Textile Finishing
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Lecture – 24
Shrink Resistant Wool

Welcome back to our class on textile finishing. As usual, let us see what did we do last time.

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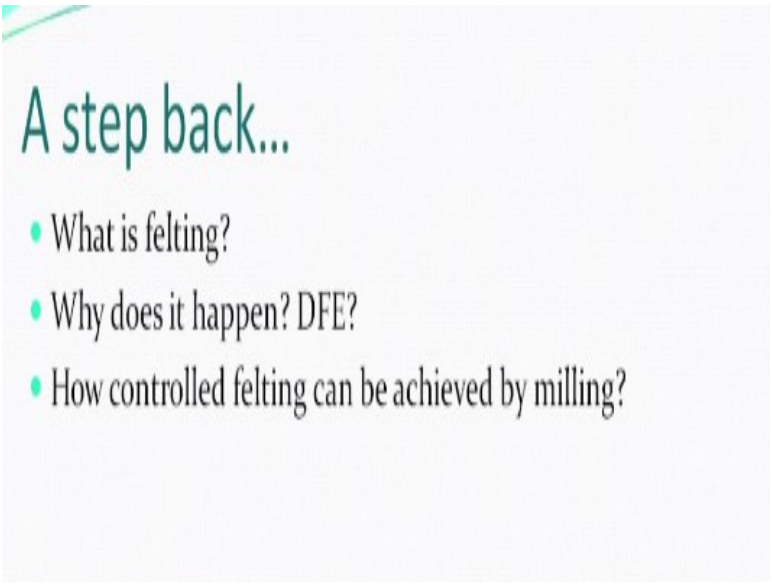

We tried to understand what is felting and why does it happen and we realized that because of the scales which are there on the fibre surface of wool, we have a directional frictional effect that is on one side you have more friction, if you move to the other side you have less friction, and therefore the fibres whenever given an opportunity are going to move and move till the time there is jamming and they cannot move further.

So you get a compact structure and if you like it is good that is why we could actually do controlled felting which resulted in a process called milling and this milling could let us say produce woolen blankets which have their own utility. Today, we are going to look at the different aspect.

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The aspect that we may like to look at is can we reduce the felting property of wool and this we will consider as a shrink resist treatment. So today, we are looking at the same property which we exploited in the previous process called milling, is it a nuisance, is this problem and what is the problem? Problem in most cases whether it is the jackets, trousers, we have knitted garments like sweaters, cardigans they are known for their fluffiness or their smoothness, appearance, and therefore if anything like felting happens in such type of garment, it is not desirable and so it is a nuisance.

Think of a jacket made from the finest Marino wool and then you find at the end of the day after washing or otherwise, there has been migration of fibres, the jacket does not look the way it was supposed, maybe one arm has shrunk more than the other and of course nothing that would happen what happens let us say during felting would be appreciated by the consumer. So, it is a nuisance. So see, one case we could exploit this property, but in general for most of the products, it may not be a very good idea to let the wool fibres felt.

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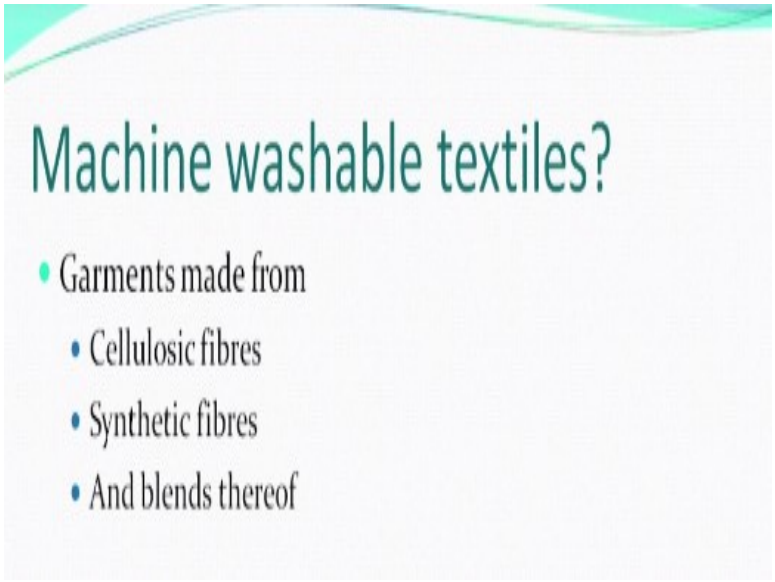

So these days, we have all the garments which have care labels saying at this temperature you wash, in that temperature you can dry and so on and so forth. Most of the machine washable garments that you actually see these days are generally made from cellulosic without any problem, they can be machine washed, of course one has to look at the you know wash fastness of dye or the finish that you are given that is one part, but they are machine washable, most of the people use washing machines.

Synthetic fibres, there is no issue at all, they are machine washed, they are cared labeled as machine washable and so they can be used and the blends of these material also. Synthetic fibres or blends with viscose or cellulosic fibres, cotton, etc., can easily be machine washed.

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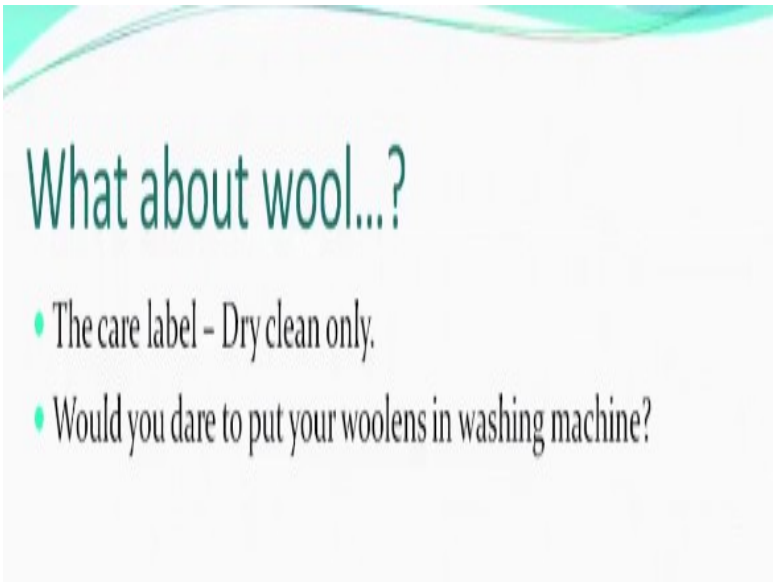

What about wool? If you see any woolen garment you buy, you see the care label, what it say, dry clean only, that means they are not confident that at the end of the washing cycle, what will you get, it is not just for the wash fastness of dye which of course in some cases may be true, but today because your dyeing and finishing chemicals are relatively more understood, therefore the care label would say what temperatures should not be used for washing, but they are machine washable, but wool, any woolen garment you will see that what is written there is dry clean only.

Such garments, would you like to put in a washing machine, you dare not, you do not know what is going to come out.

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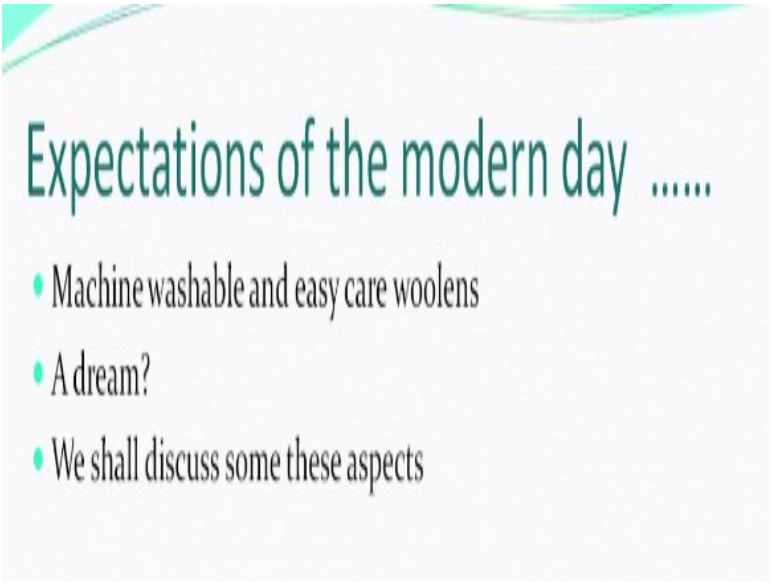

So in some sense, it could be one of the goals of all kinds of treatments that you want to give that can we not make woolen garments also machine washable, that is kind of a dream one should always have. So let us see how do we go about this. When we talk about this, the one other thing which we must probably work for is can we make wool shrink resistant? So if we are now concerned about the shrinkage, not due to relaxation, we are not so much now at the moment to talking about shrinkage due to swelling, we are now talking about shrinkage due to felting, the directional frictional effect.

