a process of intermeshing different loops together. And these loops only help each other in securing and stabilizing the entire structure. Okay.

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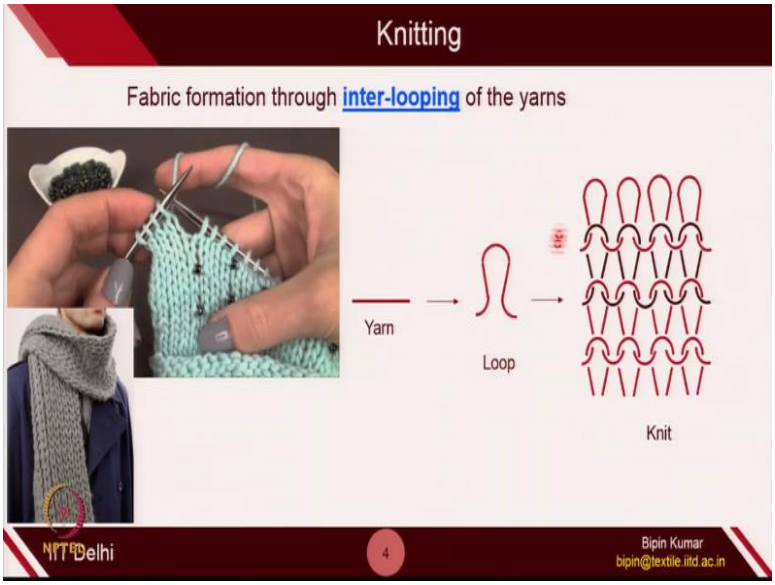

Knitting is very popular. If you might have seen in many households, womens used to do hand knitting. This is very quite common. So, they take just the yarn, they convert in the loop. And these loops are interconnected together. It is a process of inter-looping of the yarns. And you make very beautiful structure out of them.

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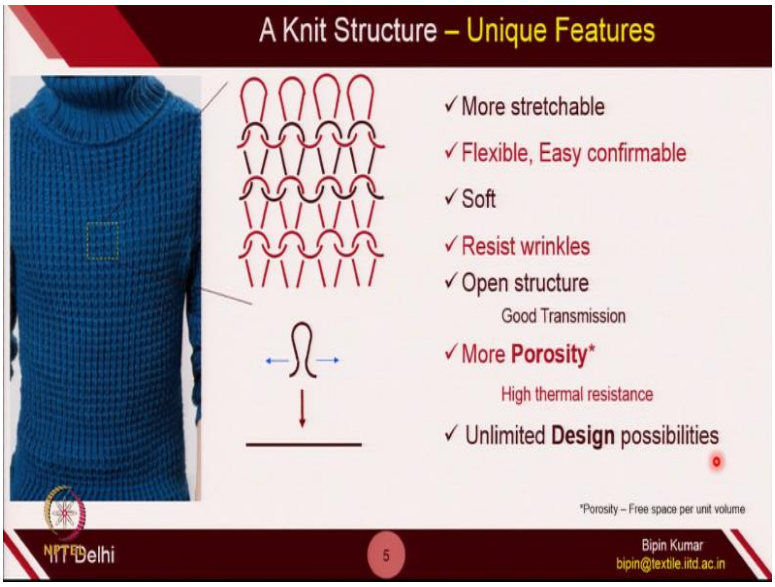

Again, let's try to see this structure carefully. You have a knit structure which is shown here. If you take out the microscope and try to see the loops inside the fabric. It will look like this. Most of the garment, knitted garments will look like this. The very interesting part is, if you just take out these loops, this is already in the bent form. But, if you try to stretch it, you can easily open these loops, because it, this is not the normal configuration of the yarn.

Because yarn is in the bent form, obviously yarn will try to move its in the straight form. So, if you try to apply any load on knitted structure, the loops will just open up very easily. So, one of the very unique feature of knitted garments is, it is very very stretchable. The second most interesting feature of knitting is, it is very very flexible as well. So, you can see, it can fix with the body contour very easily compared to, if you see woven shirt, you have to give a proper shape and size.

