Textile Finishing
Prof. Kushal Sen
Department of Textile Technology
Indian Institute of Technology Delhi

Lecture – 28
Finishing of Synthetics

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Welcome back to our class on textile finishing. Let us see what did we do? Last time when we met, last time we learned about enzymes and application of these enzymes in textile processing. We are quite sure, we are quite used to using a amylase in desizing processes. But we did talk about a finishing process called the bio polishing of cotton fabrics or cellulose based fabrics using cellulase enzymes.

Today we will look at finishing of synthetic yarns or fabrics what does it involve? And how do we do it? What type of finishes we may actually be requiring which are relatively special to synthetic fibres? So, we are quite sure about what are our natural fibres, right are we sure?

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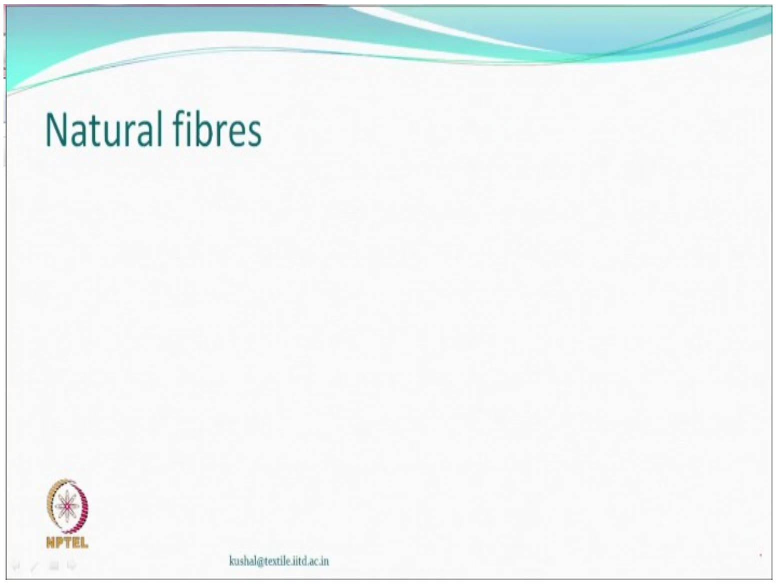

What are the natural fibres cotton, wool, silk, jute all these are natural fibres, natural fibres have their own functionalities polarities. Because of which various finishing processes that have been handled and used for them, we talk about another set of fibres which are called the manufactured fibres which do not occur in nature.

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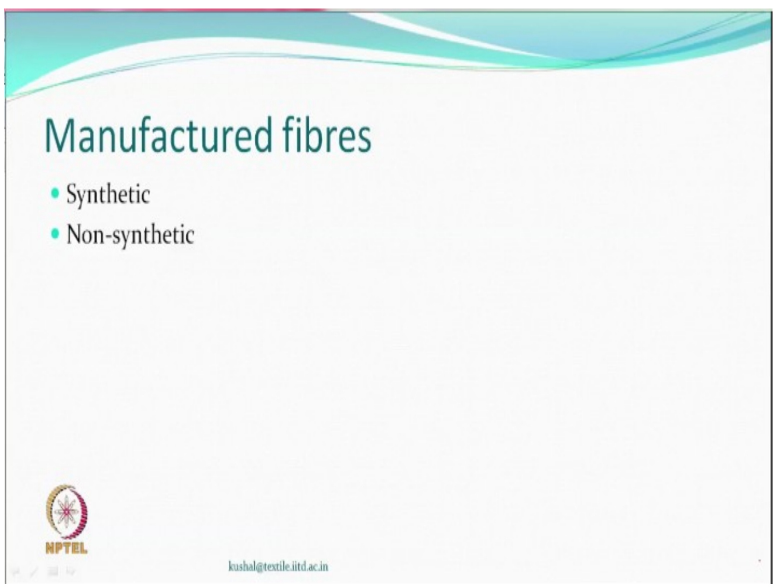

And therefore, we manufacture them, one of the group is called synthetic fibres, a synthetic fibre is a group where the polymer by now, we already know that the fibres are made of polymers. So, in the synthetic fibres, the polymer does not exist in nature at all. So, we take building blocks like monomers and do polymerization and then fibre spinning to make fibres, they are complete a synthetic because nothing existed in this polymeric form in nature.