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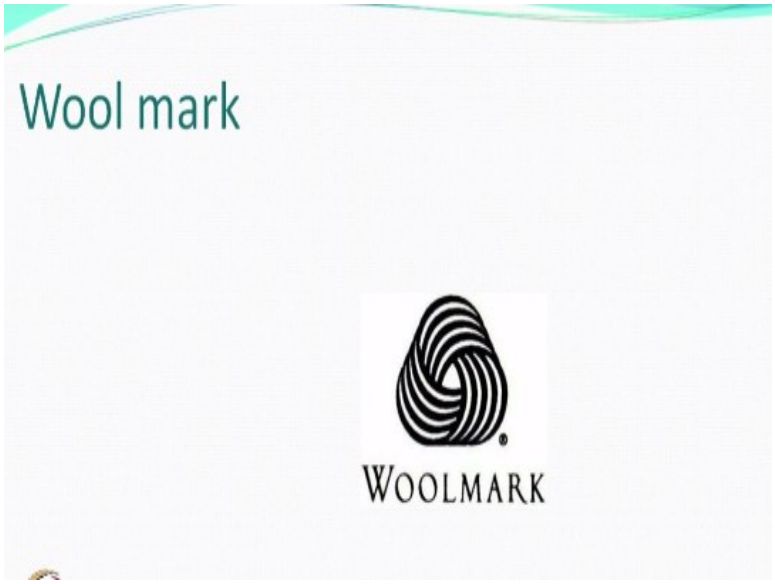

You see you are quite sure whenever you buy a woolen garment, people may like to see this kind of a mark, a standard mark which say well it is a 100% woolen fabric. Wool, fine wool for that matter is obviously costly, there may be some reasons why people may like to add different fibres, make blends of different types, those fabrics garments would not be carrying this kind of a label. So wool as such is a very costly fine fibres, quite aristocratic status it has and so one would obviously see if there is a wool mark, they are satisfied.

So this is the standard, you can have any other standard also, but wool mark all over the world has been used as one of the standard, this looks like this. We may like to have another standard later.

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So recalling what are we going to do. The DFE, directional frictional effect, is the cause for felting. It is because of the scales that the wool fibre has on its surface. The finer is the wool which is the most costly one like the Australian Marino, the more scales it has, that means it has more tendency to felt, therefore one has to take care much more. So you pay more and pay for taking care of the garment also more, well if you can afford, of course you should get it dry cleaned, no issues in that, but with the times that are changing, people would like to see can something else be done.

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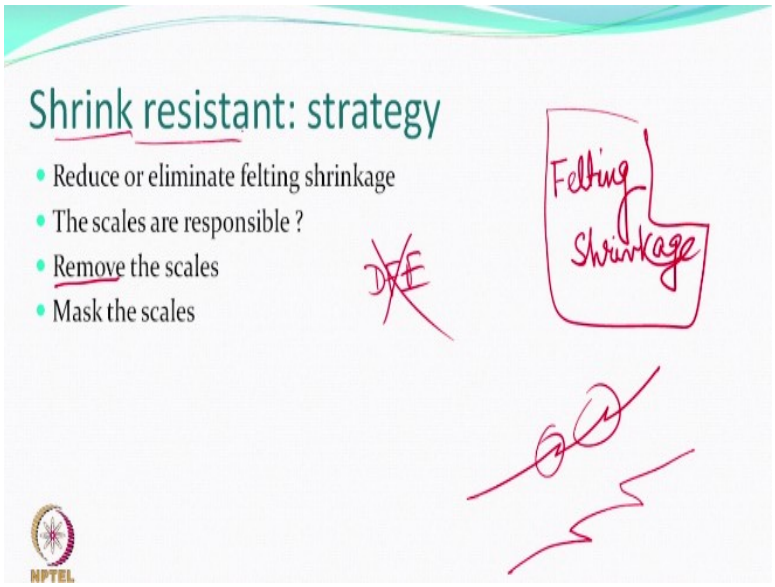

So if you want to make wool shrink resistant, let me again remind we are talking about shrinkage against felting. So all other types of shrinkages if at all there, whatever processes have to be used for any other fibre should be used, that is one part of it, but wool is special and because of the special things, we have a special issue, and now when we are talking about we are talking about shrinkage, which is felting shrinkage. What strategy? So we have to have strategy to reduce or eliminate felting shrinkage, very good.

We also know that is the scales on the surface of the wool which are responsible right, okay, and so if this is the culprit, we have to somehow handle this, what can you do? It looks very good, remove the scales. If you do not have scales, you do not have a DFE, and if you do not have DFE, you are getting towards this goal. What else can be done? Mask the scales, cover them with some polymer, if that is what can you do, then also it can work. The question is all of them will have some compromising issues.

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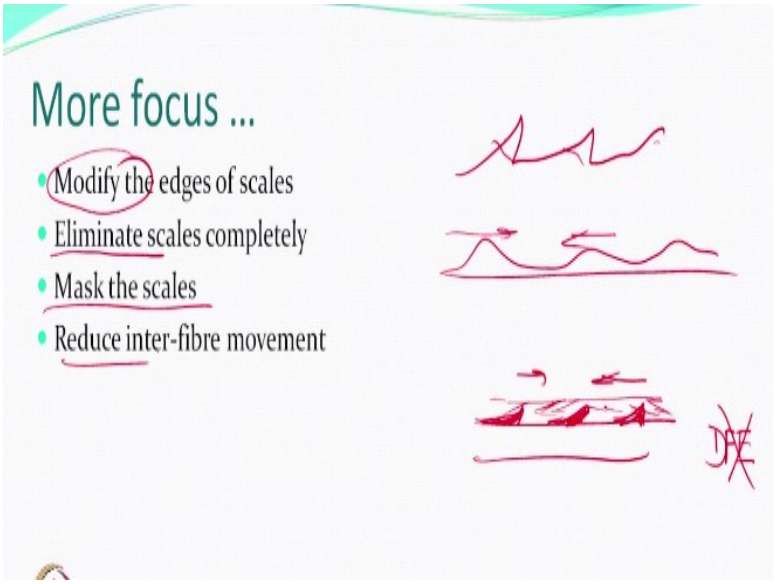

If we look at the issue little more in depth, then we may not be interested in completely eliminating the scale, but it may be that we may modify the edges, blunt them. For example if this is the kind of surface that we had and if we somehow cut it out like this and your surface becomes more like this, then whether you move in this direction or you move in this direction, the difference in friction may not be there and so the tendency of the fibre to move in one direction could be reduced.

Of course you can completely eliminate, then also the difference in friction in the two directions is going to be less right, but you can appreciate that if you completely remove the scale, the fibre becomes more vulnerable to any attack. The attack could be chemical attack, the attack could be microbiological attack or whatever, and anyway you might be losing a bit of strength also, one has to be quite aware of this. Other is masking the scale.

Masking the scale obviously means that it can mean that you have this fibre and you have this scales on the surface and you completely cover it with something, so this was the scale and you put let us say a polymeric layer here and if it can cover the scale, then obviously again in this direction or in this direction the friction may be similar and therefore the DFE may not be there. After all, you are more concerned about the DFE.

Other thing as a strategy could be that if you can somehow reduce the inter-fibre movement by additional means like you can have inter-fibre bonding if you can create, then they will not move even if they want to move and so you may not see the felting. The question that

obviously is what happens to the properties, that is what we will keep discussing as we keep moving.

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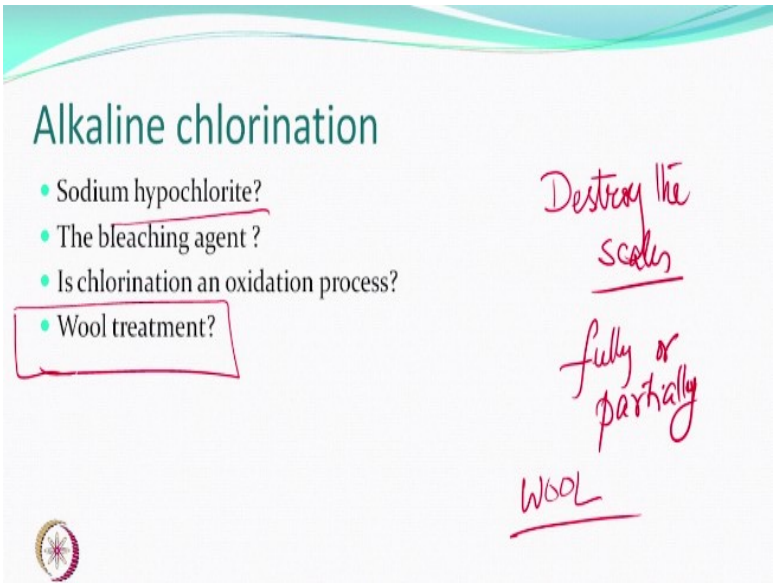

So one of the first method people had tried was chlorination. Now, here the strategy was obviously to destroy the scales, so you are not looking at now masking, but you are looking in this kind of a strategy approach is destroy fully or partially. Now somebody tells that you do alkaline chlorination of wool, you remember the fibre identification tests or otherwise the property of wool is more sensitive to alkali, is it true or not, and definitely it is going to be more sensitive to alkaline chlorination.

