Textile Finishing
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Lecture - 23
Finishing of Wool

Welcome back to this class on textile finishing. As usual, let us see what we have done till now.

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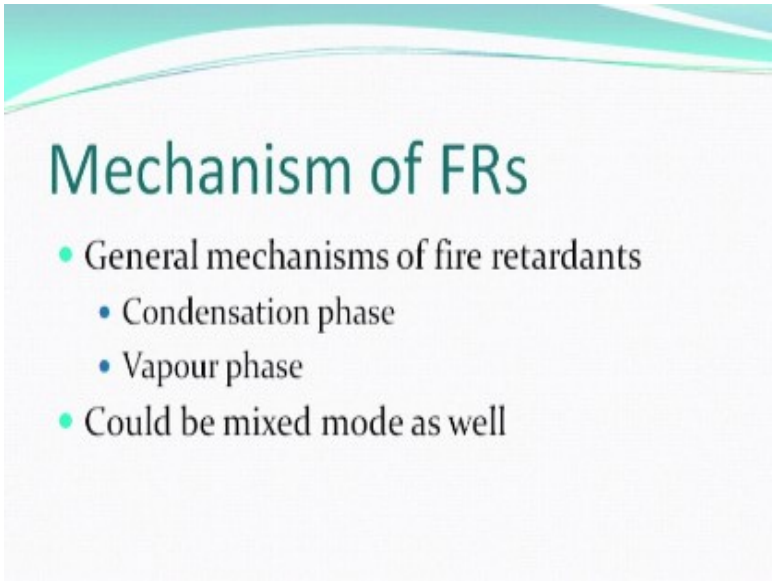

So, till now, we have learned in the last few lectures the flame retardants for textiles during which we learned what are the general mechanisms which are operative, for example condensation phase mechanism or vapor phase mechanism, these are operative. So, the FRs work either from one mechanism or other. It is quite possible that one particular FR or a combination of FRs may actually be working on both the modes that is initially they change the degradation path and later they decompose and act in the gas phase as well. So, all that we did talk about.

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Of course, we learnt something about the chemistry of FRs, various kinds of for synthetic fibres are the different and also did mention some of the inherently flame-retardant fibres which could be man-made fibres and of course how do we evaluate the FR treated fabrics. This is what we did.

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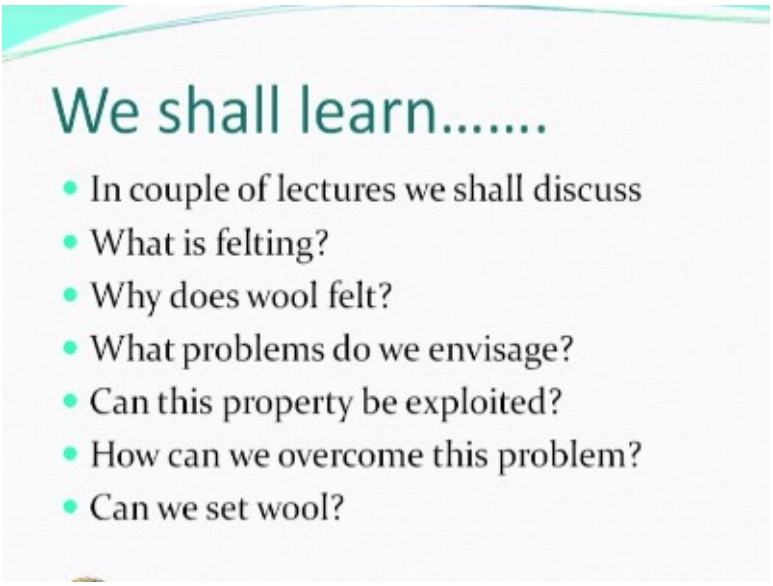

In the coming couple of lectures, we shall be talking on finishing of wool. Wool is in some sense a little different fibre, it has a little different chemistry and little different morphology, but clearly the surface morphology. So, what are we going to do? We will talk about something what is called a felting, this is a term which is only naturally was associated with the wool of course now felting and the felts have different products under this category, it does not have to be from wool, but that is what we will try to learn.

We will try to learn as to why wool felts, what problems do we envisage if there is felting, can this property itself be exploited for the benefit of the user, and also we may be interested to know can we overcome this problem in case we do not want this problem to see, and in general, we are quite sure that the woolens have less problem of crease recovery, but can we make it better and so on and so forth. These are some of things which we will discuss in coming few hours that we will interact on wool.

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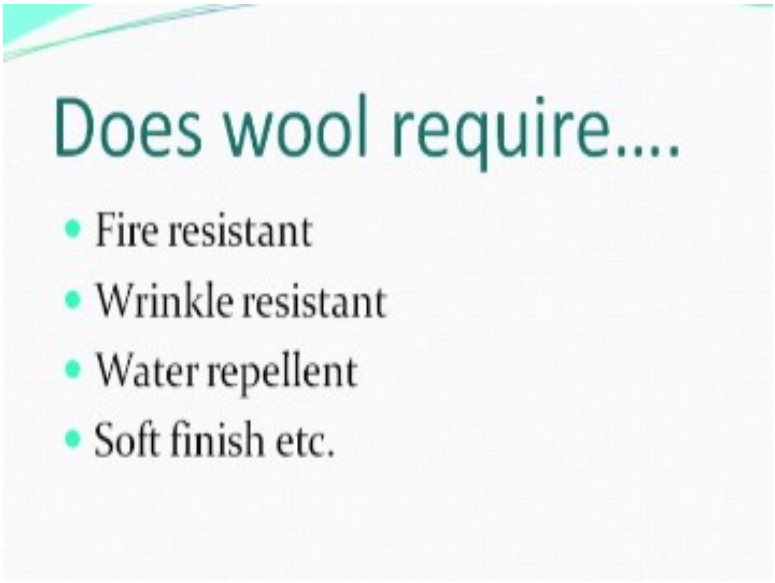

So, let us see does the wool fibre or the fabrics or the garments made from wool require let us say a fire-resistant treatment, we just discussed in the last lecture do we require a fire-retardant treatment for wool? Yes, we do require. Wrinkle resistance as such because of the disulfide covalent linkages between the molecules of wool, the wrinkle recovery is better, but in case you want to improve, we can require, and we can do that.