So, that became an interesting type of fibre and therefore, it may require something special also, we will talk about it. Then there are other manufactured fibres which are in some way, modified fibres, that is basic polymer unit exists in nature. And you modify remodel dissolve coagulate and then make fibre lot of them and this is therefore, in the category for example, viscose is one of the regenerated fibres made from cellulose basic chain. So, they are do not come in the synthetic category alright. So, synthetics are where the polymer has to be synthesized using monomers.

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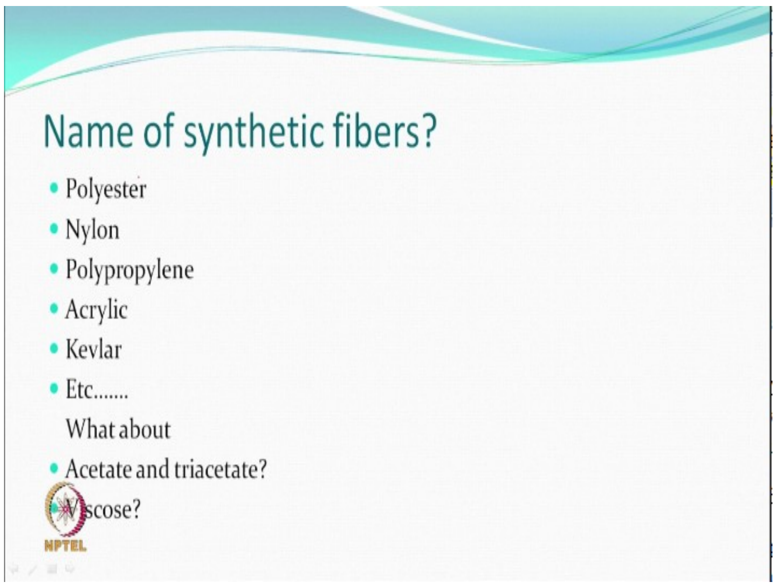

So, some of the synthetic fibres that you are aware of are polyester, nylon, polypropylene, acrylic, kevlars and so on so forth. There are so many such polymeric fibres which are synthesized using monomers. So, what about acetate and triacetate they are not synthetic, they are manufactured because the basic unit, the basic polymeric unit existed in nature, which was cellulose modified them to make acetate or triacetate fibre.

What about viscous we just talked viscous regenerated fibre where cellulose as a base is used, and then dissolved in one way or the other and then spin into a fibre that is the kind of a process that you use, which is called the regenerate. So, these 2 are the groups of these basically do not come in the category of synthetic fibres. So, in this lecture, we are only talking about some of the synthetic fibre or some of the finishes for synthetic fibres, particularly the fibres which are commercially used textile fibres, we shall not go into the kevlars and other special fibre which have special role to play.

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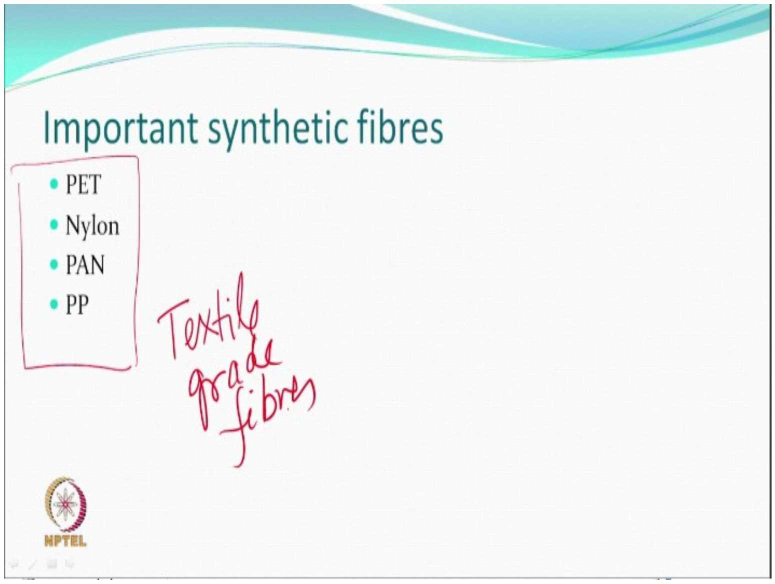

So, the important synthetic fibre that we may refer when we talk about synthetic fibre which are let us say the textile grade these are the fibres which you come across almost every day and so, what kind of a finish do they require?