So, should we attempt this? Hypochlorite you remember somewhere, have used hypochlorite somewhere, sodium hypochlorite, remember any process where it may have been suggested, bleaching of course of cotton. So people initially use hypochlorite solutions and also in alkaline conditions to do the bleaching, so they are in some sense how is the bleaching process done and what was the basic mechanism, reduction or oxidation.

So this bleachng agent which is the sodium hypochlorite in alkaline condition when it acts on cotton or cotton fabrics, is this process an oxidation process or a reduction process. We like to answer this question, this bleaching process for the cotton using sodium hypochlorite in alkaline pH, is it oxidation process or a reduction process, of course it is oxidation process, so we have done oxidative bleaching using this and later on some other compounds.

Finally of course, the most popular one these days of course is hydrogen peroxide, but wool about which all this discussion is, can you use this alkaline chlorination, they will actually destroy the fibre before you can think about it. So people can if you are very quick you can damage the only surface, but it is likely that the most of the fibre also get damaged, that cannot be our aim, our aim would be only to handle the scales which are on the surface, we do not want to penetrate inside the fibre and this is hydrophillic fibre you remember.

The moment you put in water, the water seeps in. So in such situation what do we do so, we got to be treating them very carefully, otherwise the fibre will not be there, so there is no problem of solving. The problem it actually is creating another problem, so that is what we would like to remember. Wool with this, we may not like to, but chlorination is and has been tried as a process for partially or fully destroying the scales.

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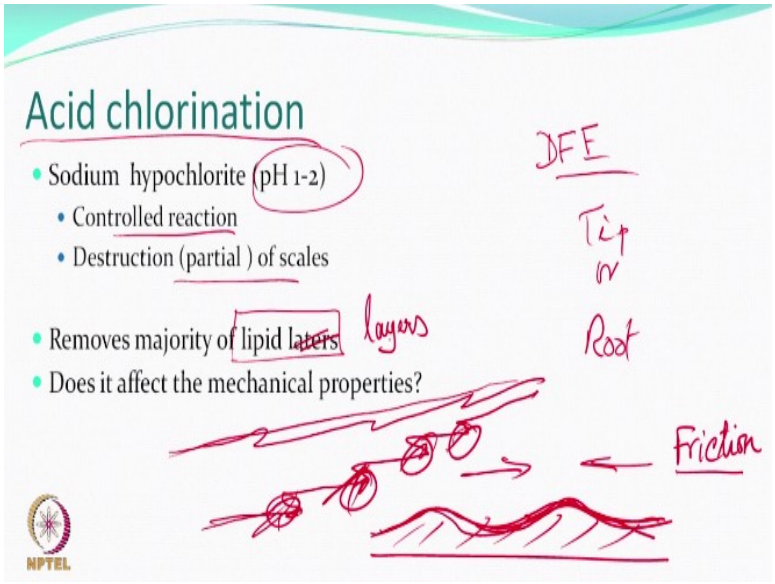

So what kind of chlorination? So, we are looking at acid chlorination. The acid chlorination has got two advantages. The protein fibres including wool are more resistant to degradation in acidic environment, so it is safer in some sense, you remember you die in acidic pH, the acid dyes are died, the wool can be resistant. If the same kind of a pH is used, the wool will be safe and if you have a chlorination or chlorinating agent within that like hypochlorite, then something like this can happen.

You can remove the scales and get a surface which is more uniform and so the friction in this direction or friction in this direction is going to be same. So when we do the acid chlorination, the scales are destroyed, we hope that the surface is going to be more uniformly

treated and the frictional coefficient in the direction towards the root or tip would be the same and so we may not therefore have the issues with directional frictional effect. So, the pH levels are pretty low, the reaction obviously has to be very controlled.

We can have partial destruction of the scales, but we have to be very careful again, although the reactivity in acidic conditions, the chlorination reaction in acidic conditions will be slower than what you otherwise would have seen in an alkaline condition, but still you got to be very careful. The temperatures are close to room temperatures, the timings will be in seconds and not in minutes, so you treat and remove, the chlorine compounds and so on and so forth and the best way to do is immediately neutralize and give an antichlor treatment, so that the reactions are stopped.

So this acid chlorination also is preferred sometimes because it can also remove lipid layers. So, lipid layers can also be removed, so acid chlorination can still be an interesting scale removal process okay, but you can understand as I said the time requirements are going to be very slow, so batch processes may not be very suitable for such type of treatments because by the time you start a batch and finish the batch and remove the thing, the time taken may be too much and destruction may be there.

So, most the processes that may be the one which are going to be used commercially are going to be continuous process. So to this type of a compound which is effective otherwise, is there any alternative because people are expecting that whenever you do this chlorination, there is an oxidation process also, something is being removed from the surface, so will it affect mechanical properties, oh yes of course, it will affect mechanical properties and if you actually are not maintaining your times very well, the situation could be that you can really have a large destruction.

It will of course have other implications also. The hydrophilicity of the surface may increase because as we said some lipid layers will also go, but you must remember the treatment that is being done here on the wool fibre which have already been pre-treated in some way or the other because the natural wool contains a lot of fatty matter, much more than the cotton for that matter and therefore the wool may have been pretreated also, but now this is in the finishing stage, but still there may be a lipid layer which are there part of the things and they may also be removed during this process because the scales are being removed.

Therefore, mechanical properties can get affected and hydrophilicity can improve, but in case you like this, it is a good idea. If more mechanical damage has taken place, then optimizations will have to be done.

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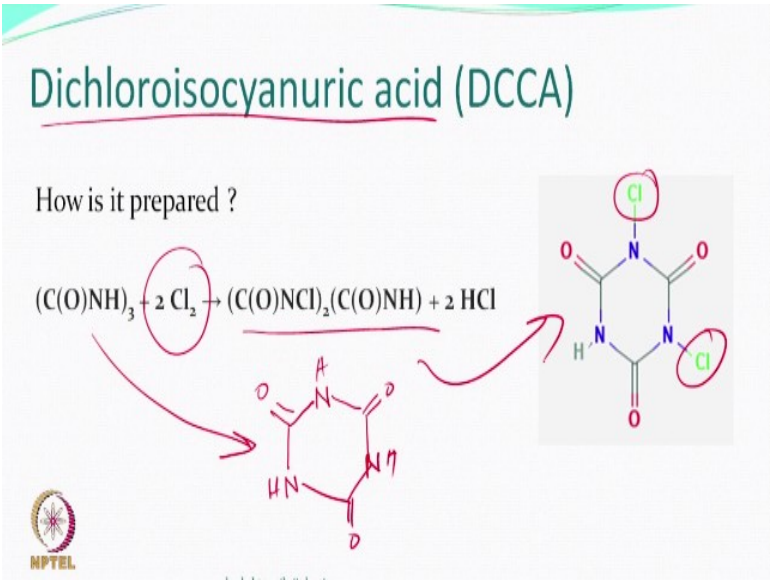

Another compound which came into notice where you wanted more controlled oxidation rather than very rapid oxidation was a compound made from you know cyanuric acid. So cyanuric acid, this is the compound which is called the dichloroisocyanuric acid. So these 2 chlorine atoms are added in otherwise what would have been called a cyanuric acid which may have a structure of this kind, so you had your cyanuric chloride formed by action of chlorine on cyanuric acid.

So you have a cyanuric acid and you have chlorine and you get finally a compound which is this compound known as dichlorocyanuric acid or DCCA is that right, invariably you may not use this compound by itself but maybe a sodium salt.

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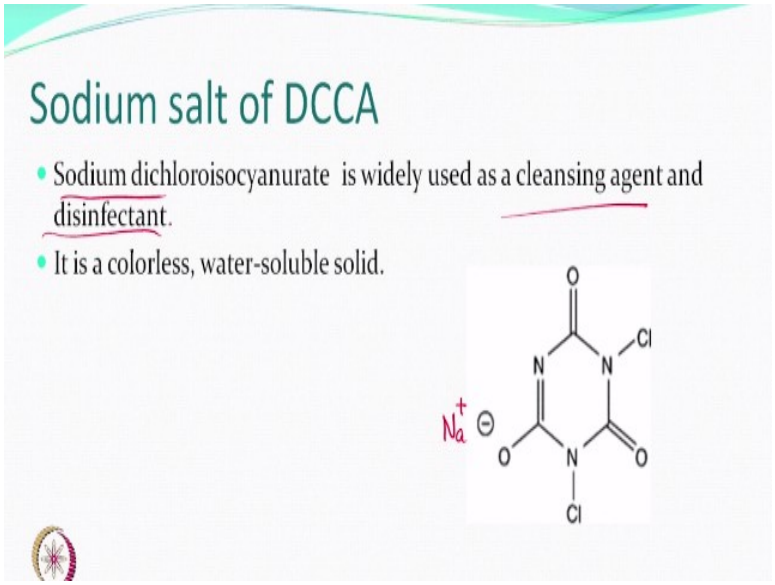

The sodium salt obviously will make it more water soluble, so you can have either a sodium or a potassium salts have been used and this type of a compound like the salt of DCCA is generally widely used also as a cleansing agent or a disinfectant, so you can appreciate some other things can also be, may be the byproduct. This is a product which is used for something else, it can be used for other purpose also.

