Science and Technology of Weft and Warp Knitting
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Module - 12
Lecture - 50
Technical Applications of Knitting …Continue

So, let's move on other technical application of knitting. So, knit for e-textiles.

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So, e-textile is now becoming more popular in 21st centuries, because here we are integrating electronics in textiles for healthcare monitoring and for other advanced functions.

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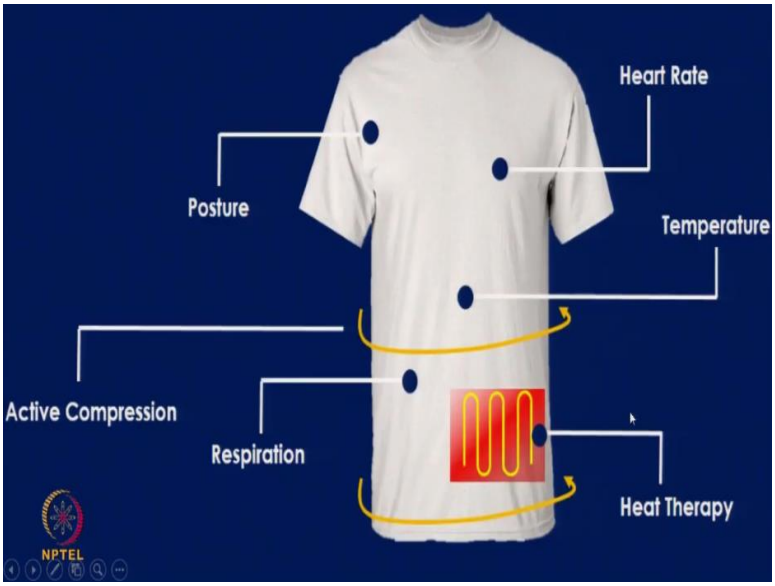

So, if you see e-textiles, basically it gives you the flexibility of monitor your health with the help of heart rate sensors, posture sensors, temperature sensor, respiration sensors. Also, in e-textiles, you can give you smart functions like heat therapy; automatically the fabric will give you some heat therapy; or some kind of active compressions. So, many research are being done in these areas where they are either monitoring your health or giving some kind of smart activation or smart actuation for your body.

So, some of the key areas I have listed here. We are also doing research in this area. I am going to show you in the next slides. So, the first area is like active compression. So, nowadays, smart materials are available, which you can integrate in the textiles. So, especially in knitted textiles, you can integrate those smart materials and you can get active compression out of it.

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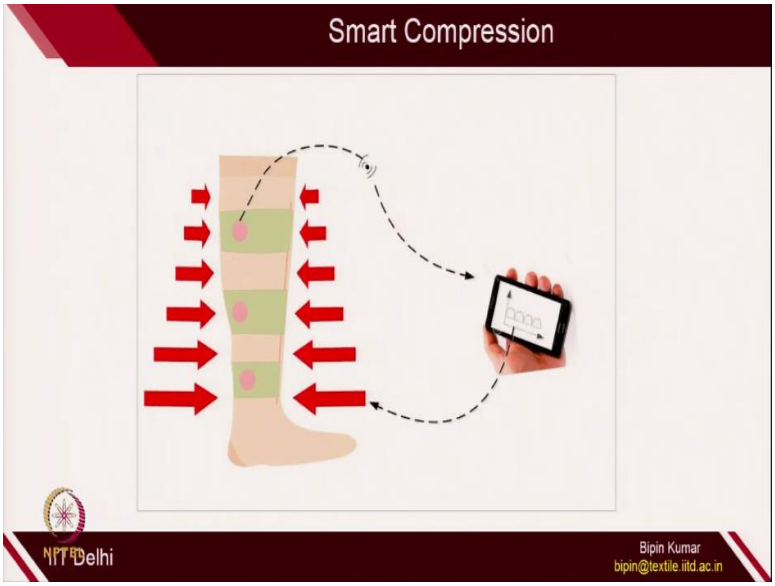

So, this is what **(Video Starts: 01:44)** is possible nowadays. So, you can take, make a smart stocking which can give you some kind of massage effect. You can wear some kind of garment which will automatically compress and release. So, some kind of, these kind of smart activations, it is possible when you integrate these smart materials in this structure. **(Video Ends: 02:07)**

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So, what do you mean by those smart materials? So, one of the materials which is very popular in research is shape memory materials. So, shape memory material is, are the materials which behaves differently in presence of a stimulus. So, it is nothing but; if you see the pine cone, it also has the similar properties. So, in dry state, it is actually opened up. But the moment you put moisture, **(Video Starts: 02:31)** automatically it changes its shape.

So, in wet state it is like this; in open states, it is like this. So, the same properties of pine cone can be generated with the help of shape memory material. And in polymer if you see, smart polymers are available, such as shape memory polymers. Which, when you heat it, it will automatically shrinks and give some kind tight performance. So, these are stimulus responsive materials.

So, in presence of heat, temperature, pH, electricity, they can change the shape; they can change the modulus; they can change the stiffness and give you smart function. So, for example, here I am showing this smart polymer. You are controlling the pressure on the surface. **(Video Ends: 03:23)**

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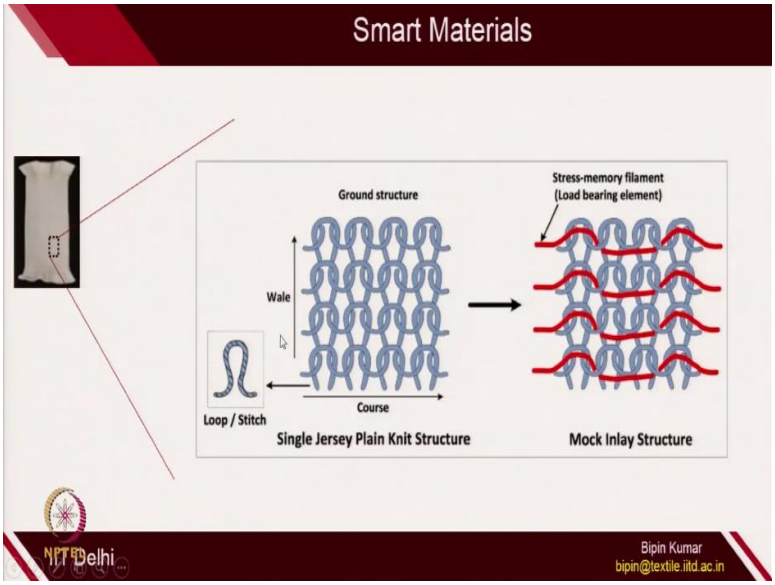

So, the same thing in knitting actually gives you a very useful platform where you can integrate these smart polymers in the form of filament. Either you can use tuck and float. Such structures you can generate, where the smart filament will be the part of this fabric. And you can get smart functions out of it. So, I have this sample with me, where I can show you these, the red one, which is the smart filament or shape memory filament which is integrated in the fabric structure.