Water repellency, soft finish, why not? All those principles which were used to impart these types of finishing are applicable to wool depending upon the optimization that you require. So, you would require these definitely.

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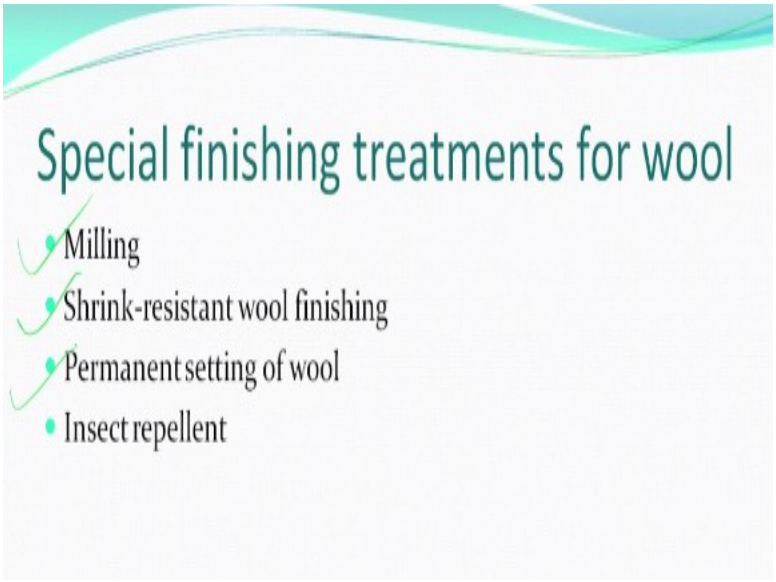

So, in this respect, wool and woolen garments and products are similar to any other textile, but there are some finishing treatments which will be very special to wool. Some of them are listed here, not all of them are listed here, but some are listed here. For example, one important finishing treatment which is given to wool is called milling, so this is only for wool and not for any other fibre, so we are quite interested to learn about it. Then, there is something called shrink-resistant wool, well this is for a reason why we want to do, and it is basically for wool only.

Then, we may talk a little bit about setting of wool and how to make it more crease resistant or how to fix dimensions, how to fix creases and the shape, all that comes in setting. So, the kind of treatment that we will discuss are going to be most special to wool, so in that sense that is what we will discuss and we would also have one interesting thing which you may have seen is moth, which is insect, you know we did talk about, shall we say antimicrobial finish, but this is different.

Different in the sense that this we are looking at insect which can actually you can see it moving right, so some of them you may have felt it like a moth, it is an insect which can move around, eat the wool up, fly also right, so we may be interested to see what can be done to make woolen insect repellent. So, before we go to some of the thing that we talked about just before, all of that we are not going to do today, but this will be covered in let us say next 2-3 lectures.

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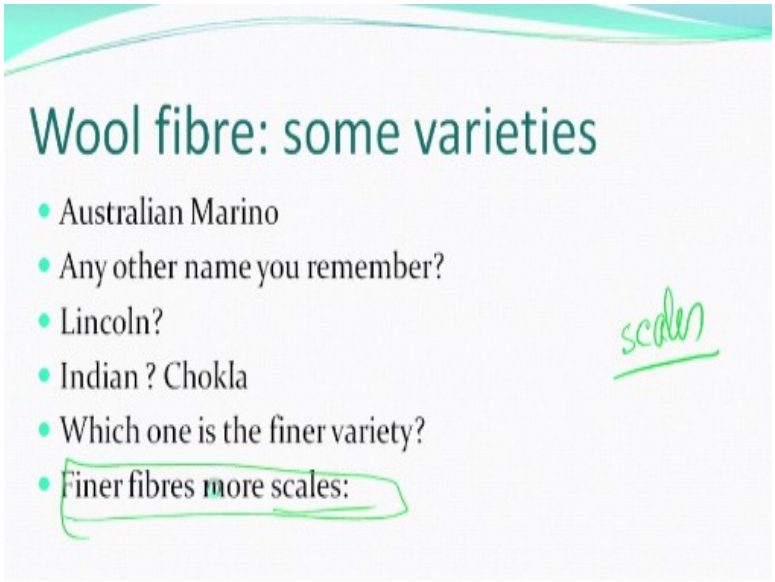

So, before we go to those finishing treatments, let us recall the wool fibre itself. You remember this name, a Marino variety of wool, remember this? One of the finest varieties of wool, Australian Marino, for something similar is in the New Zealand also and some of these as crossbreed are also being cultivated and produced in different countries including India. So that is fine wool. Any other name that you remember from your previous study knowledge of the textile fibres?

There is one interesting thing you may have heard about is Lincoln wool which is a different wool; Indian wool, there is one variety which is Chokla, there are Malpura and other varieties in India. Generally, the native Indian wool is coarser and so suitable more for the carpets and rugs and so forth, but these days we are getting the hybrids, crossbreeds from Marino's also, and of course, we are not discussing at the moment which are called category which is hair like cashmere and so on, very fine beautiful varieties.

So, which one is the finer among these, obviously Marino is the finest with a fibre diameter about you know 11, 12, 15 microns type of things, so it is a good quality wool? Which fibre would have more scales, scales you understand scales, the finer fibres always have more scales okay, the coarser ones will have less scales, that is general information about wool fibre.

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Chemistry-wise, we understand this is protein fibre and this protein is known as keratin and this keratinization process takes place as the fibre is growing out of skin alright. The sheep is moving all over and this process of disulfide linkage formation etc takes place as the fibre is growing. This cross links are obviously not available when it is in the liquid state as it is being designed and developed in the sheep, so because if that is cross-linked, then not come out very easily right. So, the cross-linking takes place as it is exposed and that is what the process of keratinization also.

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So first we take up a very simple process which is specifically designed for wool is called the milling process, right milling process.