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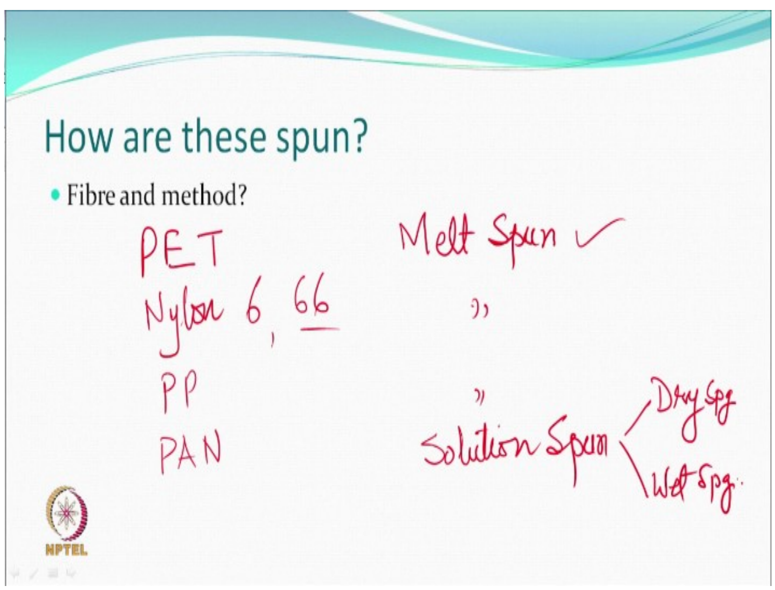

So, before that let us just approximately understand how these fibres are spun. Let us say polyester we are talking of this fibre which is commercially popular polyester fibre PET, so how is it spun? How it is melt spun right. So, you make a polymer and then you melt it and after making whatever little modifications to the polymer systems which are called finally you may be having an entity called chips, polymer chips which has to be melted and then spun through excluders.

And spinning systems. So you get fibres that means they are melt spun what about nylon 6 there is another one which is also nylon 66, how are they spun they are also melt spun all right they are also melt spun, what about polypropylene? This is also melts spun right and then we have another fibre which had talked about polyacrylonitrile or PAN fibres or the melt spun generally, are they melt spun generally? No, they are solution spun, so it could be dry spinning or wet spinning.

So, these processes could be used to make polyacrylonitrile fibres why they are not melt spun the dipole interactions because of the nitrile growth that you have is so strong that when you want to melt it the main chain also degrades and there are other processes is like cycle assertion, degradation to yellowness could we seen and therefore, generally they are going to be dissolved in some suitable solvent and then solution spun and make by either dry spinning or wet spinning.

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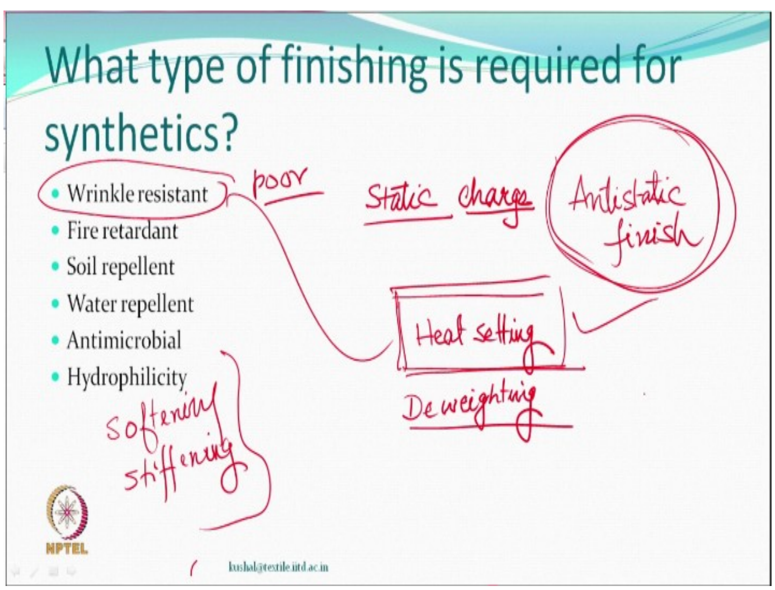

So, we like to understand what type of finishing treatment would be required for synthetic fibre fabrics. Let us say we check it out, we have done a good number of finishing treatments. Let us see all of these would you require a wrinkle resistant finish? Would you want wrinkle resistance, synthetic fabrics? Normally people would say well the cotton and other natural fibres as well as viscous which demanded fibre would require a lot of attention as for wrinkle recovery angles are concerned.