So, let me show you this fabric. So, in the form of tuck and float. **(Video Starts: 04:00)** So, this is the smart stocking. So, a kind of a stalking. This is smart fabric. And if I zoom for you, you could be able to see those smart filament in this. So, now you can see, this is the smart filament which is floating in the form of tuck and float in this structure. Okay. **(Video Ends: 04:34)** So, once you integrate these type of smart filament, where knitting plays a very important role in controlling and placing the smart filament in the structures.

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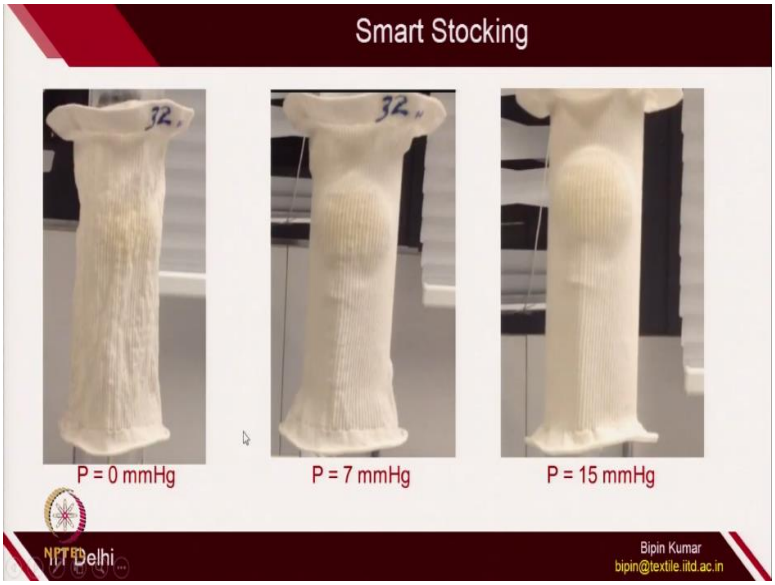

You can then activate these type of materials and generate different level of pressure. So, for example, here the, in the loose state you can be wear it out; and automatically the fabric will become self-tight and generate different level of pressure. And you can reverse this also. So, you can get a kind of massage effect; or a stocking which will give you a massage effect. Similarly, you can generate pressure garments. On the knitting, you can integrate these type of filaments and you can get a smart fit garments.

All the garments can be used in a loose state and automatically, with the help of heat, you can make the garment self-tight. So, self-tight garments can be made if you use smart materials in this knitted structure.

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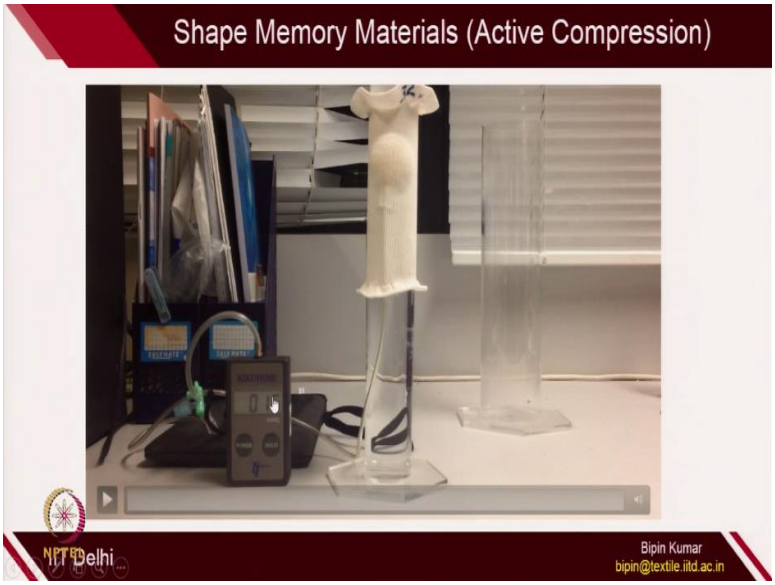

Here I can show you. **(Video Starts: 05:29)** So, in the loose state, you can wear it out. You can put it. This is the pressure sensor. So, in the loose state, you can wear it out. This is active compression. And automatically, the fabric will become tight, the moment you give some kind of heat. And you can generate different level of pressure. **(Video Ends: 05:53)** So, this is the beauty of active compressions which is now possible; so, in the e-textiles also.

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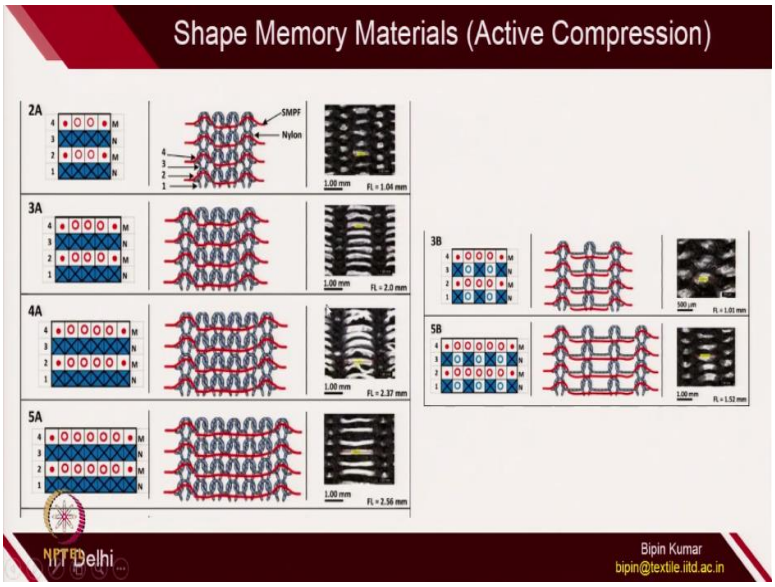

From the engineering point of view, knitting gives you those flexibilities to play with different float and tuck designs, especially the smart filaments. You can keep more floating length. And you can also play with different materials, ground materials.

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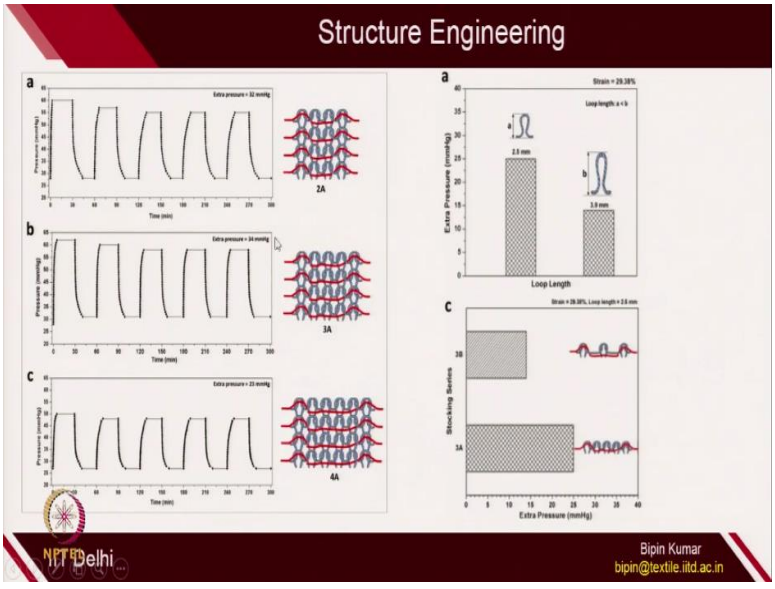

And you can get different level of pressure. So, depending on loop length, depending on the tuck and float designs, the performance can be tuned. So, this is the engineering part. So,

that's why knitting become very, very important. Not only it gives you the flexibility in terms of integration of foreign materials in the textile structure, but also you can tune it properties by playing with loop architecture.