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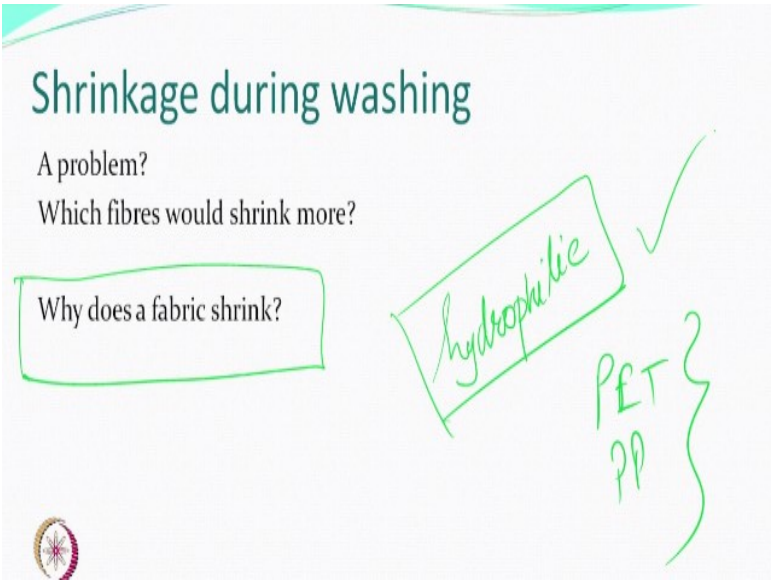

Why does anybody would like to do a milling or not, during laundering or washing, the textile fabrics, yarns show some shrinkage. Somebody wants to know is the shrinkage a problem, yeah it is the problem. You start with making a nice beautiful looking shirt and after washing, it becomes tighter or you roughly make a trouser and become a short, like not exactly in the same sense, but it is the problem, dimensions if change due to washing itself is a problem. So, which type of fibre you think would be having more problematic in the sense?

Suppose you have polyester fibre fabric, do you think you have a problem here during washing laundering shrinkage problem or which fibre for example if it is a cotton based fabric, you will see problem of shrinkage during washing in the cotton fabric, the wool fabric, viscose, which, so obviously the fibres which actually you may have experienced shrink and change the dimensions after washing are generally hydrophilic fibres. So, synthetic fibres like polyester, polypropylene, etc would not show any significant shrinkage during washing.

We can talk about it in more detail when we talk about synthetic fibres, but during washing, the shrinkage that one would see generally would be because of the hydrophilicity and what does it mean? It means that the intermolecular forces bonds can be affected by water, so after any response of a molecule is dependent on intermolecular interactions and bonding, if something happens to them, then the things can be different. So, if you look at this problem or this issue, then we can just say ask this question as to why do they shrink?

Of course, shrinkage is a problem and we understand which fibres shrink, so let us say what actually causes the shrinkage, why anything a fibre or fabric would shrink, and we are talking about shrinkage during washing, as a result of washing that is, not any other shrinkage.

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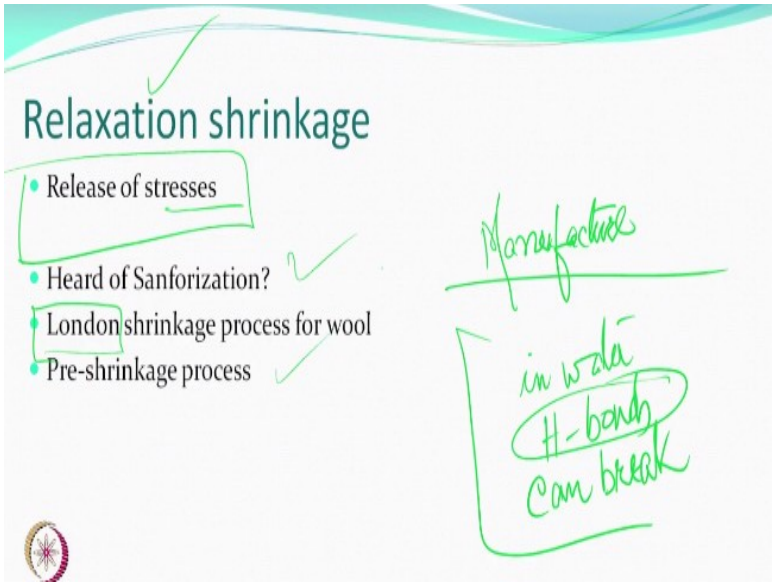

So, one important thing which one must realize is that during the washing if there is any mechanism with which relaxation of the stresses can happen, the relaxation is a thermodynamic process which would automatically spontaneously happen. Now, why the stresses, from where the stresses? So, during manufacture, the yarn in a fabric may be stressed while they were woven or knitted, so they would have a tendency to relax, so when put such a yarn or fabric in water what would happen is if they were stressed and the stress was not relieved during this process.

Then what would happen is the intermolecular hydrogen bonds which obviously can very easily break in water, hydrogen bonds can break. So if intermolecular hydrogen bond break, the molecules which are obviously under stress would like to relax, that is the relaxation and this type of shrinkage if it happens because they were stresses which were stored and because you gave an opportunity, laundering for that matter, the water could penetrate, break those hydrogen bond which can obviously form at a later stage in a different position, but molecules can then relax and shrinkage that happens due to a relaxation of stresses is obviously called relaxation shrinkage.

This would happen, wherever there is a stress during manufacture, if it gets released, one would see, shrinkage is one mechanism with which the stresses are released. So, you can

actually take a yarn, expose it to moist steam, expose it to water, they would like to relax, and the dimensions would be much more controllable, so that is one, almost every textile would go through shrinkage processes whenever there is a stress and it can be facilitated if something like this happens. Have you heard of sanforization?

No, sanforization is a process or a finish, which we will talk about later, is given to a cotton fabric to ensure it does not shrink further, it is a pre-shrinkage process. There is another name which is associated with the relaxation shrinkage process, it is called London shrinkage process for wool. Basically, what they do is they put layers of fabrics in cold water for a long time and whatever relaxation must take place, it does not have to be cold water, it does not have to be water at all, it could be steam.

Fabric under no tension would be kept let us say in an environment which is moist, and you will see dimensions getting more stabilized. So, whether it is a sanforization or a London, they are basically pre-shrinkage, the user will not have a problem, whatever shrinkage that take place, it takes place in the fabric form okay, you get the point. So, this is because of the stresses that were stored and if you can relieve those stresses, further shrinkage may not happen right. So instead of first making the garment and then allowing to shrink, it is better the fabric shrinks and then you make garments.

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Another mechanism of shrinkage in any fabric including wool is due to swelling. Now, we again remember what are we talking about, we are talking about shrinkage during washing or laundering, not every type of shrinkage okay, which would mean swelling. If you put

something in water, something will happen, what will happen? When you put let us say a fibre and we say hydrophobic fibre like polyester, will it swell when we put in water, it will not, right. We just said, so what will swell will be hydrophilic fibre which means cotton, viscose, wool also.