You have to cut the garment properly and then it can fit in the, fit to your body by proper tailoring. But, in case of knitted fabrics, most of the times it can fit very easily and conform to your body properly, because it is very very flexible. So, this is one of the very unique feature, especially in knitted garments. The other thing you will feel like, while, when you use any t-shirts compared to shirts; it looks very very soft.

And the softness actually comes from the flexibility and stretchability. Also, the type of yarn which we use in making these structures are comparatively soft yarns or you can say low twisted yarn, which in general gives the soft feeling for these type of fabrics. That's why we prefer in daily routine, to use t-shirts as a casual wearing. The other beautiful things about knitting is, it resists wrinkles.

Compared to a shirt, you need to iron it properly before you use it. But in case of t-shirts it can resist wrinkles, so it needs very limited amount of ironing. If you see this knitted structure carefully, it is very very open. These loops are comparatively open. So, that's why it is, allows you very good amount of moisture and air exchange. So, that's why, if you see most of the sports garments, they are actually made up of a knitted structure.

Because it is very open and you feel more comfortable bit because it allows you good transmission of air and moisture. More porosity: this is one of the most fundamental unique features of a knitted structures; knit structure is highly highly porous. Porosity is nothing but the free space which is available in the structure per unit volume. So, if you have, let's suppose x amount of volume, how much percentage of x is available as a free space.

So, if you see many sweaters, or woolen garments, they are made up of knitted structures. And the main reason that it is made up of knitted structures, it is very very porous. And the beauty of porosity is, because it can entrap air. And once it entraps air, air has having very high thermal

resistance. So, that's why it does not allow heat to exchange properly. This is why knitted is very popular in woolen garments, because it can entrap air which do not allow heat to pass through.

The other thing is like, the knitted is also, gives you unique possibility to create any design on the surface of the fabric. So, you can see here in the photo itself, the main body looks different, but if you see the collar, it looks completely different. It also, both of these bodies or parts of the garment contains loops only. But the designs are completely different. So, there are unlimited design possibilities are there in case of a knit structure.

So, we have seen why this knitting structure is so popular. Because it gives you some additional benefits which most of textile structure cannot provide. Because of this, knitted has been used in many many applications.

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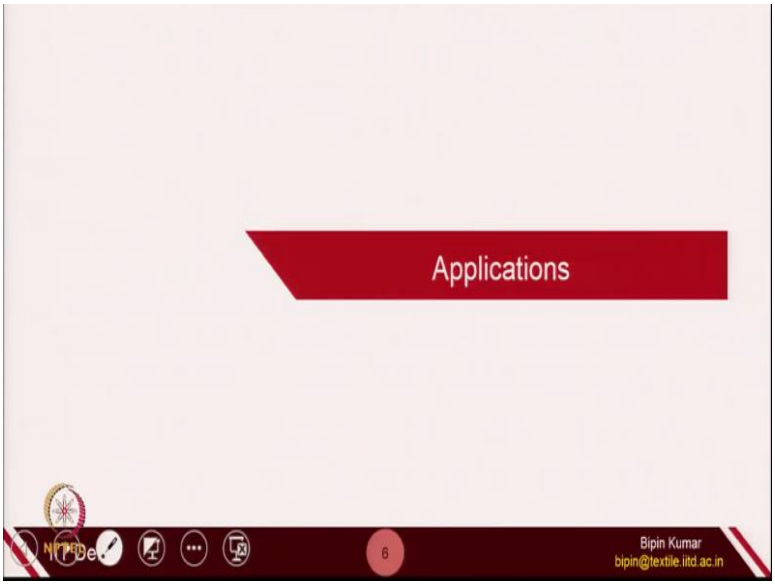

We are going to list a few applications which you might have seen in daily routine. First one is hosiery.

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If you see most of your socks, under linings, they are all made up of knitted structures. Sweaters, all woolens, most of the woolens are made up of knit structures. T-shirts, they are also made up of knit structures.