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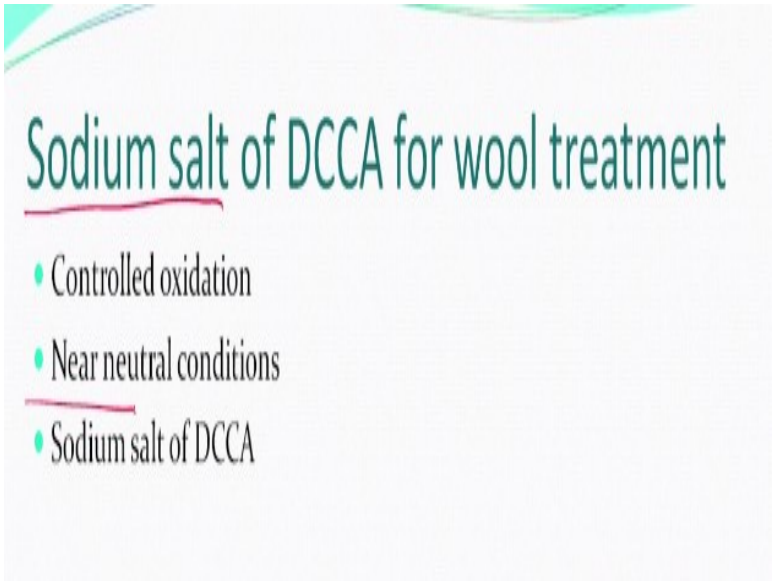

So by using the sodium salt of DCCA for partial destruction of the scales with relatively less damage to the mechanical properties has been used, so here because the reactions are slower. The conditions are near neutral and oxidation which happens here as we said chlorination process and oxidation process will happen, but people found that the damage could be less than you can actually give more time using a less reactive, less active compound which is the salt of DCCA.

So that is one way, one strategy we have talked about, that you destroy fully or partially all these things with control of time, temperatures, and optimization one can blunt at least the scales or remove based on how much treatment or how intense was the treatment.

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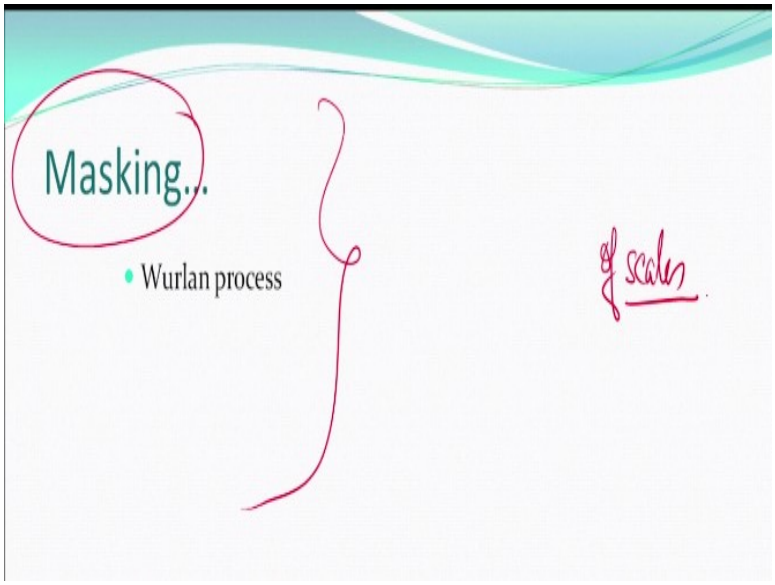

There is another process which became quite interesting relied on masking, masking of the scales. This was known as Wurlan process, you may have heard about it somewhere or the other, but very interesting process which was suggested to do the masking of scales. So when you do the masking of scales, obviously we are expecting the participation in the DFE would be less.

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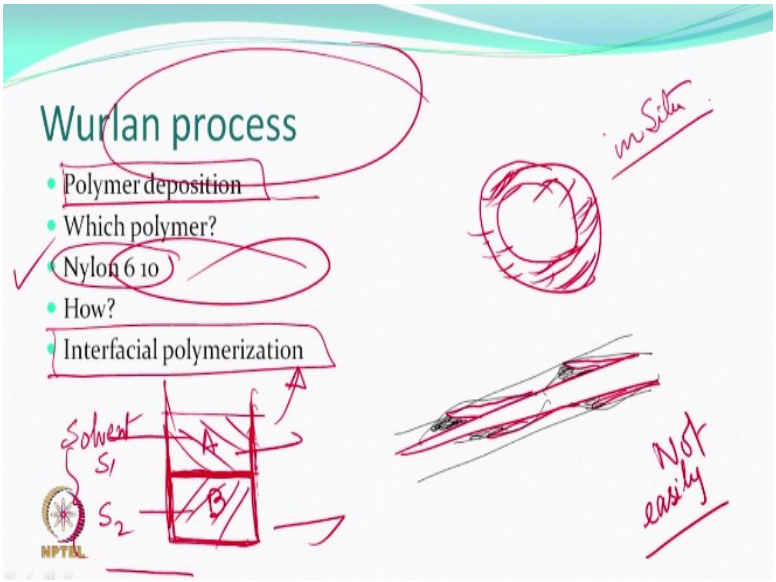

So, Wurlan process relies on polymer deposition, which polymer, Nylon 6, 10. Now, what do we do? This process is called interfacial polymerization process. An interfacial polymerization process can be done if the 2 monomers are highly reactive and this is called interfacial polymerization because the polymerization takes place at the interface. Let us say we have a monomer A and monomer B which are dissolved in solvent let us say S1 and another in a solvent S2.

So you have a situation where 2 monomers are dissolved in 2 different solvents. These 2 solvents are definitely not easily miscible. So, they do not mix, when you pour them, they will make layers. So how can it be and one of them could be more hydrophobic, other could be hydrophillic, one could be nonpolar, other could be polar, and if that happens, they may not mix alright. For example hexane is more polar or nonpolar, hexane it is a nonpolar and if you have water on the other side which is polar.

If you have monomer which can dissolve in water, another monomer which dissolves in an organic solvent which does not mix very easily, then what happens? When you pour such solutions in any container for that matter, then the reaction will take place only at the interface. If that is what happens, then this will be termed as interfacial polymerization. So this Nylon 6, 10 polymer was made using interfacial polymerization in situ, on the surface of the fibre itself.

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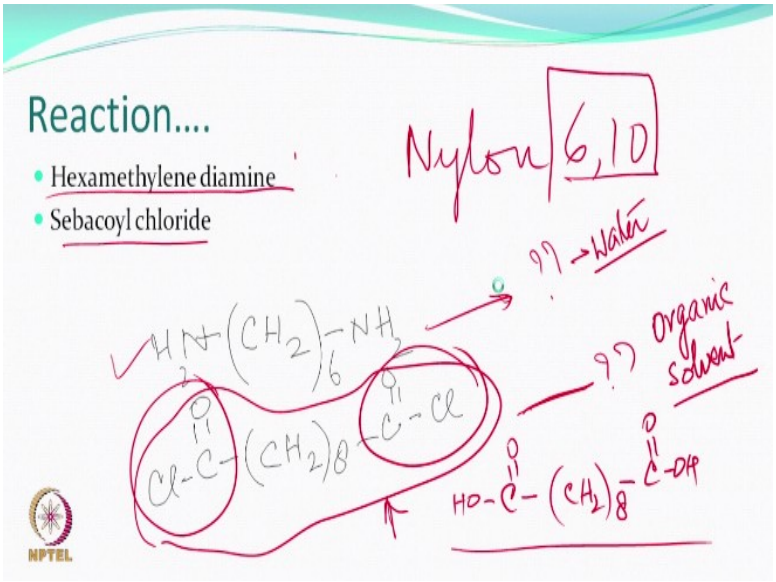

So one of the monomer for this nylon 6, 10 is hexamethylenediamine, this is hexamethylenediamine $(CH_2)_6$ and diamine, alright hexamethylenediamine, and the other

compound is sebacoyl chloride. There are 10 carbons, $(CH_2)_8$ and 2 more carbons, sebacoyl chloride. If instead of sebacoyl chloride, you had the acid, not the chloride of sebacoyl acid but the acid, that means you had only a compound like $(CH_2)_8$-COOH and COOH, this is sebacic acid.

This and hexamethylene chloride if you want to react, this reaction will have to be done at higher temperature, higher pressures, this is almost similar to nylon 6, 6 preparation where we use adipic acid right, you get the point, but the moment you make a chloride of this acid, this becomes very reactive. Theoretically, it can react with anything, hydroxyl group, so you cannot store it in water. So, what it means is this is the one which will be dissolved in organic solvent right, will be dissolved in organic solvent while the amine can be dissolved in water.