Now if you put the fibre in water, let us say this will not shrink, this will not swell we are talked about swelling, it will not swell, these will swell okay. So, when it swells, what happens to the length of the fibre? Length of fibre when you put in water, what happens to the length of the fibre, will it increase or decrease? What happens to the diameter of the fibre and remember we are not talking about only hydrophilic fibres because we have just said they will not swell.

Synthetic fibres, particularly polyester, polypropylene, acrylic, etc. will not swell, nylon can little bit but did not go to swell too much. What will happen to the diameter when it swells, will it increase or decrease, it will increase. Diameter will increase, true, diameter will increase. What about the length, will it decrease or increase, length of the fibre increase or decrease, decrease or increase? Length also increases. So, for example there is a fibre with some dimension, you put in water, so it may increase in diameter and also in length depending upon what type of thing. So, it increases in diameter, it increases in length, so where is the question of shrinkage? It should extend, so what are we talking about shrinkage due to swelling.

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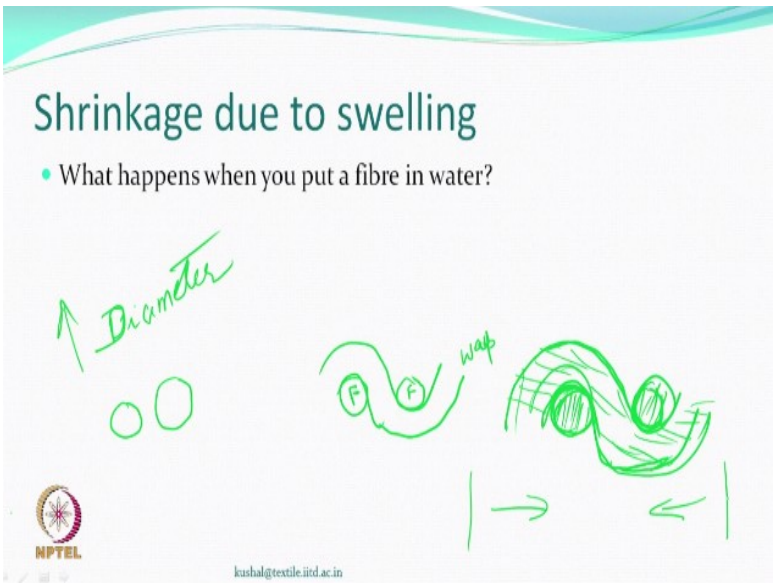

So, if everything increases, then why are we talking about swelling induces shrinkage, why are we talking about this, yeah, have you any idea? You see definitely diameter is going to be high, okay diameter is high, it is going to increase, so this was the diameter and let us say the diameter becomes this, so what happens? Let us say we have woven fabric, simple woven fabric, there a warp and weft going around in this state you see, so this is let us say warp right, so I have written filling, so let us say it is filling which means weft and this is warp, does not matter okay, so one of them is warp, the other is filling.

Now, let us say they swell because we have put them in water, then what happens, all the diameters let us say become this. So let us say both warp and weft increase in diameter, then this yarn has to traverse a larger path along this, so how will you do it, it just come together, you see this is what you are considered as shrinkage due to swelling there is a structured warp and weft and then both the fibres increase in diameter and now because increased diameter, the other fibre has to move around much more and traverse a longer path, so how will it happen.

This will happen only if they start coming together, so this length or width of the fabric it will start shrinking, lengthwise are shrinking. If the yarns swell, obviously fibres in the yarn swell which is weft and warp both, then this will happen, if only one of them, then the other thing will happen. So, if suppose somebody asks a question warp is polyester weft is viscose, which direction the swelling will be there? There is no direction of swelling okay, which direction the shrinkage will take place, in the warp direction the shrinkage will take place or in the weft direction?

I leave this question to you, but you must remember that because the diameter has increased of this yarn, the other yarn has to traverse a larger path. If the other yarn has to traverse a larger path, the only way it can happen is that the fabric width in this direction is reduced because then only it can accommodate alright. The increase in length is not too much, it is very small, the swelling can be very large and because of that the shrinkage takes place.

If both weft and warp are the ones which swell, then shrinkage in both directions will take place. One question I have left, which we will answer later. Similarly if there is a twisted yarn, if this shrink, the outer fibres have to traverse a larger path and so in length the yarn can shrink, so remember the length of the fibre increases, the diameter of the fibre increases, but

the length of yarn can reduce, dimensions of fabric can reduce and therefore that is what we call as shrinkage due to swelling, is that clear, right.

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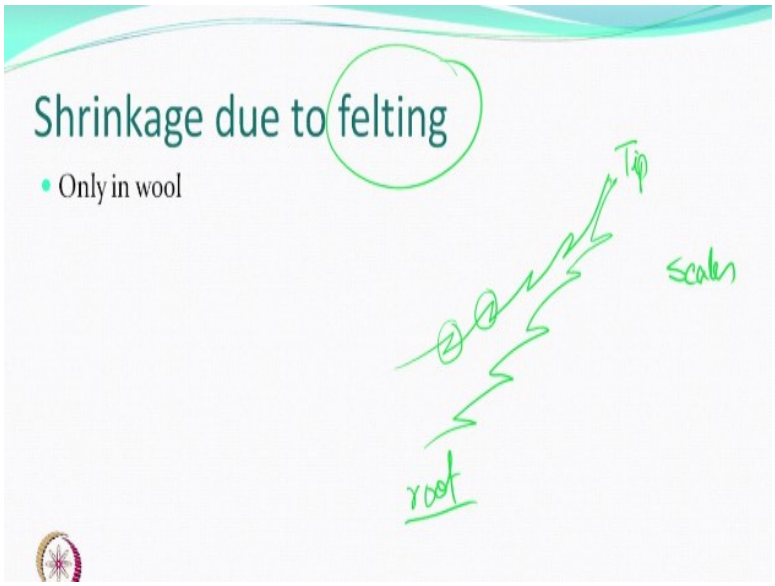

Now, there is another shrinkage which is associated with wool, is called felting, shrinkage due to felting. Now what is the shrinkage due to felting? Now we see the structure of a wool surface, the wool surface has got something remember, these are called the scales. This is the tip of the fibre, this is the root of the fibre, so the scales are projecting, so this is the way the wool fibre grows you see. Initially, it has grown a little bit, then something comes it pushes and then other material comes which pushes and so something extends outside and so scales are created.