And so they require wrinkle resistance finish. People generally believe that synthetic fibre less polyester for that matter would not require so much of wrinkle resistance treatment. But you would want the wrinkle resistance to be good. That is true. But you will be surprised that if you do not give as special treatment to this then we may not get the same type of wrinkle resistance as you expect. So, actually we require what type of a thing that we will see, fire retardancy are they flammable or not? They are flammable.

And therefore you would require flame retardant treatments you already know what kind of a treatment they would like to give. So, soil repellency, did we say that some of the synthetic fibres because of their hydrophobicity get soil more and particularly oil based soils. So, they would require soil repellents of course, they will require but we know about this also we already studied whether they require water repellents? Yes, depends on whatever application that you are thinking of the synthetic fibre fabrics also would require water repellent finish as well.

Antimicrobial this question somebody can ask, would they require antimicrobial? They said they are synthetic that mean, these polymer did not exist in nature and therefore, nature does not have where whittles to break them down easily. So, are we worried about that the microbes and the bacteria that is in a fungus would break down these fibres, we are not worried about that. Okay. What we are worried about is the oxidates which get stuck.

Let us say perspiration. In case of a wound, something else that happens or blood or any such thing, which can get a test, which may be nice for the bacteria or the microbes and therefore, you may require anti microbial treatment for them, we already know what to do? Hydrophilicity. Now, this is something which is interesting, most of the fibres, most of them are compared to let us say the manmade other manmade fibres and natural fibres more hydrophobic. So, in case you require hydrophilicity, we would probably so they require that also what else?

This is what we said they already acquire and what else would be required? What about static charge development. So, do you think some of these synthetic fibre fabrics may have some difficulty in terms of static charge development, if that is true, then we may require antistatic finish, do you believe that you know we do then we talked about this wrinkle resistant if we do not give this treatment which we call a heat setting then this wrinkle resistant will be poor. But if we give heat setting then this wrinkle resistance can improve.

So, as said would you require mirth proofing here? No, any other inset resistant treatment? No, there is interesting thing people sometimes do which is called Deweighting the waiting obviously means removing weight. So, for some nice applications you may require. So we will actually concentrate on 2 finishes which are really specific for synthetics which are required one is the heat setting and the other is antistatic finish, deweighting, yes we will just brush upon this at some stage. All other finishes which are generally required for let us say waterproofing.

Yes, you can do waterproofing. There is well softening, stiffening all this will be required based on the requirement or application, you may require these waterproofing as we said the synthetic material also all part of the waterproofing treatments. So, they will be required but they are we already talked about them. So, the ones which we have not talked about till now, which are specific to these are going to be heat setting and antistatic a mention of deweighting also we will do in the course of next few lectures. So, we start with thermosetting, okay. They start with thermosetting.

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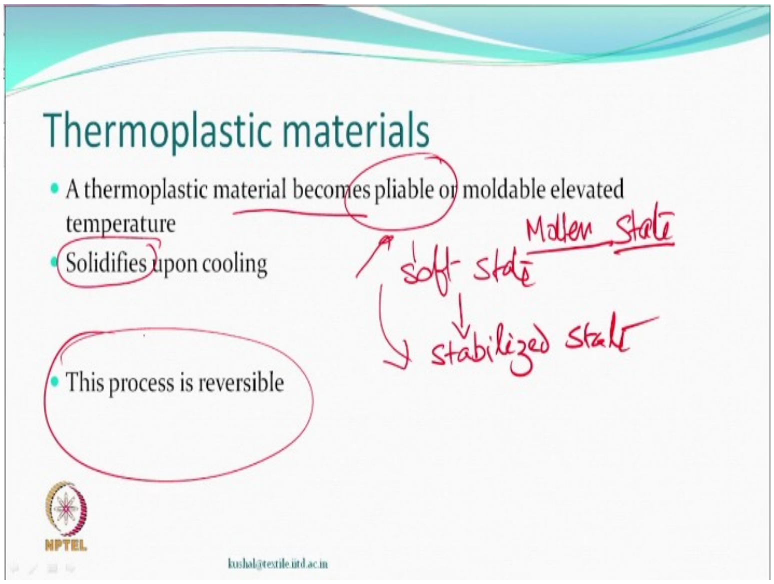

So, thermosetting can be done only on thermoplastic materials. There are some material was called thermo sets, the setting can be done there also, but we are not talking about them. We are talking about our textile fibre fabrics, which if they are thermoplastic materials, then we can do this type of setting which you just mentioned, thermo mechanical setting or heat setting. So, what is the thermoplastic material? It is a material which would become soften, become pliable.