So if this organic solvent is nonpolar, they will make layers, they will separate out even if you do that and so we are obviously not interested in that. So what we can do is let us say in the Wurlan process what people did, that you dissolve amine in water and pad the wool fabric yarn through the amine solution., squeeze it, and pass it through the solution of sebacoyl chloride in an organic solvent. So the moment it enters this bath, immediately the polymerization takes place at the interface and so what you will get?

You will get deposition of nylon 6, 10 polymer on the surface of the wool fibre. This is masking. The question that people may like to know that would you have preferred a masking of this kind where the polymer is all along the fibre surface, it may not be the right idea, why because now the wool is inside and the polymer which is now nylon 6, 10 is outside surrounding the wool, what will happen to the properties of this fibre.

So you take an Australian fine Marino wool and cover it completely with a polymer system, then what you would see on the surface is nylon 6, 10 in case you are using the Wurlan process okay, so that may not be right, that means the wool is not wool anymore. So, you might as well use the nylon 6, 10 by itself, why wool. So your aim would not be to completely cover and therefore we do not have to add too much of a polymer, but your aim would be to if this was the scale originally, your aim would be to cover this in a manner with a polymer here, the polymer here, the polymer here, and the polymer here.

So finally you may get surfaces of this type okay where a large amount of this is exposed mainly as the wool itself, only in the spaces that were there under the scale are the ones which you are covering with a polymer and so you have large spaces which may be exposed as wool and the wool property would be predominant. So, your aim is not to cover the whole surface, but only to ensure that when you move from the other direction against the scales, there is another material which has been added and creates a condition where the friction in this direction is reduced.

So, you may have hills and valleys and of a surface, but it is not fully covered because that will probably change the whole property of the material, which you may not like. So, this is what we had just talked about right.

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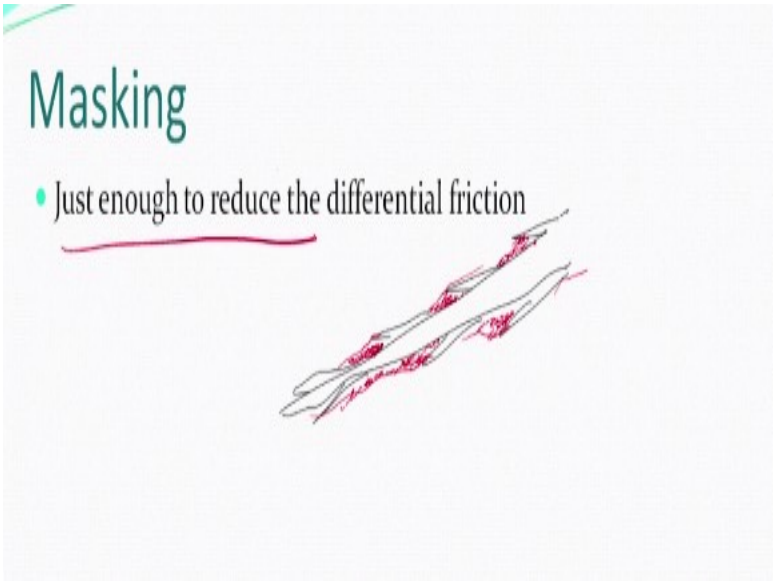

So our aim is just enough to reduce the differential friction, the effect of masking is that correct? If that is what is done, then we will get a wool which would have less tendency, reduced to quite an extent the tendency to felt.

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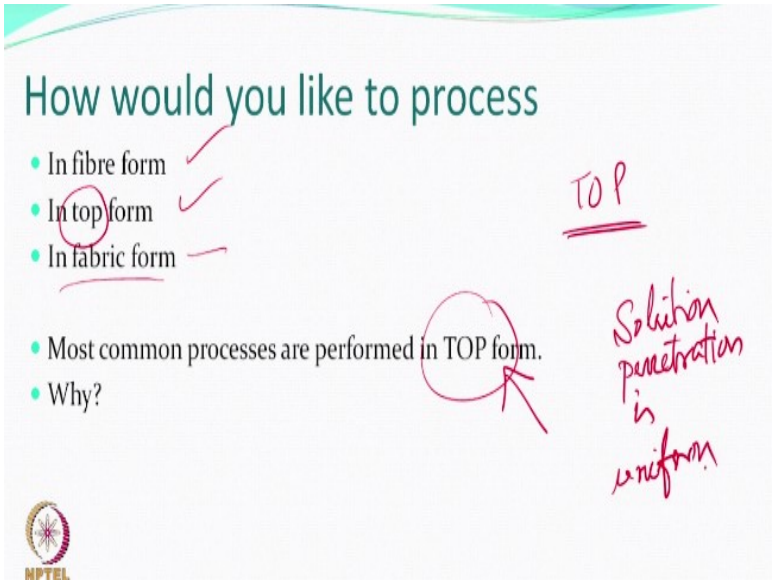

One question we may like in what conditions would you like to treat wool fibre, in the fibre form, in the yarn form or in the top. You know what is the top, the top obviously is something like a sliver which we call the name as a sliver in cotton spinning, in woolen the same thing is known as top. So would you like to treat in the fibre form, the top form, the yarn form, or a fabric form. Interestingly, most of the treatments are done in top form.

If you do in a fibre form which is a loose fibre, exactly what happens one is not very sure, then paralyzing them is going to be a tough process, there may be entanglements, breakages and so on and so forth. A top is a product where good number of alignment, good amount of alignment has already been done and if we treat in this form, at least this alignment will be there and then you only twist and make your yarn and then of course later make fibres.

Why not we do this kind of a treatment or any other kind of treatment in the yarn form which will be much more easier or in a fabric form which will be much more easier. The problem is when you do the surface treatments which you are hoping, only some surface will be skimmed, so top surface which is exposed to the chemical treatment or a polymer treatment will be treated, you may have a good number of fibres which may not be treated as I told you, both the treatments are going to be quick, so it is quite possible the fibres on the surface are behaving in one way.

The fibres which are in the core of the yarn or again in the fabric, some of them, may be majority of them may not get any treatment. So if that happens according to all the studies that have been done, this is as bad as not treating, not giving the shrink resist frequent

because these fibres are going to move anyway. So when they move, they will come in, go out, all those things will keep on happening, so it is as bad a situation as having not treated and that is the reason why people would prefer to treat in the top form so that the solution penetrates more uniformly right.

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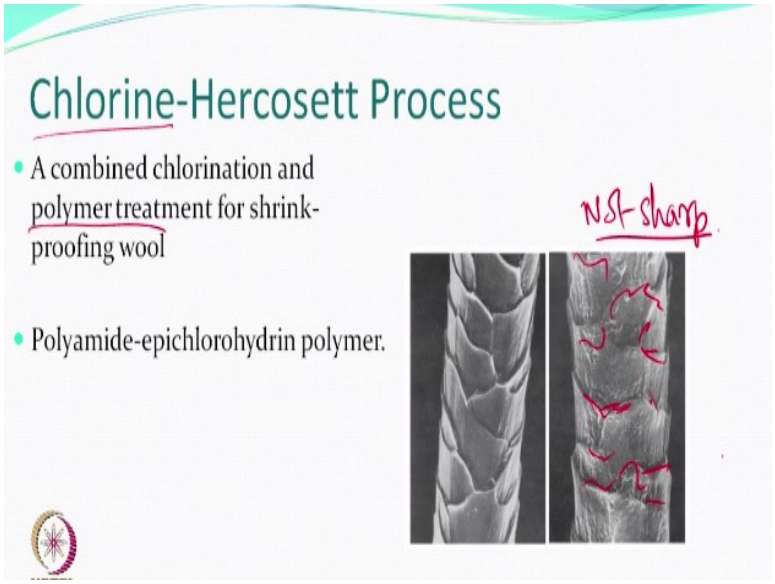

So talking about uniformity, this is one process which is commercially quite a successful process. So what are we talking about is that if you complete this process, this is a very smart process which uses the chlorine treatment as well as polymer treatment together or one after the other let us put it as a sequential treatment, but what you see in this thing is the fibres you can still feel that there are scales you can see them, but either they are blunted or there is some amount of polymer deposition.

So if these kinds of things if you change these, see the surfaces which changes and so they are not as sharp. If they are not sharp, then it is hoped that the friction in the direction of the root or in the direction of the tip are going to be similar and so the shrink resist property would be achieved. Now instead of doing only one or either, we are doing both. So this is called chlorine-Hercosett process which uses a polymer which is not the polymer that we just discussed before nylon 6, 10.

It uses a polyamide epichlorohydrin polymer, epichlorohydrin if you remember is a cross-linking agent, it can cross-link hydroxyl groups, it can cross-link amines, so it can make a network structure based on how much polymer you want to do right. So this is a process

which uses polyamide, so which is just like some kind of a nylon right, polymer epichlorohydrin which can cross-link also, so wash fastness could also be improved.

Chlorination treatment if you give the partial chlorination that you are making the scale softer, edges are more blunt and then you are doing some polymer deposition as well. So together, this process actually became quite an interesting and successful process alright.