Naturally this is a good process because the densities are high and it protects the wool from the natural changes in weather, whether it rains or shines or what happens, it protects, so it meant for the protection hazards, but this can cause some interesting things which is called felting.

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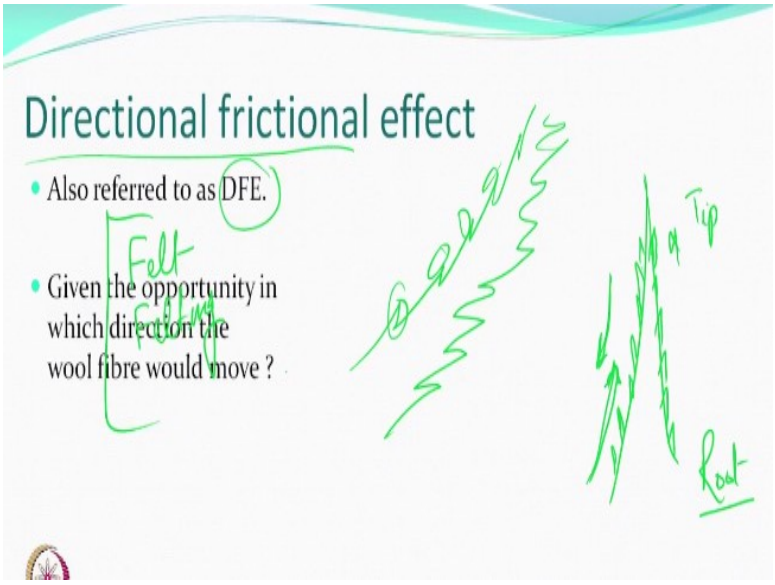

This happens because of what is known as a directional frictional effect. What is this directional friction effect? We just had the same fibre, so this is pointing in one direction right, so let us say we have this fibre and then you have these things pointing in direction towards the root of the fibre is it or towards the tip. So, these scales are pointing towards the tip. So, if you move your finger in this direction versus in this direction, you move your finger towards tip versus if you move your fingers towards root in which case would you see more friction?

When you move towards the tip friction is more or when you move towards the root the friction will be more, your finger, yeah, so if you move towards the tip, the friction would be less, if you move your finger away from the tip, the friction will be more, is it natural, this is called the directional frictional effect. So, in one direction, there is more friction, in the other direction, there is less friction. If you have let us say ball of fibres, you know you just keep doing this, softer.

So if it is soft, the fibres will try to move, so when you press, they move, but then want to come back the friction is more, they may not come, so it may happen that if you keep doing this, a good number of fibres will try to move towards the direction of their root, towards the root whenever there is a chance, you wash them, you do mechanical stresses, compress, relax compress relax, suddenly find the material which was like a loose mass of fibres is now more compact because there is an entanglement.

The fibres have moved and they are moved almost permanently, they keep moving towards the tip and that kind of a product is called a felt and the process is called felting. Can these phenomena happen in any other fibre; cotton, viscose, polyester, it should not. So, this felting which happens because of directional frictional effect is specific to wool. So, we have answered this question, have we, that given an opportunity, in which direction the fibres will move, have we answered this question, yes, we have.

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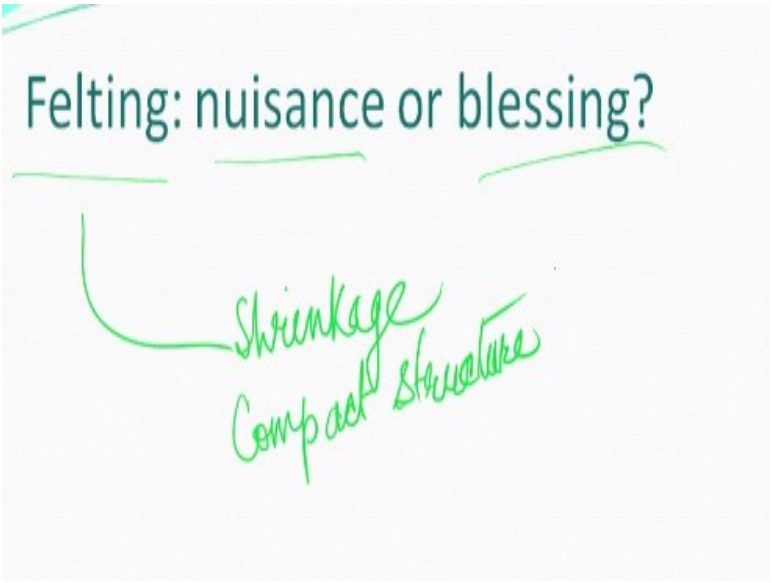

So now somebody would say is this felting a nuisance or a blessing? I make a knitted garment like a sweater from wool, put in washing machine, take it out and see dimensions have changed, some of you may have noticed that the underarms where moisture is more and obviously mechanical agitation also is more, the knitted fabric or the sweater under this feels different than the rest of the material because it has felted in those areas, become relatively more compact in those areas and therefore you may not like it.

That is the reason a lot of people would suggest that anything which is a good woolen garment, it better be dry-cleaned. You know you are hoping the dry-cleaning solvent does not do what water does, so your structure, dimensions are going to remain same which you expect to happen, so in some sense this is a nuisance, that your dimensions can change because felting leads to shrinkage, felting leads to compact structure.

So, a knitted garment was not a compact structure, it was flexible, fluffy, it contained a lot of air within the yarn and therefore the insulation that you were getting, suddenly becomes a compact structure, the air is no more entrapped in that system, so it does not feel good and of

course dimensions have changed. So, in some sense, this is a nuisance, one would like it that if it did not happen you know that will be case, but if you are smart enough, you may be able to utilize, exploit this property itself.

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You have seen some woolen blankets, real woolen blanket not acrylic blankets, woolen blankets, in this case, let us say it is a blessing. So, let us count the blessing first, we will talk about the nuisance later. So, woolen blanket is a product which people use it, it is compact, relatively much more compact. If you try to unravel the yarns from blanket, it is not going to be easy. If you have a normal woven fabric, you can remove the warp, remove the weft from the sides and keep removing and unraveling the fabric, but if you try to do that in woolen blanket, it is not that, you cannot do it very easily.