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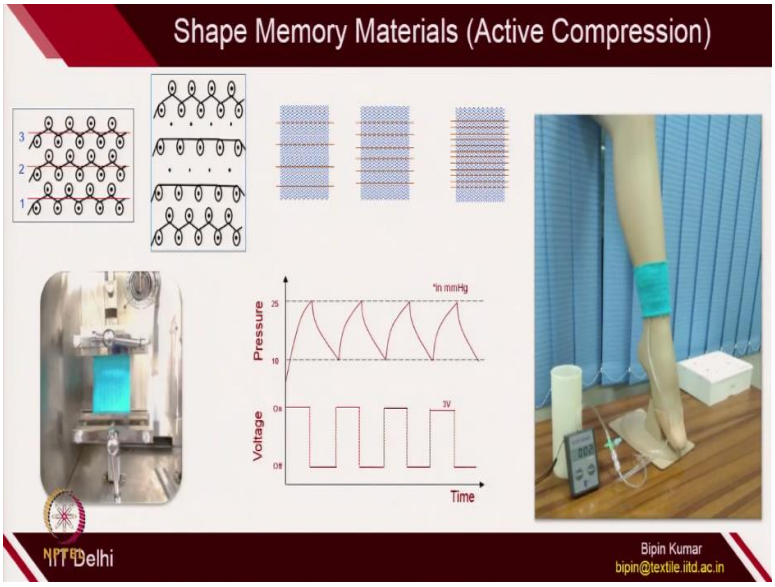

The other material similar to this is shape memory materials, which is shape memory alloy. So, in rib network, you can put shape memory alloy in this. And you can activate it. And you can get dynamic benefits. So, I also have the shape memory materials with me, which I can show you. This also have the similar functions, but very useful in some aspects. So, this is, can see, this again in a rib structure.

(Video Starts: 07:21) So, this is the shape memory wire. So, this is your shape memory wire, which is, with the help of braiding, the entire wire is integrated in the fabric structure. And this is the part of the fabric. So, you cannot take out very easily. So, if you try to pull it, it cannot be taken out. And this is the stocking where the polymer was integrate in the stalking. So, both shape memory wire or shape memory polymers; both flexibilities **(Video Ends: 07:54)** are there to get active compression out of it.

So, here you can put the wire and lock those wire in the loops. And you can generate smart pressure or a dynamic pressure with the help of current source or voltage source. Okay.

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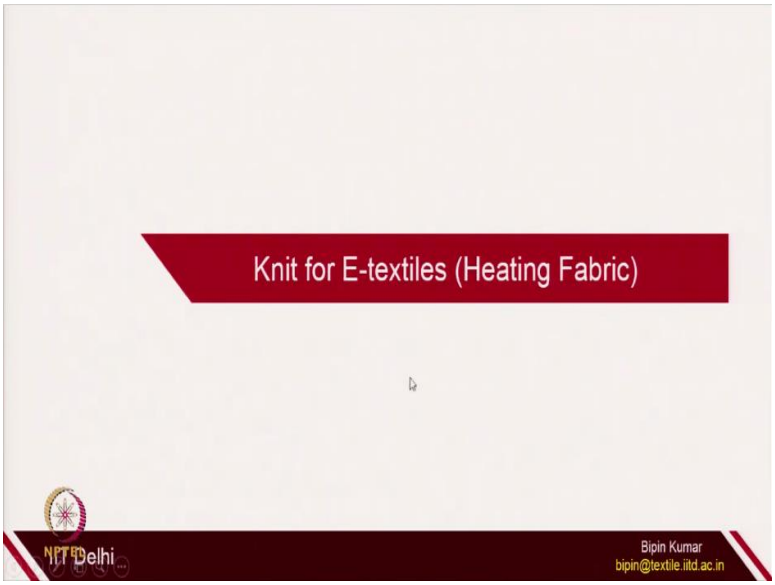

The other areas of e-textiles where knitting can play a very useful platform is the heating fabric. So, in heating fabric, you can put heating wires inside the fabric structures.

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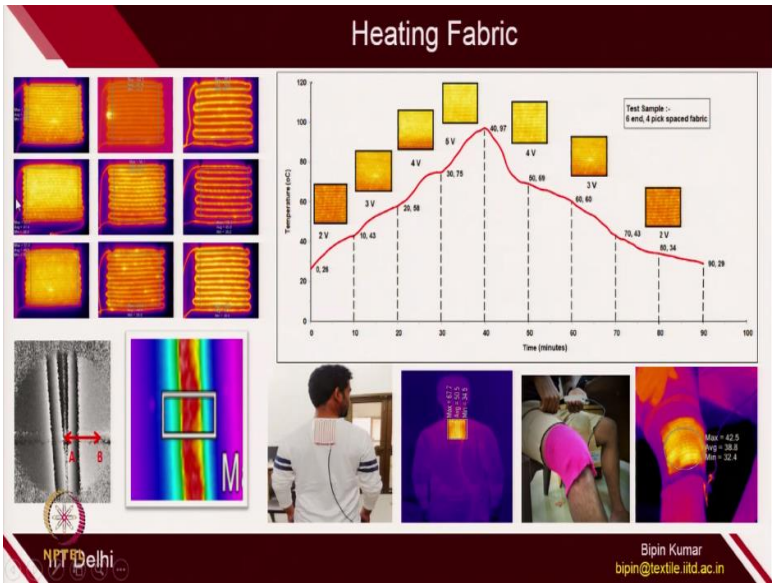

And you can get different level of temperature by controlling voltage. So, here also, I can show you. I have some samples with me. So, if you want to put any heating filament; so, this is **(Video Starts: 08:46)** how, this is one of the flexibilities on a rib network. The filament can be fixed inside. Okay. And you can control the spacings also of heating filament in the rib network.

(Video Ends: 09:03) So, let me show you the actual samples which I created. So, there are 3 types of **(Video Starts: 09:09)** thread densities. So, this is the heating wire. So, the copper wire which is there. And you can get different thread densities. So, this is high thread

densities. This is low thread density. And this is even different thread densities of heating wires.