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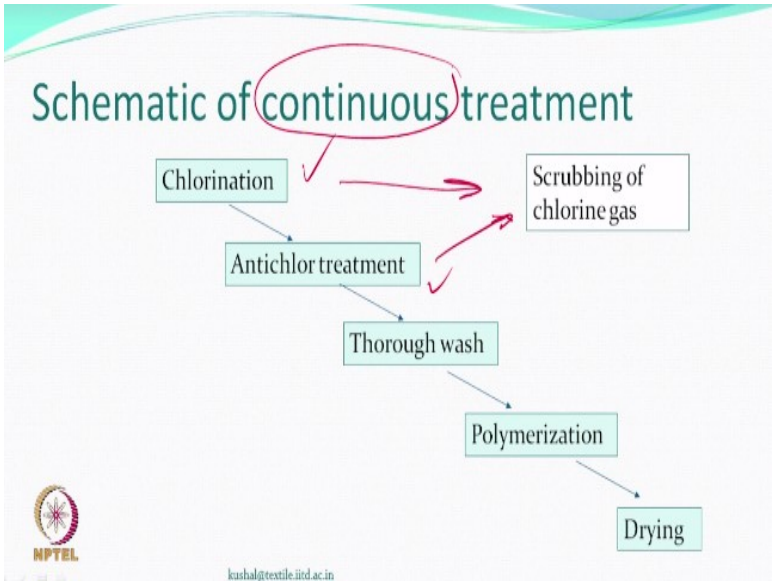

Let us see what the process is about. So I am talking about at the moment the chlorine-Hercosett process. So obviously, you have as the name suggests you are going to do some chlorination for a very limited amount of time okay. So you do a chlorination for a very limited amount of time and immediately after that you do antichlor treatment neutralization. So because you do not want the process to continue, the chlorination oxidation process to continue for a long period, so you would immediately want to stop this reaction, so that is where the antichlor treatment will be done.

Then of course, you wash everything completely. After that, you do this polymerization which is polyamide epichlorohydrin based polymer system okay and then of course you dry, this process will be complete. Of course, evolution of chlorine gas is likely to be there in this process as well as in this process and so you will have to have suction systems which will remove this gas and take it through some scrubbing, right, neutralization of this gas, so it does not go to the environment, that is the must.

So it is a complex process from that point of view, but a continuous treatment, I told you earlier because most of the processes are likely to be continuous because the time required is very small. You can appreciate a batch process, would expect the reaction to be very slow and you will talk in terms of minutes or tens of minutes, here you are talking in seconds and therefore the only way you can do this is a continuous process. So most of these shrink resistant processes are now we are discussing chlorine based Hercosett process where the anti-shrink wool fibre is produced.

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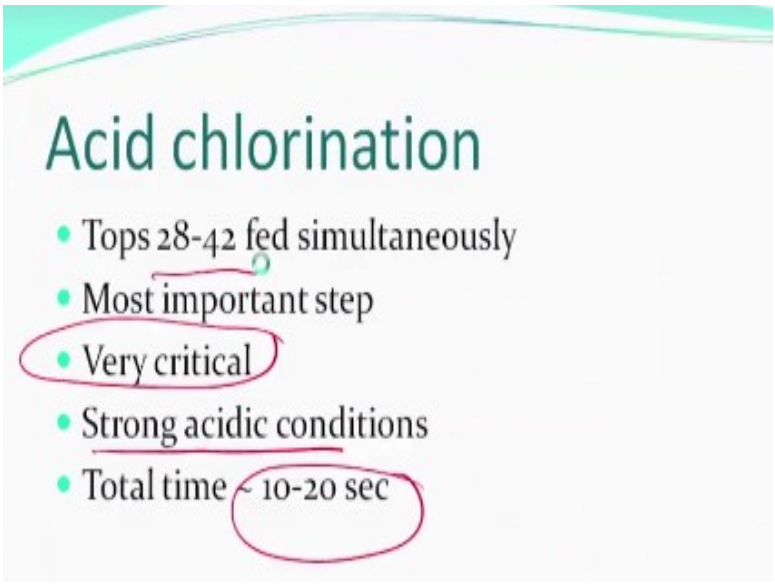

So this process as we say first is the chlorination process, an acid chlorination remember, strong acidic conditions, time required is only 10 to 20 seconds, more likely 10-20, think of that things are moving fast, obviously very very critical process. If you spend more time, you will be damaging, your aim is only to make it softer, invariably when you feed the top, one single top will not be fed, you will have a series of tops together being fed into the machine, get the point, so may be number could vary from 28 to 42 tops are going.

This will almost look like a web, but they are separate you know and very nicely, remember when you handle a top, the tenacity of the top is very small. If you put any stress, they will just break, so you have to handle it very carefully, you do not want any breakages in the top, you do not want any movement of the fibre at this point, you want them to just pass through slowly through these chemicals which may be chlorination chemicals and then the polymerization chemicals very slowly.

So instead of passing as we said we do not want to, it will be easy to treat a fabric, it will easy to pass a yarn but we do it in top form which in some sense fragile, the structural integrity of a top is very small, very low and so you have to handle with care.

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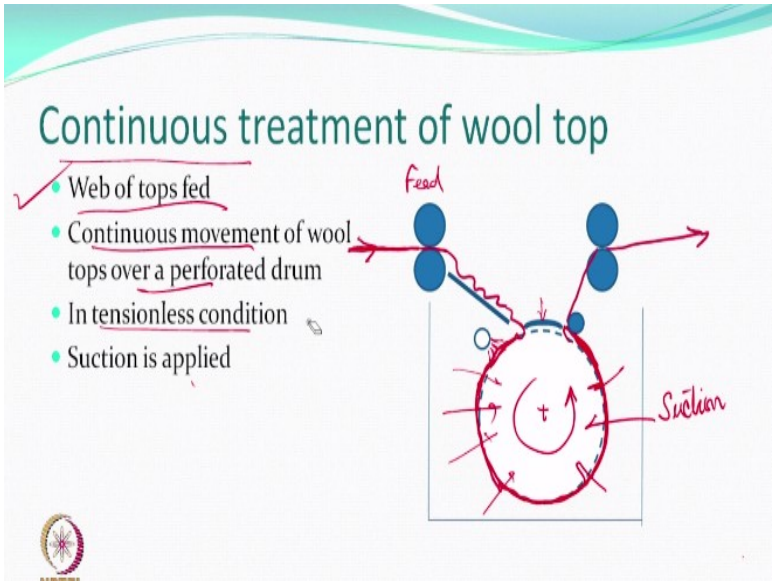

So treatment as I said this could be a large number of 24 to whatever number of tops going together and supported in a manner the tension is less. So you have a feed system, feed roll nipped, then it goes over a support system like a plate maybe where almost in a tensionless form, it is put on what we have is a perforated drum okay. It also should be moving in the same way and what you do is do some spray of the chemicals. Actually there can be various method.

You can actually have a dip, the whole thing may be dipped, but you may have enough spray so there can be a spray bar which is spraying the chemical, the chlorination chemical which could be hypochlorite in very strong acidic conditions. So you have a spray bar and so the whole series of tops which are moving are sprayed with the right chemical just at the time as it is entering because you want to control the time of reaction and then give some time so that it moves from one direct part to the other part over a perforated drum which is moving and there is suction.

So you have suction okay and if there is any extra chemical it could be somewhere there, so whatever is being sucked, so one is that there is going to be penetration from the top to the bottom layer of the top and then this is moving and extra of course will be taken away

drained filtered and reused if they can be, and then of course you guide. This is plate so as to ensure that between this point and this point directly the air cannot move in.

So it is like a suction control system and so you will have penetration in this from all directions, perforated drum, and then it will be taken out of this unit which is in a way a chlorination unit or chlorination treatment, that is an important one, obviously in acidic medium. After that, what you do? So what have we done, web of top is fed, continuous movement of wool over a perforated drum in a tensionless condition and suction is applied okay, so all this is happening in this unit.

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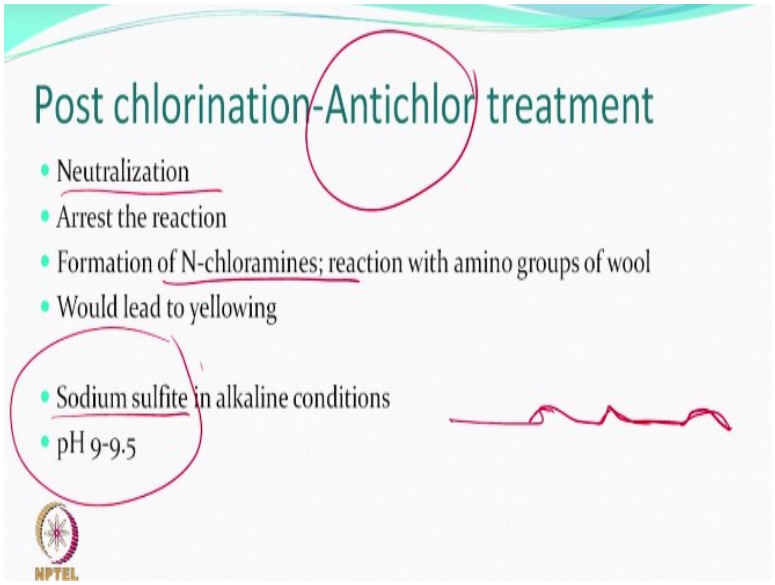

After this, what you do? Most important, post-chlorination treatment, neutralization is the process. What we call as an antichlor that any chlorine which obviously is being carried through this process must be now removed and one of the ways is chlorine the oxidative things you get to some kind of reductive systems and sodium sulfite or sometimes bisulfite sulfides etc. can be used. They will react with anything called chlorine to form chloramines. So wherever there is amino acid, which has been formed because during the chlorination, all these may be containing the chlorine.