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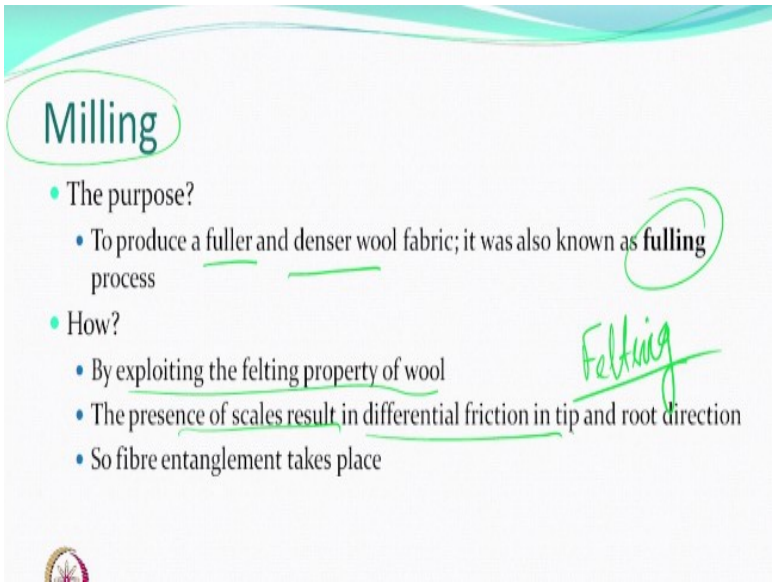

You must have seen it, have you used a woolen blanket. So, this woolen blanket is produced by the process which is called milling. This is in a way is a finishing process and what are we doing. We want to make a fuller, denser wool fabric like a blanket. Sometimes, the milling is also known as fulling. So, this is the process you do something, and how do we do it? By exploiting the felting property of wool, so thing which we said is going to cause problems is the one which you like to use so that you get a better product which is called a blanket or a felt.

Now of course, the felt can be made by different technologies using different kind of fibres, but the term felt, and the felting came from wool. So, this is like a nonwoven system, you do not really have to do anything, you can still make a felt, but blankets are product which are woven products, but they go through a process called milling. If they go through the process called milling, what happens is during this milling process, felting happens, now we know what is felting, where the fibres may have moved from their position to another position.

They will keep moving till they cannot move further and which direction every fibre will try to move, wool fibre in the direction of the root keep moving till they cannot move further, then they will be jamming, and this is because of scales which give the differential friction, one direction friction is more, the other direction friction is less. So, there is a differential friction and so it happens, so entanglement takes place and you make a compact structure, this is milling.

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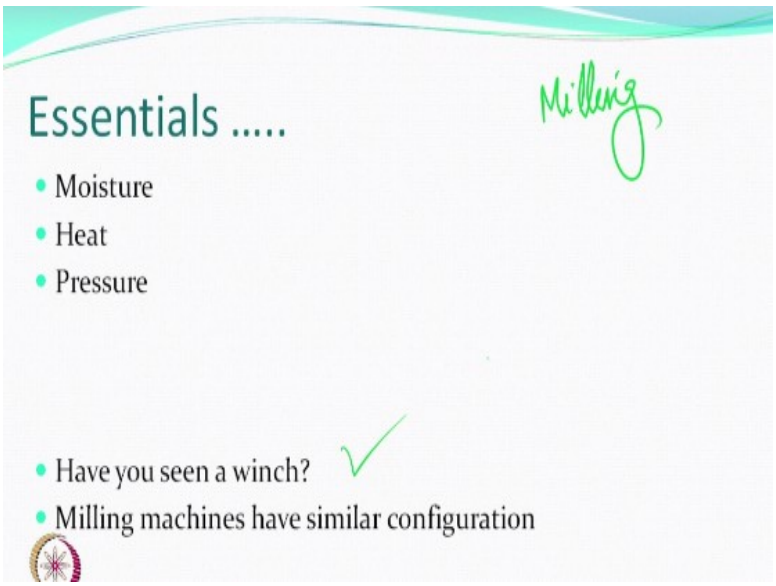

For this process to take place, 3 things are essential and what is the process termed out, felting where the fibres must move. There should be moisture, so some kind of a lubrication. If there is a little bit of a heat, that means pliability. If you have pressures, so they are forced to change their position in the fibres and so you will get a felt with an entangled fibre structure and more compact structure, which we thought was a good idea and that is the process of milling. Have you seen a winch, a machine which is similar looking as winch can be used to do this milling or fulling process?

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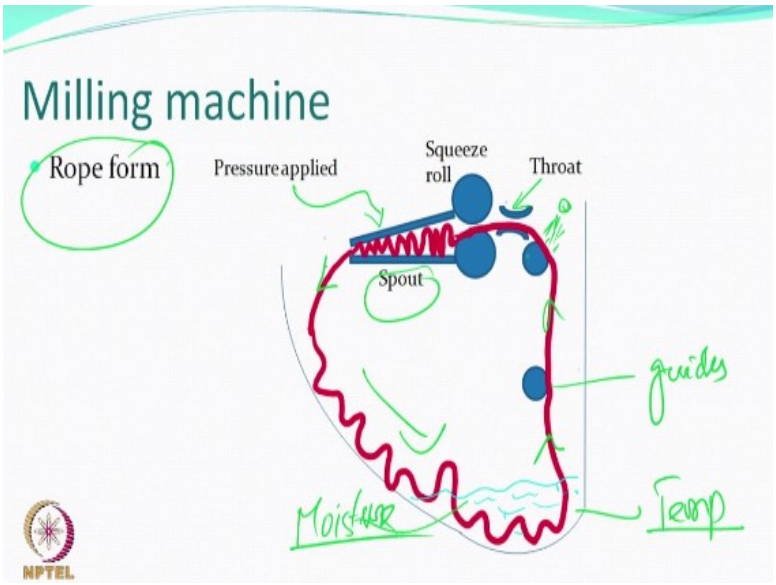

So, the machine may look like this. The fabric in the rope form for that matter can be milled, you can do it in open width also, but this diagram which I have used we are doing it in a rope form for example. So, there is this portion which is called the spout. These are the squeeze rollers. There is some liquor, it could be there, or you can also have some spray system which can spray the liquor on this rope, it is an endless rope of a wool fabric which needs to be subjected to milling process alright.