So, once you have this, **(Video Ends: 09:36)** you can supply the power in this. And because of joule heating, it will give you different values. So, mostly the filament which is used for heating is **(Video Starts: 09:48)** either silver coated, copper coated. So, this is your silver coated filament. So, if you give current to this, because of the joule heating it will **(Video Ends: 10:00)** generate heat; and the temperature will be raised.

So, this is what is done here also. So, in knitting, you can fix the filament inside the fabric structure; you can control different thread densities. And with the help of different level of voltage, you can generate different temperature. And you can use it underneath the garment; and for orthopedic applications and for normal heating application.

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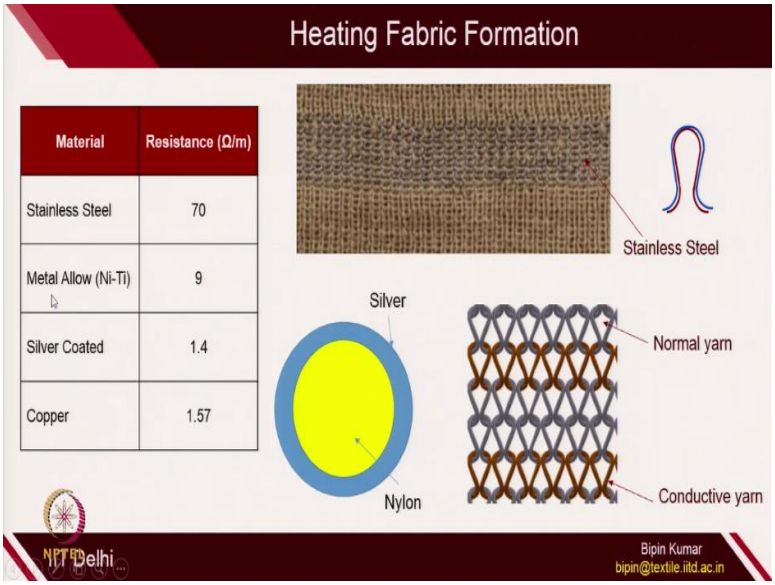

Usually in generation of heating fabric, we can go for either stainless steel; metal alloy; silver coated filament, which I just showed you; or the copper filament, which also I showed you just now. So, in silver coated filament is mostly used. You have the silver which is coated over the surface of nylon filament. And once this is there, you can put it inside the fabric structure; either in the form of loop or in the form of float.

So, here also, you can see the stainless steel filament and the normal filament are knit together to create plied loops. Okay. So, this is how you can generate heating fabric and you can go for different application.

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Other key aspects where knitting can be used is for making sensors. So, for sensing, we can go for e-textiles.

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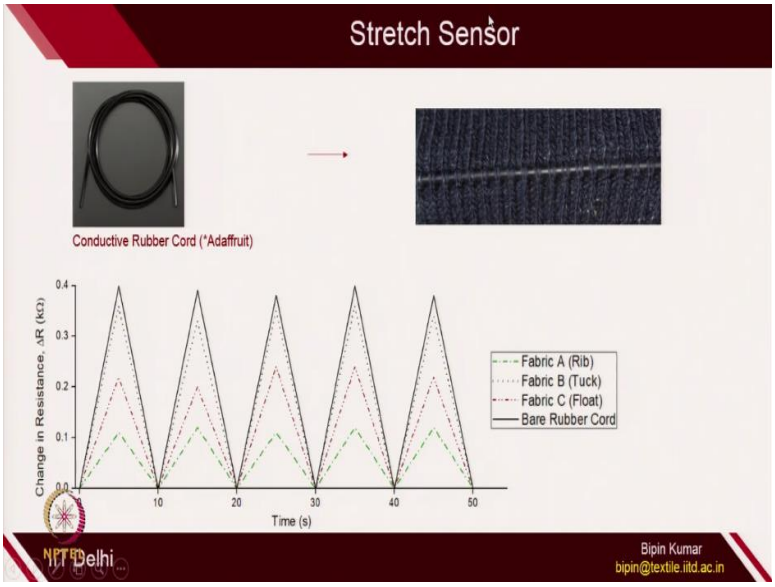

So, in e-textiles, you can easily, inside a knit structure, we can use sensors. You can integrate those sensors in the fabric. And if the fabric is stretched, the sensors will give you those readings. And you can find out the extensibility. So, stretch sensors, you can generate. So, I have those stretch sensor in with me. **(Video Starts: 11:50)** So, this is a simple stretch sensor.

So, if you stretch it, the resistance of these sensors will be changed. So, depending on that, you can find out how much stretch is happening. So, this is a rubber chord stretch sensor. So,

once this sensors are there, you can integrate inside the fabric structure, which is just shown here. So, you can see, the red one is integrated inside the rib structures; and which is the part of the fabric.

Similarly, you can integrate these type of stretch sensor inside the fabric; and you can generate a stretch monitoring fabrics, which can be **(Video Ends: 12:25)** used for e-textiles. So, I have also shown you here, like different types of double jersey fabrics. Whether you go for rib design or tuck design or float designs, different types of performance can be shown here. So, usually the tuck one is giving better results in a stretch sensor.

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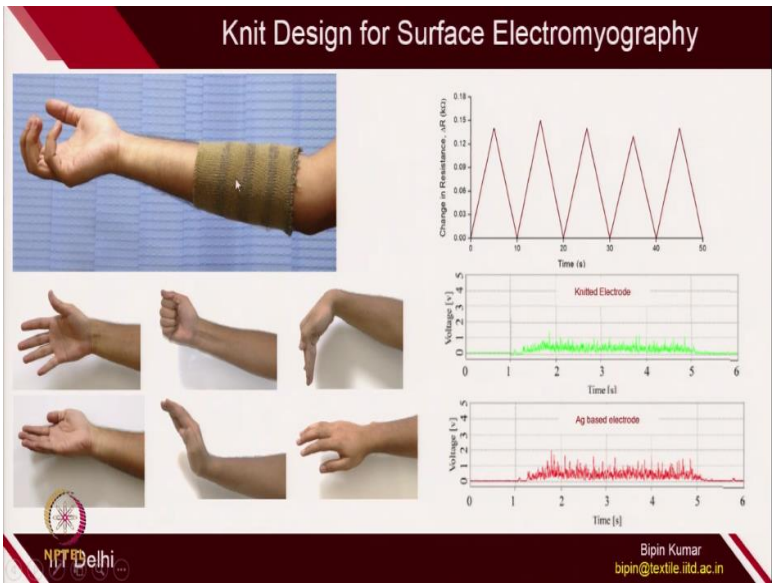

Similarly, you can go for electromyography. So, if you want to find out the neurosignals, you can integrate conductive filaments in the fabric structures. And the moment if you go for any movement, there will be some changes on the surface resistance of these fabrics and which you can tune. So, electrode, knitted electrode based garments are now being used for surface electromyography, which is very much useful in prosthetic applications.