So that you can mold it, crease it folded, put it in whichever shape that you want and that can happen when you raise the temperature right. So, that is an important part of the thermoplastic, thermo sand. And then after you have done whatever heating you have done, you should cool it down. So, that it comes to the temperature and becomes more solid, shall we say, this word solidification can confuse, whenever heat any material. So, that it becomes or it comes to a molten state.

Of course we can melt because we know we have done melt spinning of these material thermo plastic material. So, if you do take it to a molten state, this shape will be completely last for example, if there is a fabric and I take it to its melting temperature it will be liquid. So, there will be no fabric right. So, while we will like it to become pliable we would not like it to get melted right. So, but from something which is a soft state they can come to more stabilized state okay.

So, but of course, their properties there they can be molten also and they can be solidified also upon cooling. That is of course, but as far as we are concerned, we may not be interested as a textile person to go after we made a fabric or a garment or a yarn that you like to melt it again normally obviously that does become part of finish. So, this process of making it pliable and then cooling it to stabilize let us say take it to 200 degrees centigrade.

Let us say polyester fabric will have some changes and after that you cool down to let us say room temperature and after that we are happy. For example, something like this could also happen like you make a crease right. So, the crease can be can remain stable for a long period right. So, that way, so, you heat it like you do ironing, heated and then obviously, let it stay in this position and cool it and after that defined well you can see that the crease are go right or the surface remains as crease less if you are into the other way around.

So you make it soft, that is take it to a certain temperature which is high temperature, then cool it down to stabilized. Now the question is, is this process reversible? Is this process reversible? This so called process that we are just discussing? Heating, cooling, changing the shape molding? Is it reversible? Yes. So for all thermoplastic materials, this process is reversible. On the other hand, if you are talking about thermoset materials, whatever mold that you make after that, you cannot change that shape, right?

Even if you heat, in this case, if you reheat up to the same temperature or little higher temperature, the process will help you to change the shape, so they are thermoplastic materials. So now we are talking about fibres just followed the refreshing what are the sum of the non thermoplastic fibres.

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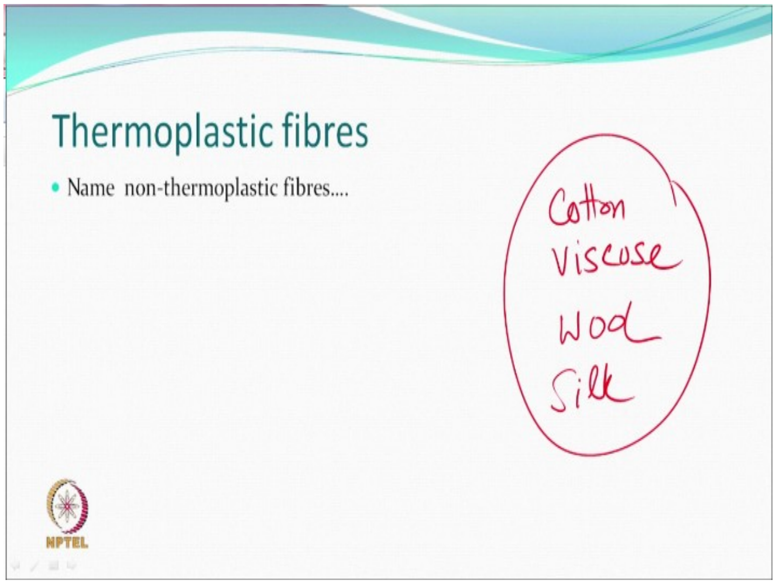

Say cotton, viscose, non thermoplastic, wool, silk they are not plastic fibres. So the kind of treatment that we are talking about will not be used for such type of material. okay.