So, you take this rope, so this goes up because of the squeeze rollers and they pull also, guiding rollers guides, this is called spout. This is called a throat through which this is directed, and it is pulled, put some pressure here so that the fabric folds in a wet state, so there is a pressure, so you have mechanical pressure. The temperatures can be increased. You can have a heating system, so temperatures can be increased. It has moisture, so you have moisture because you have liquid which could be aqua solutions.

So, all the 3 things which we require, the moisture, the heat and the pressure are going to be applied. Continuously this rope can move up, go to the spout, then it is thrown onto the slanted surface and keeps moving down, goes into some liquor which may be stored and then is pulled up and goes through the throat and the squeeze roll and the spout continuously for whatever time is optimum time and then at the end day you do washing and you have a product which is milled product, which is felted already, it may become like a blanket.

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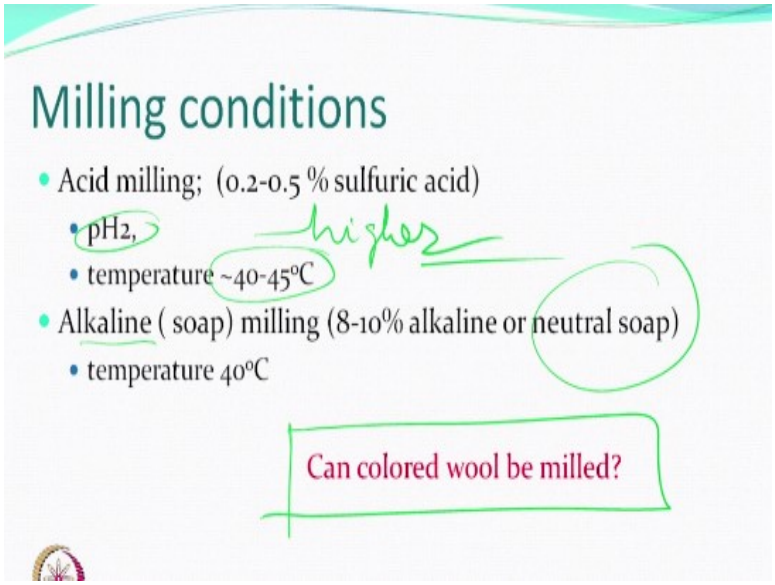

So sometimes, different conditions can be used, you may be probably quite aware that wool fabrics are relatively quite stable, more resistant to acids, they are susceptible to alkaline conditions, so nobody will use a strong alkaline condition, but you may use a strong acidic condition. If your solutions are acidic in nature, pH below 7, then you have acid milling this is called and the pH could be 2, but does not have to be, it can be higher based on what you want to do, but it is in the acidic range.

Temperature is not very high, just a little above the room temperature, this could be 45 degrees, so you have about 20 degrees above approximately and just keep doing this milling process in a winch type of machine or a which is sometimes called a rotary milling machine and keep doing this for a required amount of time, maybe 45 minutes to 1 hour, wash it and use, so this will be acid milling conditions.

Alkaline milling or soap milling to give a bit of a lubrication okay and neutral of course will be there, but alkaline when we say it is alkaline soap, but you are not going to go to a pH of 11 or pH of for example 12, 13, does not high pH, of course will not be stable, so either a

neutral thing or alkaline soap could be used to this milling that would be the good. So, you have a nice neutral soap, you can do soap milling, but it may take more time. The same machine can be used as scouring or similar machine can be used as scouring also.

The spout may not be so much of necessary, but it can be used. What happens if we use colored woolen yarns? So, your yarn is died and then you weave the fabric and then take it to the milling operation, you remember the dyeing is also done in acidic medium and if you keep doing this for a period, dye can come out also right, but do we do it. Have you seen blanket which have got some designs, if they are designed, they are not printed, the yarns were died, material was woven, and then subjected to milling?

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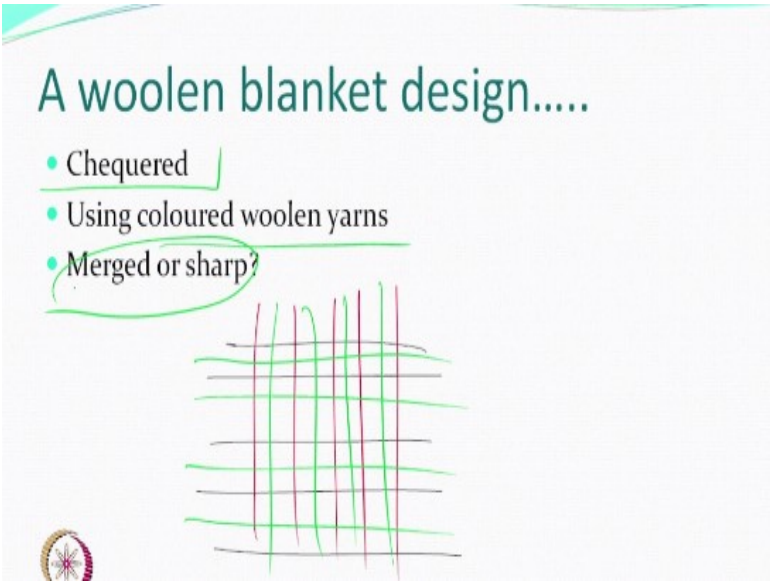

A woolen blanket you may have seen this is died some chequered kind of designs. So, you have let us say red or black died yarn or maybe more number of colors can be used, you can have for example some greens in between also and you will get a different chequered design alright and this fabric which has used colored woolen yarns now can be milled. So, the design will go through this and you will see at the end, what do you see?

This so called design is it merged, the green is merged into the red and the black and so on so forth and something like this do you see that or is a very sharp line like a printed garment that you see the checks very clearly, in a blanket do you see that, you do not see that because the fibres started moving during this milling process, it could be a green died fibre which is moving into the red died fibre or a black died fibre and so there is a migration taking place all over.

The things are becoming compact and suddenly find the so-called chequered design which look very sharp in the woven fabric before milling, after meeting is very diffused, but you can still see yeah there is green, there is red, there is some check you can see that, but it is diffused, that mean that shows that the fibres have moved from their original positions because you have given an opportunity for them to move in this milling process, but because of this, a set of acid dyes have to be used which will not come out very easily during this process and some of these dyes therefore called milling dyes.