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Apart from garmenting, knitting is also very useful in decoration. So, in home furnishing, you can see, these are knitted structures which is used for decoration or covering a contour surface. Why is it so? Because, as we have seen, knitting is very conformable, very drapeable. It can fit to any shape very easily. So, that's why it is used as a home furnishing to cover any shape and size. It is also very popular as a underwear, because it gives you very good stretchability which is required underneath our body.

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Apart from garments, you might have seen a lot of structures in daily routine, where again knitting has been used. One of the important things from Indian perspective is mosquito net, which is very very popular to prevent malaria. These structures, you can see it is very very open, yet sufficiently closed so that mosquito cannot enter. So, this is your, made up of a knit platform.

Agronets, which is also quite popular in agricultures, where you use knit structures to cover the plantations, to prevent or give little bit amount of sun lights, depending on what type of crop is being used or generated on the field. So, knitted has been used for covering as well. It allows air and moisture to pass out. But, also it can protect little bit of sunlight to prevent damage or excessive intensity of sunlight to certain crops.

So, agronets is also very very useful. You might have seen in the supermarkets, they used knit structures for as a packaging material. So, you can collect these; these structures are not stretchable, but still, it is so coherent that you can keep many materials in these structures. So, these are the common things which are very frequently used in real life. Apart from these applications, some advanced applications which is now-a-days happening around the world is e-textiles.

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So, e-textiles is like one of the areas where you actually integrate sensors or actuators and make the garment responsive. These garments can be used for health monitoring, which is the top priority in 21st centuries. Everyone wants to know the health benefits or they want to track their health. So, in that case, you can fit the sensors inside the knitted structures and these structures will still be conformable and flexible.

It can fit to your body, it can give you the signals. Sensors can be appropriately locate to certain segments of the garments. So, that's why knitted is so useful for very highly advanced applications. In sports also, knits gives you lot of flexibility, because it is open porous, it is more comfortable, breathable, it is stretchable, which is the prime requirement for most of the sports. So, that's why knitted garments are quite popular in sports as well. Now-a-days, in last 3 to 4 years, we have seen a shoe shift in shoe market;

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Where shoe is replacing foam and they are using knitted as a shoe uppers. So, most of you might have seen most of the top brand shoes, they are making knitted shoe uppers, because it is very porous, conformable, breathable and durable as well. And these are replacing foams. Knitted is also being used in composites applications, in cut resistance fabrics.

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So, this knit structure is not only just limited to garment, like undergarments or underlining, but also, when you design this properties or design these structures, you can achieve very significant properties for different applications. Cut resistance is one of those areas where you can use this fabric for, as a cut resistance garment, because knitted is so flexible that, when you try to cut these structures, the loops will try to consolidate at one point and it will not allow easy tearing of such fabric.

So, that's why knitted is used in such, some technical applications as well, because of its structural features. So, before we end this lecture, let's finally try to understand how fundamentally in knit and woven is different.

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You might have seen woven fabric in daily routines.

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Most of the shirts which we wear are made up of woven structures. And most of the t-Shirts are made up of knit structures. So, I have few samples to show to you, how these 2 structures are completely different.

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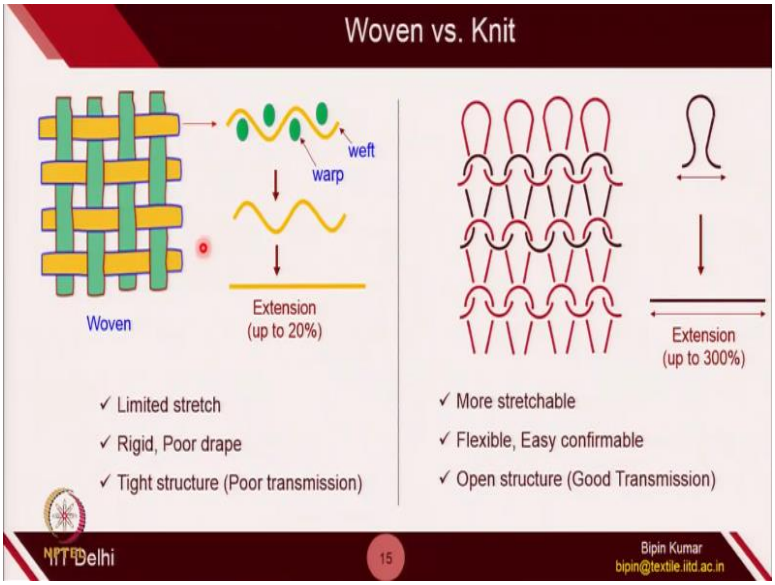