So, I also have these type of fabrics with me, which I can show you. So, this is again. **(Video Starts: 13:34)** So, conductive filaments are knit with the fabrics. And if you stretch it, the resistance will change. And that signals you can acquire for getting the body response. This is also; you can see the conductive filaments are integrated in the fabric. So, these are some of the conductive filaments.

There are different types of conductive filaments are now available in the market; silver based, copper based, steel based. **(Video Ends: 14:17)** And depending on the applications, you can choose different types of conductive filaments.

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Energy harvesting textiles are also used using knitting. So, whenever you go for energy harvesting textiles, you need 2 types of materials.

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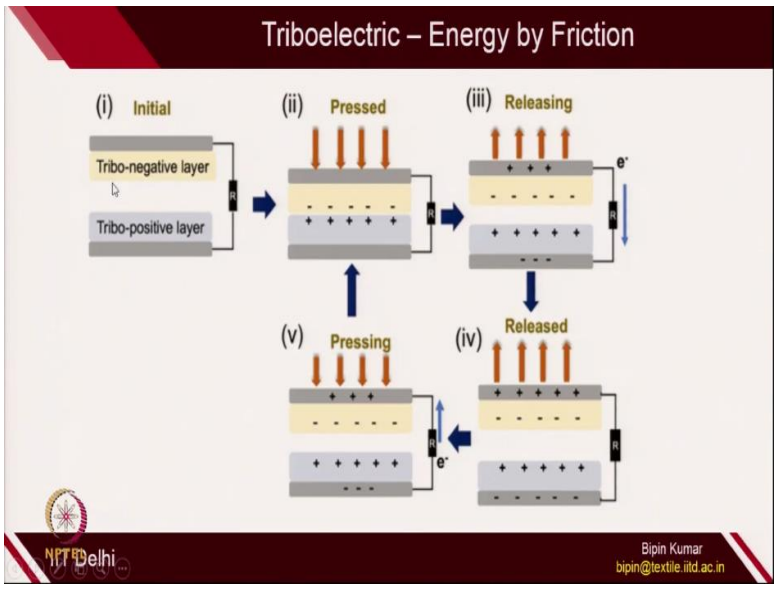

One is tribo-negative material and tribo-positive materials. And if you apply pressure on this, the energy is being generated. So, usually polytetrafluoroethylene yarn and nylon yarns are more suitables. So, polytetrafluoroethylene is triboelectric negative layer; nylon is triboelectric positive layer. So, if you make 2 types of fabric, knitted fabric; one positive triboelectric material, another negative triboelectric material.

And if you try to rub it out or apply some pressure, the electricity will be generated. And that you can harvest. So, energy harvesting also, knitting is playing very much important roles.

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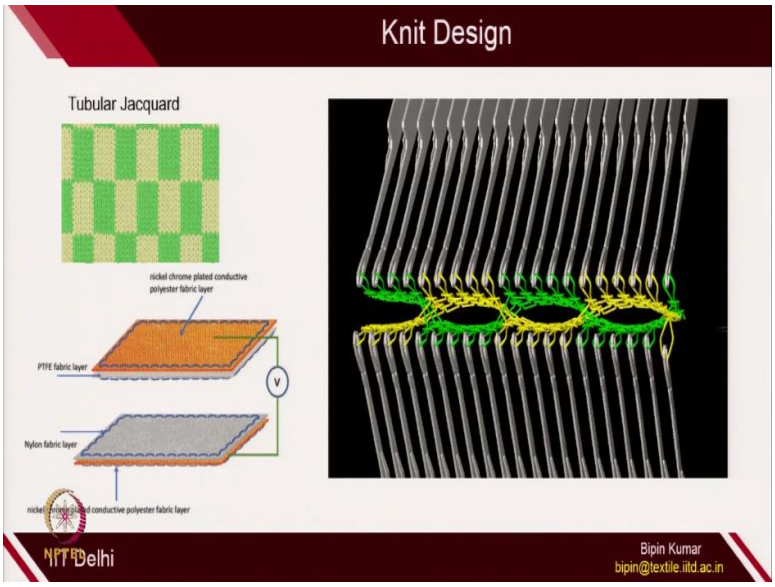

Especially, tubular jacquard is, I found some literatures where tubular jacquard are actually used. **(Video Starts: 15:24)** So, 2 types of a materials: Triboelectric positive material: you can say this yellow one is a triboelectric positive material. The green one is a triboelectric negative materials. And they are placed opposite to each other. And whenever the pressure is applied, the charge will be accumulated.

So, with the help of conductive fabric on the top, you can harvest those charges; and harvest the energy. So, this is how a simple knit designing is useful in making smart technical **(Video Ends: 15:58)** products.

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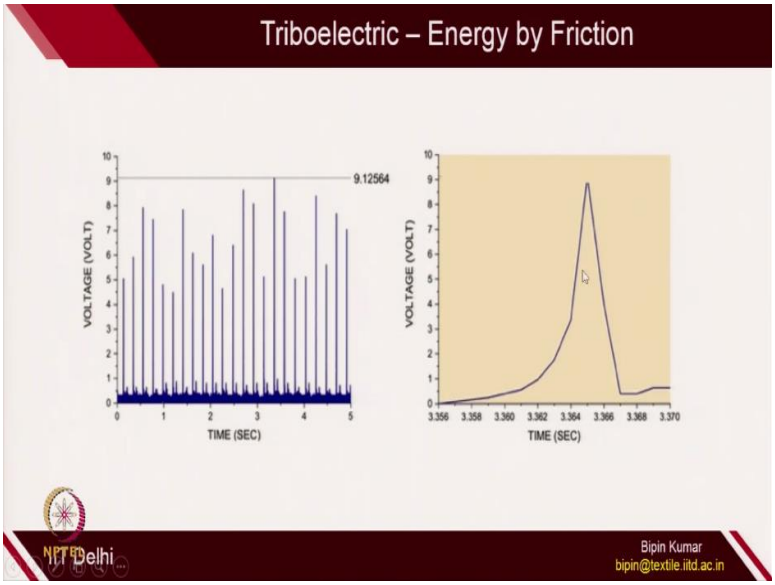

You can see it here by tapping how much voltage can be generated. So, up to 9 volt is generated by simple tapping of 2 layers of fabric.

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The other key areas of knitting is for cushioning applications. So, in cushioning applications, usually 3d spacer fabric is used. So, as I have already mentioned, 3d spacer fabric.