You remember the name has come from the milling process itself, so we have to find some dyes which are not going to easily come out alright, they will be called the milling dyes.

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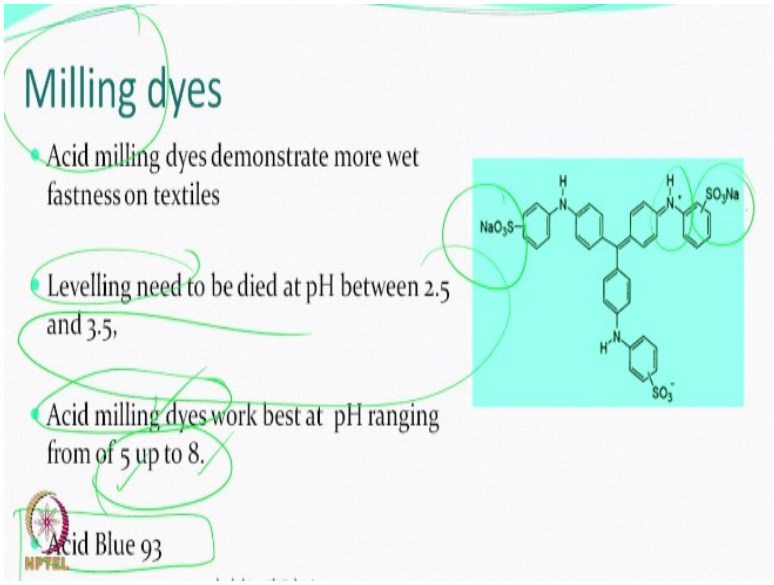

So acid milling dyes would demonstrate more wet fastness okay. They are died at little higher pH maybe higher than this pH, the ones which are died they are called levelling dyes. Levelling dyes you may recall are the dyes which give uniform dying on a fabric, they can go to one side, if there are more dye in that side, it come out partially, then go to the side where the dyes concentration is less and so they keep leveling by themselves during the dyeing process, but we are interested in other class of dye if felting and milling is the process which have to employed.

They are called milling dyes and they will be died in neutral to little alkaline or towards more neutral like higher pH of 5 to 8, 8 is an alkaline side, but not highly alkaline right. So now you have milling dyes, specially designed the molecule structure, molecular weight is high,

find difficult to come out. One of them I am just giving you an example an Acid Blue 93 is one dye which is a class of milling dye alright.

See this very large structure, this is a lot of phenyl groups, aromatic groups, of course you have solubilizing group, so that is water soluble because it is being dyed let us say in alkaline medium, you may actually have a situation there is a plus charge here, but mostly it is going to be negative, does not have to be, but this is a milling dye and if you dye with these type of dyes, then the dyed yarns can be used for weaving the fabric for blankets and then blankets can be formed by milling process

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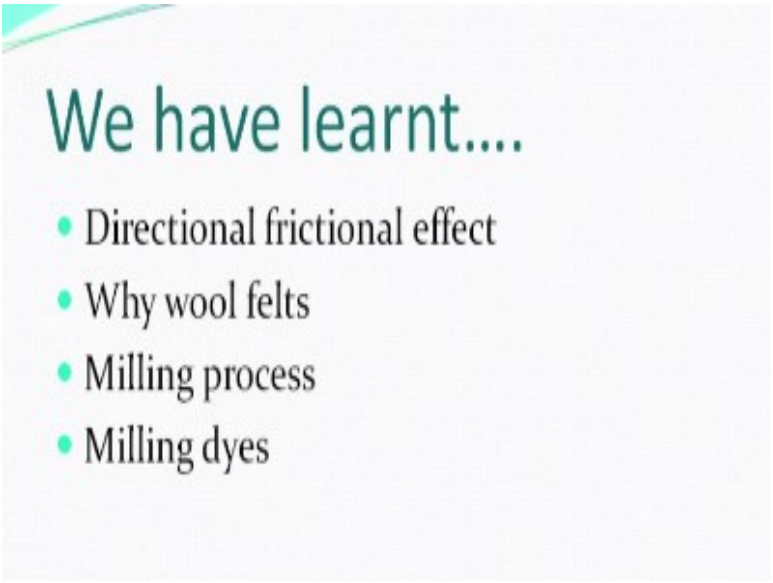

So, what have we learnt today? We have learnt about directional frictional effect which is so specific to wool and because of this why wool felt, it felts because the fibres have a tendency to move in the direction of their roots. We have learnt about a milling process or milling finishing process and about some dyes just suitable for this process because we would like to use pre-dyed yarns, they are called the milling dyes, that is what you learned today.

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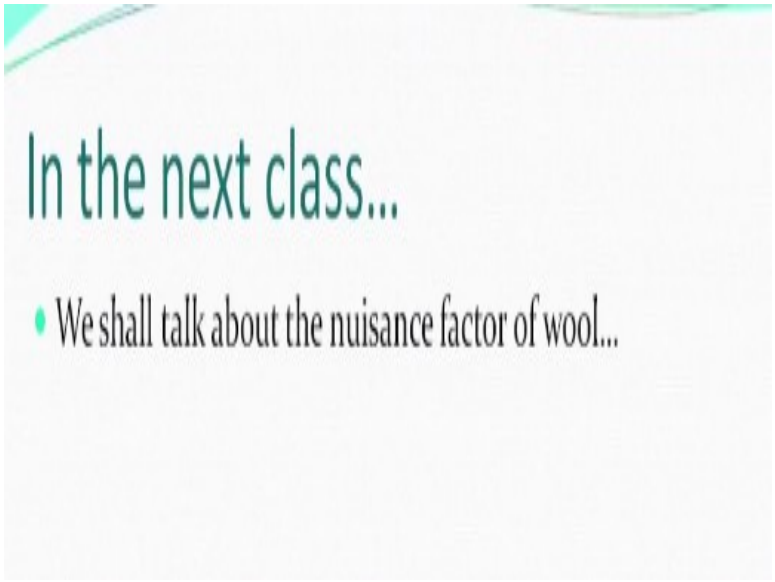

In the next class, we will look at this felting property not as the blessing in disguise, but we try to understand the nuisance factor of this compaction process making the system denser, if you do not want, then what do we do, that is what we will talk about in the next lecture. See you later. All the best, have fun.