If you see a woven structures; I am going to show you these structures in a while. Just try to understand how these 2 structures are completely different. So, in a woven structures, it is actually made up of 2 sets of yarn. You can see the green yarn which is the warp yarns and the yellow yarns which is the weft yarns. So, these warp and weft yarns are actually moved in a certain fashion.

For example, if you see, this yellow yarn which is the weft yarn, it is moving one up and one down. So, the, in the first point, the green one is on the top. But on the second green one, it is at the bottom. Then again, the yellow one is on the top and then green one is on the top. So, the structure looks like one up, one down. But the most interesting point which you can notice is the movement of these yarns.

So, the movement of each individual yarn in this fabric structure is just like zigzag. If you try to pull out these structures from one of the ends with sufficient force, you can just take out these yarn very easily from this structures. Also, if you try to straight these fabrics, maximum this crimps or this curliness will just become straight. So, you can see, even if you give force to this type of fabric, the extensibility is not that significant.

So, maximum, upto 20 to 30%, you can extend these type of woven structures. So, in reality, whenever you encountered a woven structures, it is, first of all it is very very limited stretch compared to knit. It is extremely rigid. Because of rigidness, it cannot fit to any 3-dimensional shape or structures. It is extremely extremely tight. So, it has very poor transmission compared to a knit structure.

While knitted, as we have seen, it is made up of loops which is very easy to deform. So, when you try to give any force, it will try to extend very easily, because the loops will try to open up. Because of that, it is more stretchable, more flexible, it can conform to 3D structure very easily, it is very very open, that's why it gives you very good transmission property. So, these 2 structures are fundamentally different in many properties. Let's have a look physically both of these structures and try to see how they are different in many aspects.

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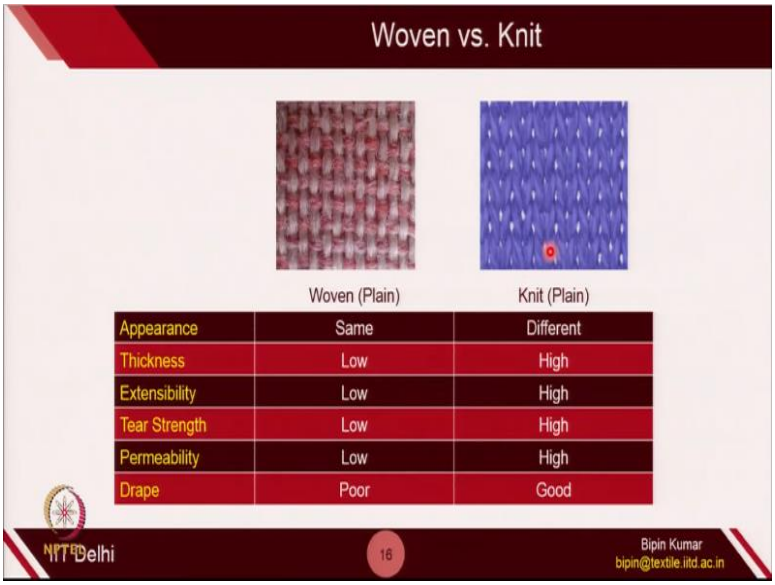

So, I have listed a few of these things like appearance, thickness, extensibility, tear strength, permeability and drape. So, we will try to understand how these 2 structures gives you different performance in terms of all of these properties. So, I am going to show you these 2 samples, one is woven, and one is knitted. So, first let's try to see a woven structure. **(Video Starts: 20:52)** This is your, a woven structure.