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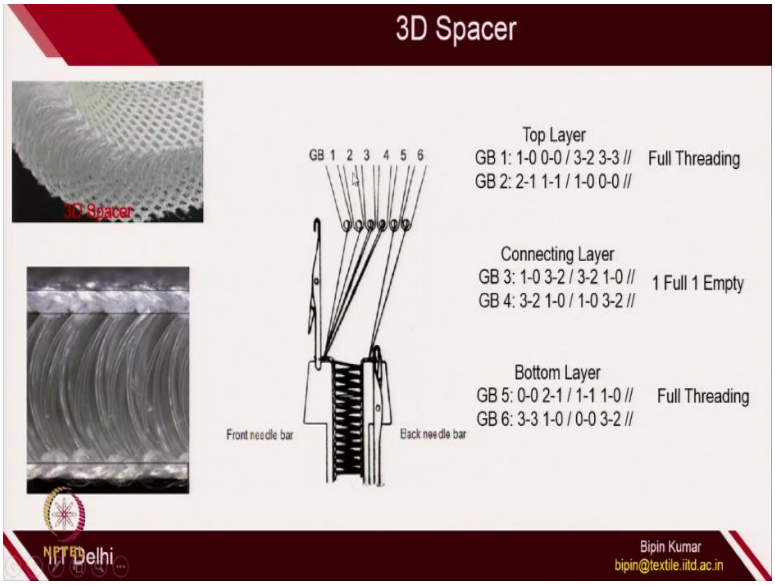

There are 2 layers of the fabric which is connected by a spacer yarn. So, this 3d spacer fabrics is actually created on double bed machines, where one bed is making one layer of fabric; the other bed is making different layer of fabrics; and these 2 layers of the fabric is connected by connecting guide bar. So, here is the lapping plan for different guide bars. So, there are actually 6 guide bars.

So, the top layer which is created by the left bed is made by guide bar 1 and guide bar 2. Connecting layer which is 3 and 4, which is connecting these 2 layers. The bottom layer is created by guide bar 5 and 6. And top layer is created by guide bar 1 and 2, on each of these 2 beds. And 3, fourth are the connecting guide bar, which is connecting top layer and bottom layer. So, this is how you create 3d spacer fabrics.

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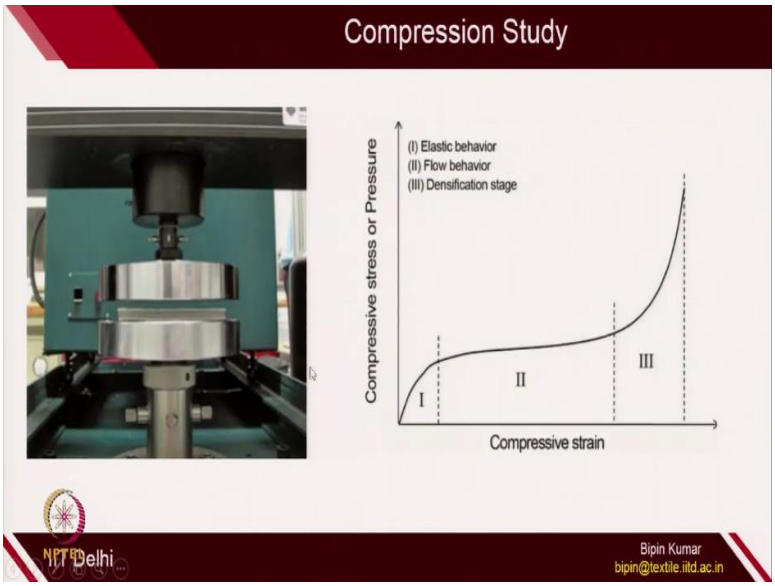

And 3d spacer fabrics has very good compression properties. So, once you compress this 3d spacer fabric, it will give you elastic behavior, flow behavior and densification behavior. But the good part is, when you release the compressive load, it bounce back. So, this is the perfect material for cushioning. So, it gives you elastic and flow performance; as well as recovery is very, very good. So, that's why 3d spacer fabric is very much useful in cushioning application.

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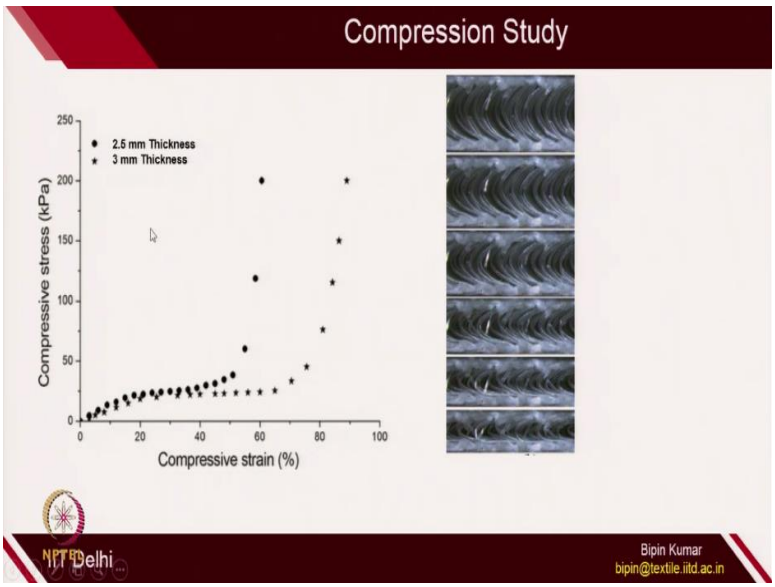

In knitting also, if you see, if you change the thickness of spacer fabrics, you will get different types of cushioning applications. You can see it here. How, when you are start compressing it; finally, as the thickness of the material is reduced, more on more spacer filaments are densified. And because of that, the force or the compressive load increases after certain compressive strain.

So, engineering point of view, you can play with different thickness of the spacer fabrics; or you can play with different material of the spacer filament; or you can go for multifilament; you can go for monofilaments. You can also go for different types of material. You can go for polyester; you can go for nylon; you can go for PP; and you can check the compression performance.

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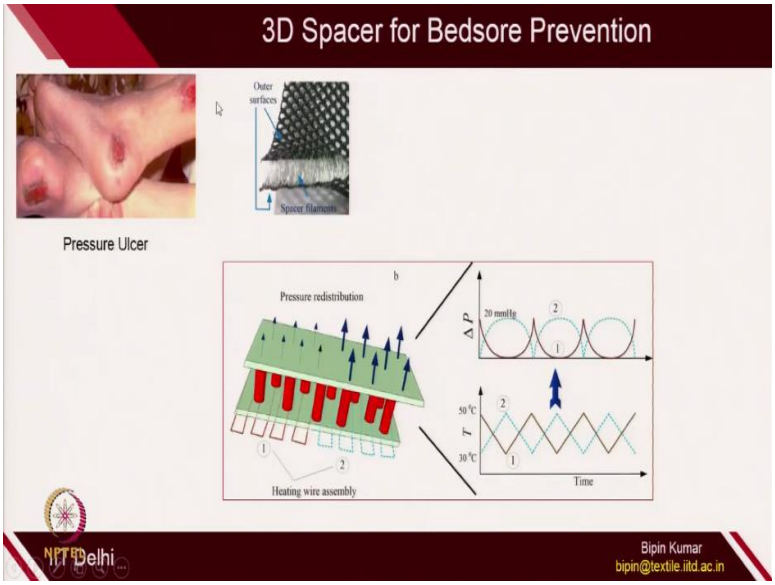