This has to be removed by using some reducing things which are called the antichlor treatment. Immediately, the chlorine will be removed and what you will get is material which is softened, but does not contain chlorine, it has been removed alright. Some softening treatment in this has happened, so you have the scales which are softened, so you may be

getting something like this on the surface, ready for a further treatment okay and what is the further treatment, has to be polymer treatment right.

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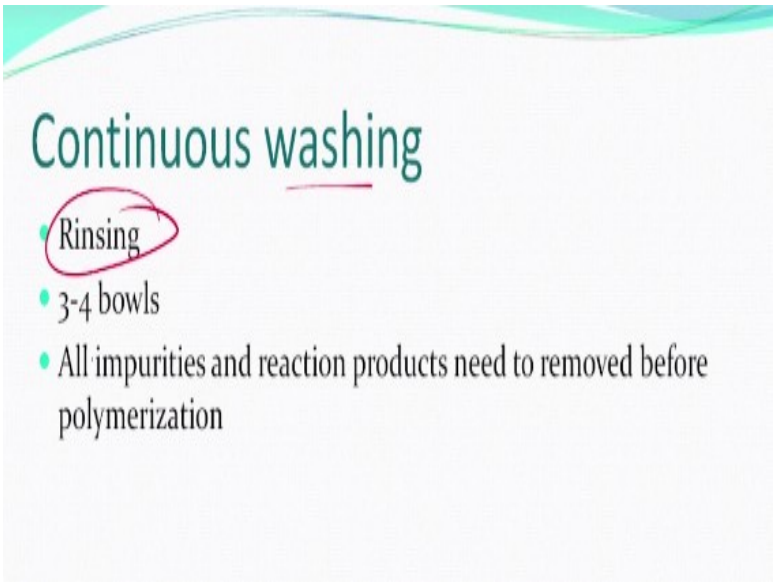

So before the polymer treatment, you will do continuous washing which may have 3 to 4 continuous washing bowls so that everything is removed which could be impurity, reaction products, the lipids which we expecting would be removed during this chlorination treatment, they must be removed. So if they are removed, you say our tops or the web of the tops is ready for polymer treatment.

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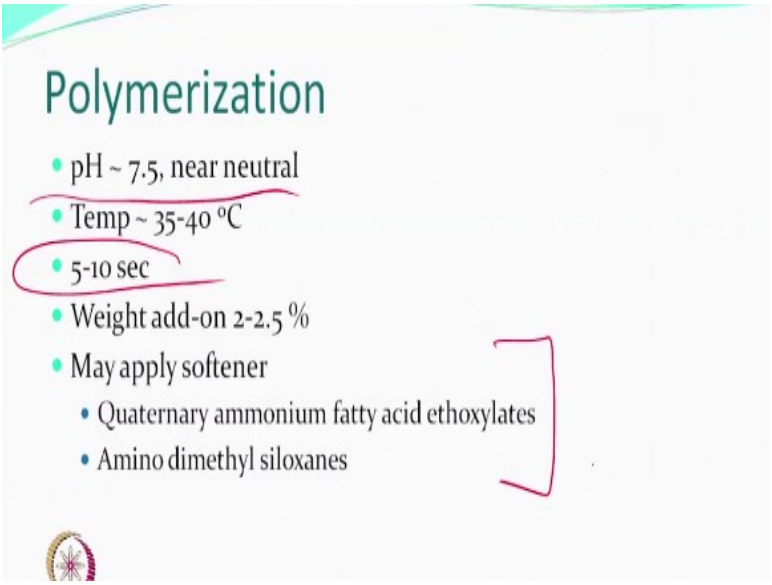

The polymer treatment as we said is the polyamide epichlorohydrin based systems and they are treated almost near neutral conditions. Temperatures are also quite low, they are not very high, temperatures is just 35 to 40 degrees. Time is just about 5 to 10 second is required for

all this reaction to take place. The add-ons this side cannot be very high 2% to 2.5% or maybe less than that is what you may require. After this, theoretically your process, the chlorine-Hercosett process is complete, but of course, you will do some drying or may apply some softener, purpose of softener you already know.

These are the type of softeners which you studied before, the quaternary ammonium compounds and the aminosiloxanes okay, dimethyl aminosiloxane. So, all these things can be used also for softening treatment.

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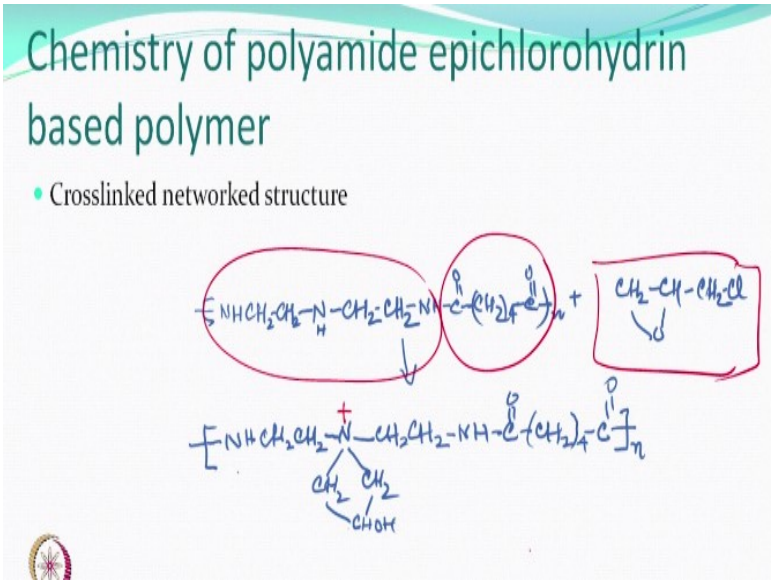

So the polyamide epichlorohydrin system looks approximately like this. So you do have this acid and then you have an amine or whatever type, not exactly the same, and you have this epichlorohydrin. So if you treat them, you get structures like this. These structures obviously mean there is a positive sign here on these materials and they can theoretically break from here and do another crosslink, I think you know that epichlorohydrin can make a crosslink.

So you can have a crosslinked network structure which means the wash fastness could be good and the polymer wherever it is required is there, in whichever amount it is required is there, and so the directional frictional effect can be taken care of.

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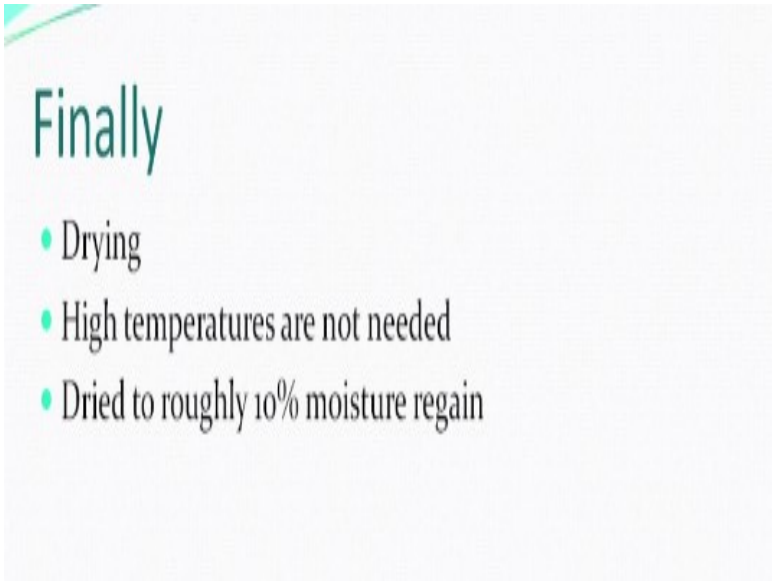

Finally of course as I said you do drying because polymerization temperature is also very low, room temperature polymerization takes place, they are also reactive now, and then to dry the material up to about 10% moisture and that is it, whichever kind of a dryer that you may like to use.

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Blends, suppose we have blends with wool and polyester, would they require a shrink resistant tool or the counter fibre which is the let us say a polyester will take care of this anti-shrinking, what do you think? If you really are interested that no felting should take place, then even for the blends, you should use fibres which have been given anti-shrink treatment and then blended.