If you try to zoom it, you can easily find, there are 2 sets of threads. So, you can easily see, let me show you, 2 sets of threads which is moving. So, you can see this vertical threads and you can also see the horizontal threads. So, basically it is the intermeshing of 2 sets of perpendicular threads. And if you try to stretch these fabrics, if you try to stretch these fabrics you can see it is not stretchable.

I am giving, I am applying very high force to this structures, but it is not stretchable. Okay. If you try to flip this fabric, it again looks almost similar. You cannot differentiate which is top surface, which is bottom surface. So, in terms of appearance, they are completely same from

both the sides. Okay. Also, one thing you can easily do is you can take out the yarn from the ends. So, I am trying to pull the yarn.

So, you can see these yarns can be easily pulled. So, you can take out the yarn from either sides, from all the sides you can take out the yarn. Now, let's try to look at a normal knitted structure. So, this is the basic knitted structures. Some of my students, they help making these samples. Let's see this structure. So, you can easily see, it is made up of some fundamental units which I have already shown, the loops.

You can see, it is, the vertical columns of loops. As well as, if you move along the horizontal line, it is the series of loops. Okay. So, and these loops are basically connected with each other. So, one loop is connected with top loop and bottom loop. And along the series also, it is connected with left loop and right loop. And the symmetric is all around. So, each loops has almost similar type of appearance, left right top bottom.

The interesting thing is, when you try to flip this fabric on the other side, the structure is completely different. So, can you see here? The structure is completely different. So, this is the front side you can say, may be its top side. And this is the back side. Okay. Compared to woven fabric, it was very difficult to differentiate both the sides. But in knitted, you can easily see, these 2 sides are completely different.

Other interesting thing which is practically very important in terms of applications is extensibility. So, if you apply little bit amount of stretch, it can stretch to up to 100% or 200% very easily, depending on the structure. So, you can see a woven which was not stretching at all, but a knitted can be stretched so easily. And also, we can see, the structurally, they are different from the top side and bottom side.

Also, in case of woven, these 2 structures on the top side and bottom sides looks almost similar. **(Video Ends: 25:37)** So, fundamentally from the yarn movement point of view, these 2 structures are completely different. So, we have just noticed the appearance of woven fabric is almost same in case of woven structure. But in knitted, you have seen on the top side it looks different but on the bottom side it also looks different.

Thickness: Because, if you see woven and knitted, especially the thickness of a woven fabric is much much low compared to a knit where the loops are actually in 3D plane. So, because of that, the thickness of a knitted is much much higher compared to woven structure. Extensibility also, we have seen woven is very limited stretch, but a knit fabric is very high stretch. Tear strength: This is also very interesting, if you, because the fabric is so tight;

So, when you try to tear it, or you, if you try to cut the fabric and if you try to apply force, the woven will just torn out very easily, because the structure is very very tight. But in case of knitted, it is very very difficult to tear. That's why knitted has been used in cut resistance gloves. Permeability: We have seen how open a knitted structure is. So, obviously, knitted gives you very high breathability compared to woven.

Drape: Because knitted is very highly flexible, conformable, so it can fit to your body contour very very easily compared to a woven structures. So, fundamentally, these 2 structures are entirely different, having different properties. That's why these 2 structures are also recommended in different types of applications.