(Video Starts: 18:54) 3d spacer fabrics is now being suggested for pressure ulcer applications. Where, usually when you sleep in on a normal mattresses; because of poor breathability and pressure peaks, usually you get ulcers or sores. We also call pressure ulcers as a bed sores application. So, once you use 3d spacer fabric underneath your body, the pressure redistributions will be very, very good. And there is a less chances for bed sores. **(Video Ends: 19:25)**

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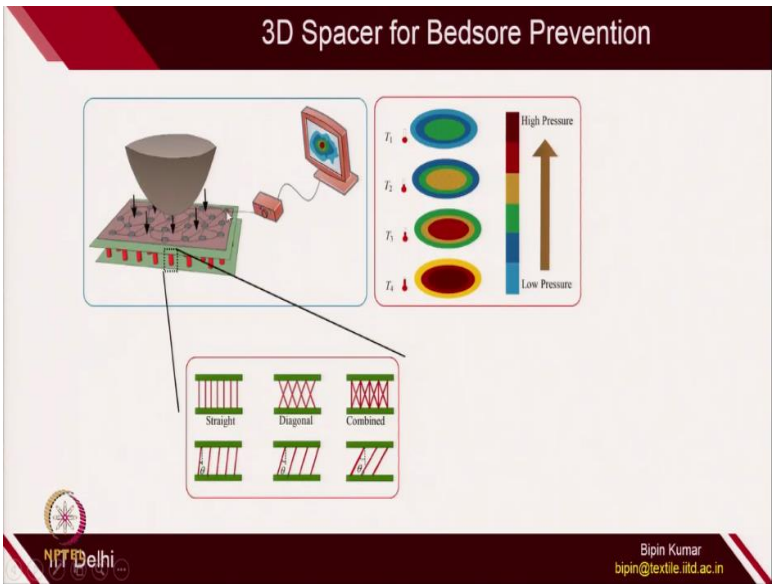

So, in, when you are using 3d spacer fabric for bed sores applications, you can go for different types of lapping plan for connecting guide bars. And you can generate different types of a spacer fabrics; and you can control the pressure. So, 3d spacer fabric has a whole lot of research has been done in this areas. And I expect you to please follow the literature on 3d spacer fabrics.

They are being used in protection; they are used for medical purpose; they are used for energy harvesting; they are also used for cushioning. So, different application of 3d spacers has been given in literatures which you can follow and look for doing some project in this area.

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Knit for protective gloves. Knitting is also being used for protection.

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So, in protections like, now the knitting also because of a very good shear performance, knitting is used for cut resistance protective gloves where ultra high molecular weight polyethylene and high performance polyethylenes are used. We use e-glass, aramid or steel wire in the structure to give you a very good cut performance. And mostly, weft knitted plain structure are being used.

So, I also have one cut resistance gloves with me, which I can show you. These are the cut resistance gloves, **(Video Starts: 20:51)** which is nowadays very much popular. Especially, many companies are following the standards for protection of their labor form cut. So, you can use cut resistance yarn in which you can have a steel wire. So, you can see it here. This steel wire is put it in under the core; and normal filaments are wrapped around it. **(Video Ends: 21:18)**

So, with this steel wire filament, you can make these kind of gloves. And you can test its performance. **(Video Starts: 21:27)** So, usually for protective gloves, different types of standards **(Video Ends: 21:34)** are being followed. For example, to have the good quality gloves, you need to test it abrasion resistance, which is measured in the scale of 0 to 4. 4 is the highest rating.

Cut resistance gloves with coup test: 5 is the highest rating. Tear resistance: 4 is the highest rating. Puncture resistance: 0 to 4; 4 is the highest rating. Blade cut resistance: using ISO standards. So, once you develop the gloves, you need to perform all of these testings and give there some marking.

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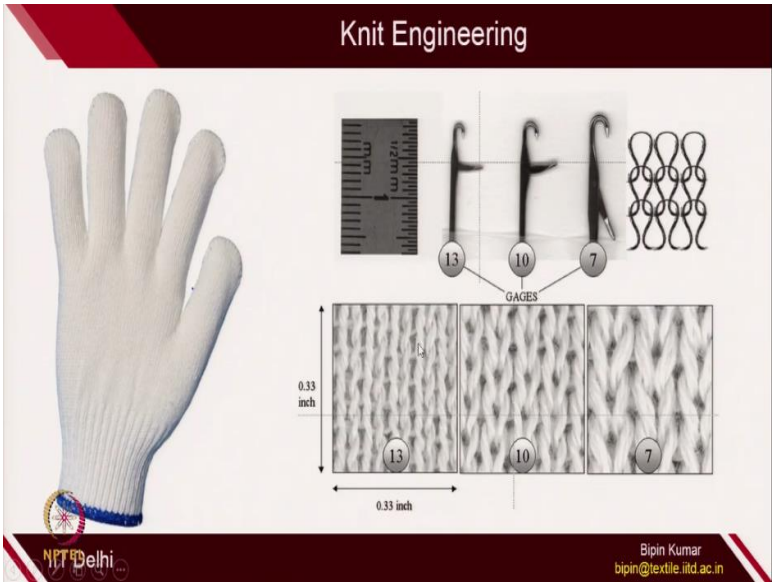

So, usually in knit point of view, we can go for different types of gauge 13 gauge, 10 gauge, 7 gauge. And you can generate different types of cut resistance gloves. So, highly dense loops, more open loops. So, this is how you can control the engineering; and you can check the performance.

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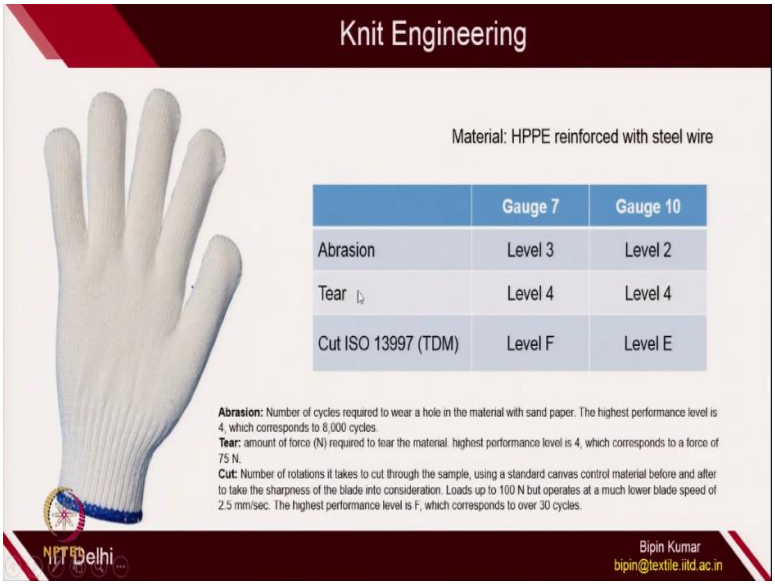

Some data, for example, if you develop a gloves on 7 gauge and 10 gauge, you can see how the properties can be different. So, a 7 gauge gloves where the loops are bigger, the abrasion performance is better than 10 gauge. Similarly, if you see tear; tear remains same, but cut resistance of gauge 7 is better than 10 gauge. So, this is how knit engineering is important in protection also.