So you have a top of polyester and the top of shrink resistant wool, then you mix them and break the blends and not depend that the polyester will be able to ensure after blending that the wool fibre does not go through the felting process okay. So, you are not going to spoil this party. So even if you want to make blends, first anti-shrink treatment.

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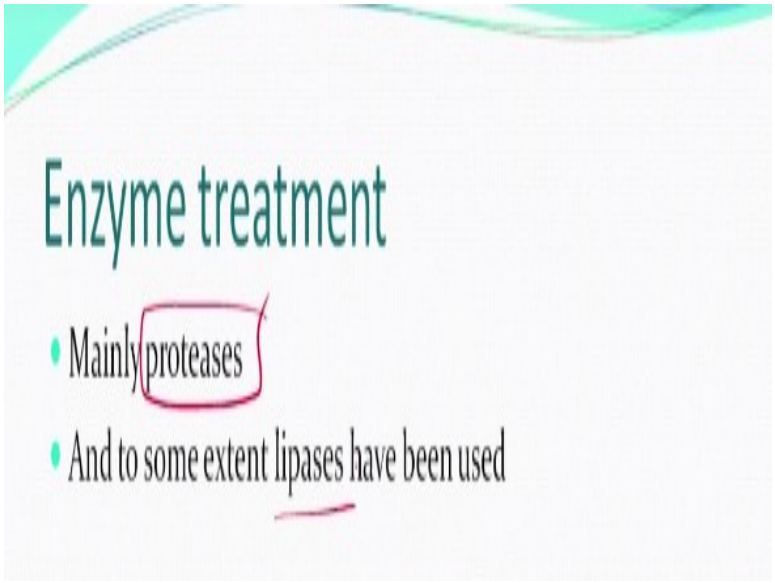

Well, just because people can be interested in non-chlorine process, although this chlorine what everything is being removed by suction and neutralized in a closed system, it is a very interesting closed system, which cannot be just as the chlorine cannot go to the atmosphere. The scrubbing is a must that happens, but people say well why not use something else like enzymes or which can be also used to destroy the protein like proteases, they obviously destroy proteins or scales can be removed partially, this is true, people have tried that also, that happens.

How much successful commercially at the moment we cannot say. Proteases plus lipases, etc. can be used to you know soften the surface like we are doing, but it will be a slow process, theoretically slow process are good, it can be controlled very well, but if it is too slow, then maybe techno-economics does not work for it, it works actually against this kind of process, that has happened, but alternatives have to be tried.

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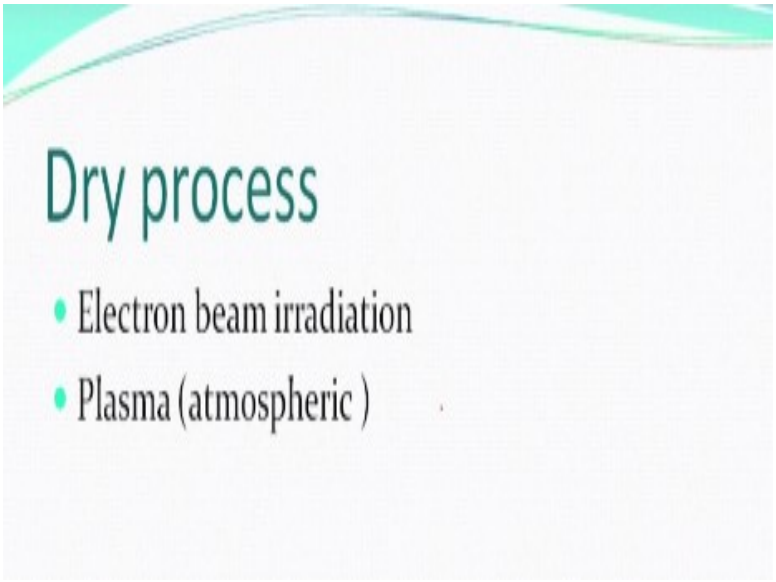

Now handling a top is being done and taking it through solutions is not the best textile technologists would love. We would like to handle the top in a dry state rather than first wet it, chlorination, polymerization, washing, drying and then you say now we will make yarn out of it which of course is being done. We love everything is dry, so people did try things like electron beam irradiation, so where the electron beams fall and destroy the outer surface to an extent that they say it is safe from shrinkage point of view.

We are again talking about felting shrinkage and not any other shrinkage, but these days people have been talking about atmospheric plasma treatment also. You can appreciate electron beam irradiation even if it is very effective cannot be a continuous process, you cannot generate electron beams in atmosphere, you got to be having a vacuum created, so it will be a batch process, it cannot be very successful, but anyway for research, one may have to look at all the possibilities which are there, may be today it is not possible, tomorrow something else can happen or a different product you are aiming for.

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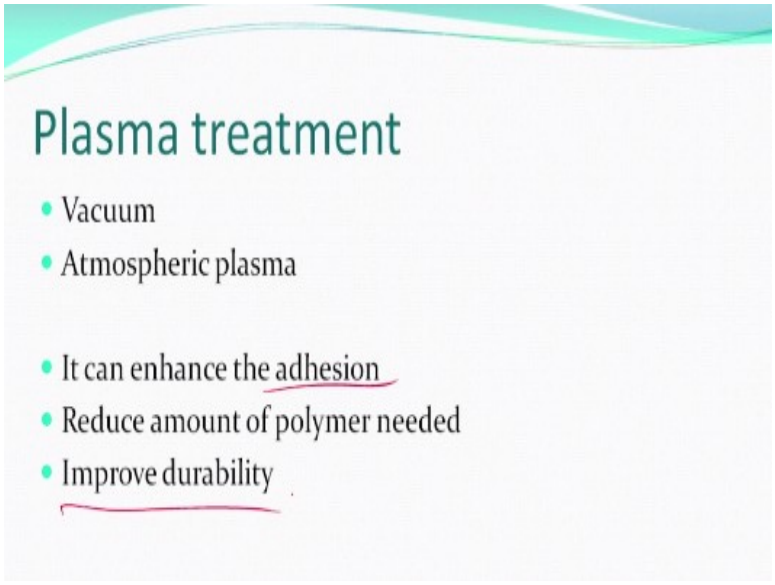

Plasma, particularly atmospheric plasma has also been suggested which can be completely a dry process by its own, if it is tried and plasma itself can be done by itself as I said alone, but if it is done before as an assistant assisting process like, a plasma assistant until shrink process if you have, then it also works, people have tried that. It can improve the adhesion of the polymer because based on what gases are also there along with the plasma, you can create maybe many polar groups and so adhesion could be improved by this and then you add polymer to this and maybe you would not then require a chlorination treatment.

So in a process we do not require protein treatment and you can use plasma and followed by a polymer and then of course it can assist in improving the durability of this polymer treatment. So what we have learnt is things which are commercial and some things which are not necessarily so much commercial, but the possibilities exist of the treatments to do what we are intending to do is either destroy scale or mass scale.

So we actually are almost thinking that we do not want to destroy the scales completely because then you are exposing the fibre to the environment too much, so you partially soften the scales and then support it by a polymer treatment, together they are a good combination.

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So these days, it is quite possible that you may land up in a store and find that this woolen garment is machine washable, well that will be nice. Of course, we would have to pay little more, but that can obviously be the goal and some products particularly after lot of hard work are now available and being promoted as machine washable woolens.

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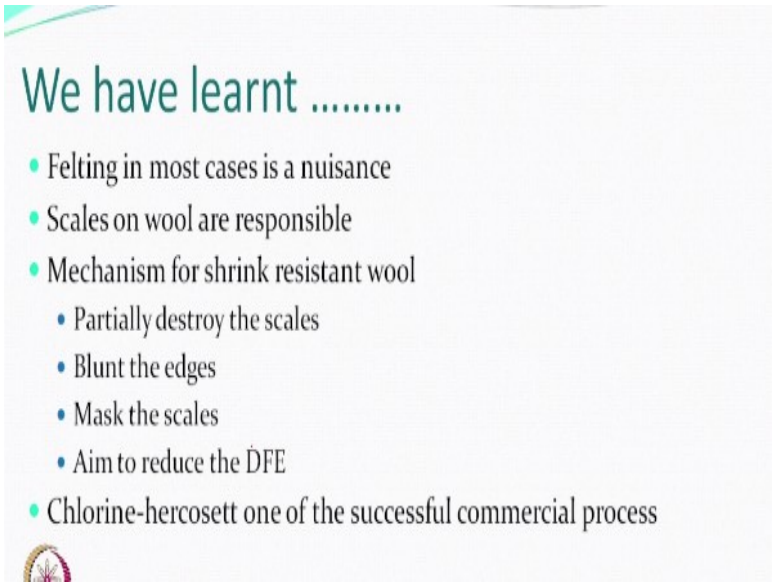

So, what have we learnt? So, we have learnt that felting in most cases is a nuisance right, responsible obviously the scales. Mechanisms we say either blunting, masking so that the differential friction between the two directions is reduced and chlorine-hercosett process at the moment is one of the more successful commercial process. So, we stop here, meet you next time on a topic, may be like to continue on finishing of wool a little more. Thank you.