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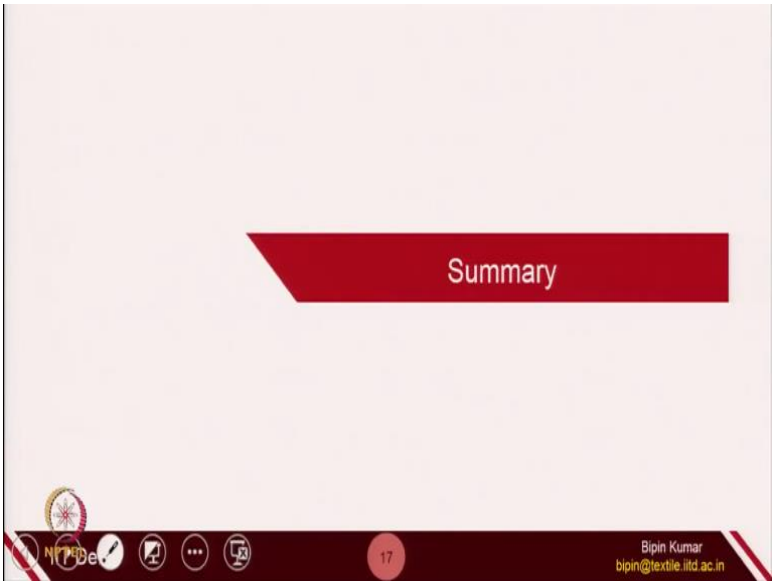

So, lets summarize what we have learned, particularly in this lecture. The first one is: We learned, tried to understand what do you mean by knitting.

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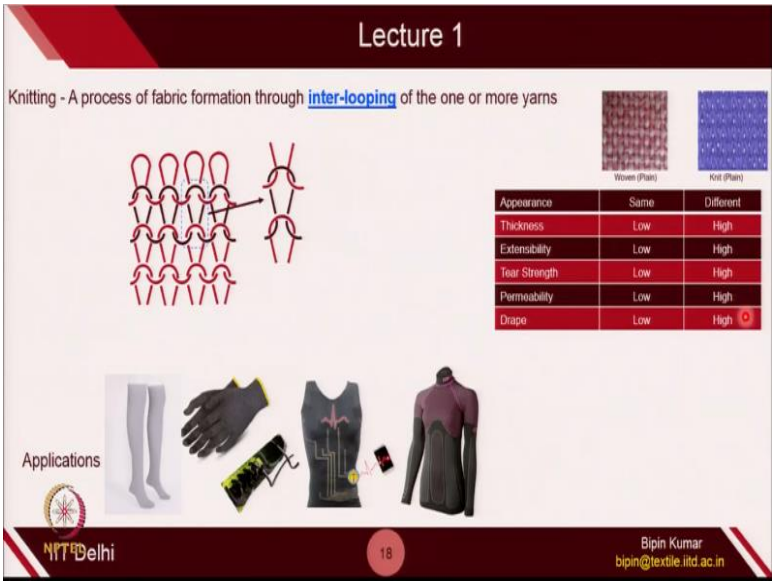

It is nothing but a process of inter-looping of the one or more yarns. So, you take the yarn, you make loops and these loops are connected together. So, each individual loops are intermeshed at the top, by the top loop and the bottom loop, so that it remains in that stable state. If you take out any of these top and bottom loops, these loops cannot be stable. It will just open up. So, fundamentally, this is called knitting where you make loops and you connect these loops with each other.

And neighboring loops helps to secure and stabilize a loop structure. We have also explored different application potential of knitting including hosieries, cut resistance gloves, shoe uppers which is quite new. In 21st centuries we are moving towards highly advanced medical technologies where knitting can, is playing very important role to integrate sensors and giving you very valuable information regarding your health. It is also being recommended mostly in the sports.

And there so many other technical applications where we use a knit structure. We also fundamentally try to understand how a woven and knit is completely different. In summarize, woven is much more rigid, stable, as well as low extensibility and poor breathability. While knitted is very high extensibility, very good breathability and very good fitting properties. So, this is how these 2 structures are different.

From the next class, especially in next lecture 2, we are further going to understand a structure little bit more. We will also going to learn different interesting terminologies which is being used in knitting, because we are starting this course, so we first should learn about some terms

in knitting which I will be using frequently. So, it will help you to understand the subsequent lectures. So, we finish the lecture 1 today and we will move to lecture 2 in the next session. Thank you.