So, if you are working in the gloves fields, you can play with different gauge; you can play with different loop length; you can play with different materials. And you can check the performance.

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Knit is also being used in composite applications, where you can make very irregular surface of preforms using knitting; because knitting has very good drape property and very good, very low stiffness.

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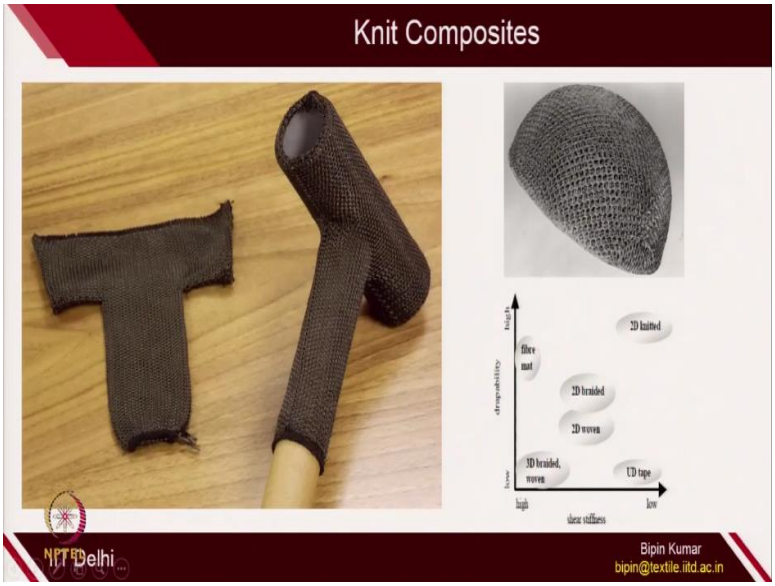

Because of this, any 3-dimensional geometry can be performed very easily. And hence knit is very much useful in composite applications.

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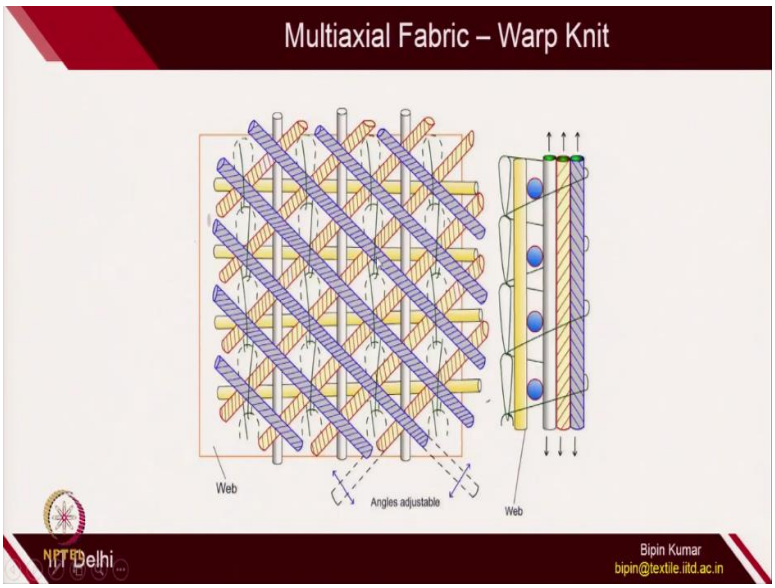

Multiaxial fabric from warp knitting is to, is useful in knitting applications, where the threads are moving multiple directions. And hence the properties are controlled in many directions. Here, warp knit structure are used.

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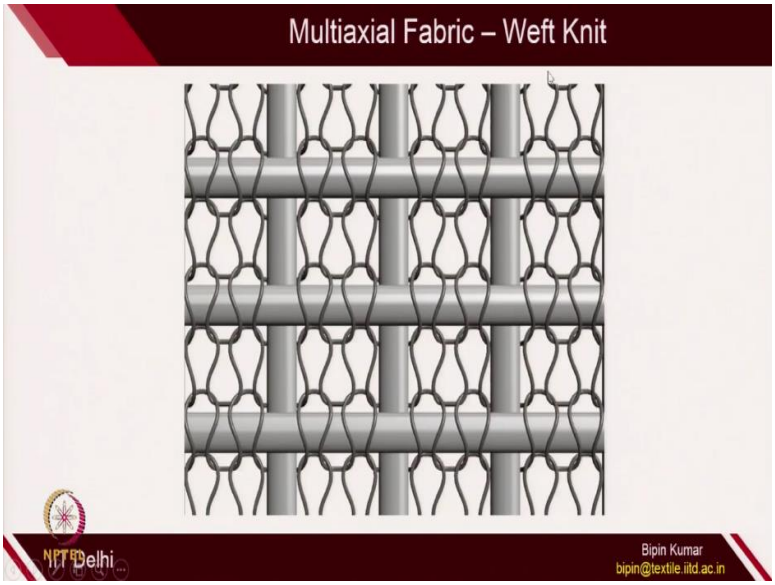

Similarly, in weft knit also, you can integrate smart high-performance filament in different directions. And you can generate multiaxial fabric in weft knitting category also. So, knitting also become very, very useful in composite applications. Although, in terms of a strength, knitting does not gives you that quality as respect to woven fabrics. But, for some specific applications where the drape is the big concern, then we use weft knitted or warp knitted structures for composite applications.

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Other potential areas: If you see, knitting is not just limited to medical, electronic textiles, protection, infect, agriculture. There are many other areas where you can find lot of literatures which is available.

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For example, in artificial muscles, sports, rehabilitation, robotics, orthopedics, cars, geotextiles, civil, solar, packaging and protections. So, now you can see how important it is to understand the knitting. Because, knitting is really a very useful platform. If you understand the knitting and its potential, I am 100% sure that you would be able to generate innovative products in your area.

So, with this, I am ending this series of lectures. In case if you have any doubts or any areas which you really want to learn, please write email to me and I will try to give you write literature in that field. But in my opinion, knitting is more useful when you do the practice. Because, until unless if you will not make those fabrics, if you will not see it by yourself, all of these lectures will be just a paperwork for you.

Until unless if you do not do the practice, I do not think you would be able to learn the knitting. So, in my opinion, whatever or wherever lab you are working, you keep making different types of fabrics samples; keep learning the analysis; keep doing the designing; keep following other innovative technologies in the field. And this is how you can expand the beauty of knitting in the world.

So, with this, I am ending this series. Many thanks for all of you for continuously listening to me. I am hopeful you will give the feedback. For the next time, if something need to be added or removed from this lecture series, your suggestions are welcome. Thank you very much. See you soon in the knit exams. Thank you.