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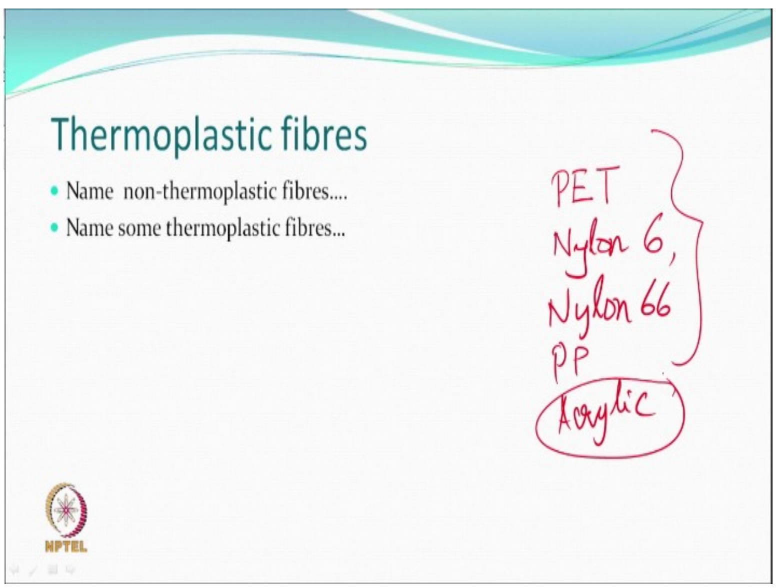

So, some of the thermoplastic fibres we already are been talking about it now so the synthetic fibre that we talked about polyester, the nylon whether it is 6 or nylon 66 they are commercial, polypropylene, acrylic they are thermoplastic fibres okay. These are all we said melt spun, this is not melt spun. So, is it thermoplastic? It is thermoplastic at temperature which have to be controlled temperature some changes obviously can be brought about within the systems thermoplastic fibres.

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So, if somebody says how do you test it is a thermoplastic fibre or not thermoplastic fibres, have you heard of this flame test, so you take a bundle of fibre near the flame not in the flame, but near the flame it shrinks right it shrinks this is one of the tests that you may do to find out the thermoplastic or non thermoplastic, if you take the acrylic fibres also they also shrink right so they will be thermoplastic but have cannot be easily melted.

That is a separate story but they can be molded. the creases can be put some of these things can be done at appropriate temperatures. So this flame test they have talked about it said fibres shrink. Why do you think they synthetic fibres shrink when you take it near the flame why? We did talk about relaxations. So, this is a relaxation process. What do you mean by that?

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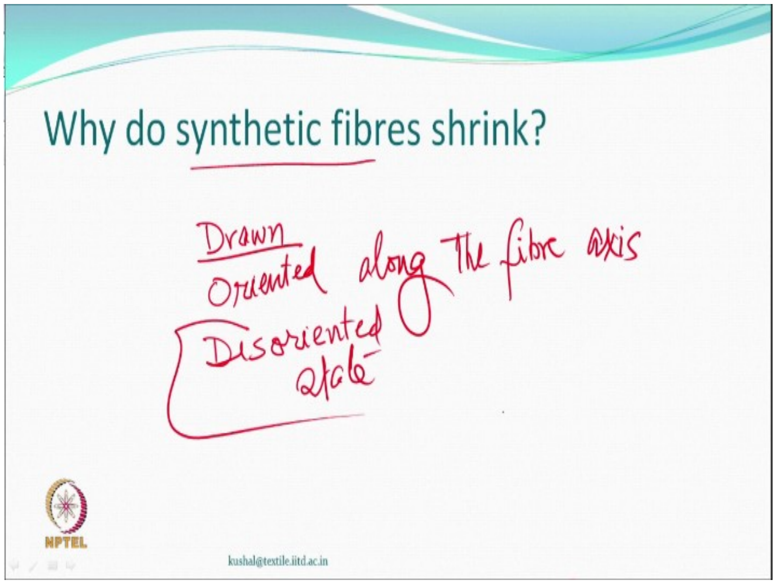

The fibres when they are made, they are drawn that means, oriented along the fibre axis is true. We drawn them spin and draw. So what happens the molecules are stretched in the direction of the fibre axis. So and then you cool them. So, this is the thermoplastic behavior right you just drawn them and then cool them. So, let us say at a higher temperature you have drawn them and then cooled them the molecules are they remain in a more oriented form they cannot go back to their random state.

So, molecules do not like it that means, there is some stress already been stored by this process right. So, whenever they get an opportunity like you raise the temperature again, whenever there is kinetic energy available the motion and the molecule sets in and they would like if possible to go back to little more random state. That means, disoriented state not completely disoriented, if you melt it obviously will be completely disoriented state.

But if you just heat and give an opportunity that means do not put tension the molecules would try to go to some best position that they like. So, that is what is the relaxation process and therefore, the, the whole fibre appears to be now reducing in length, that is called the shrinkage. So, that is what happens that is a thermo set material responding to heat.

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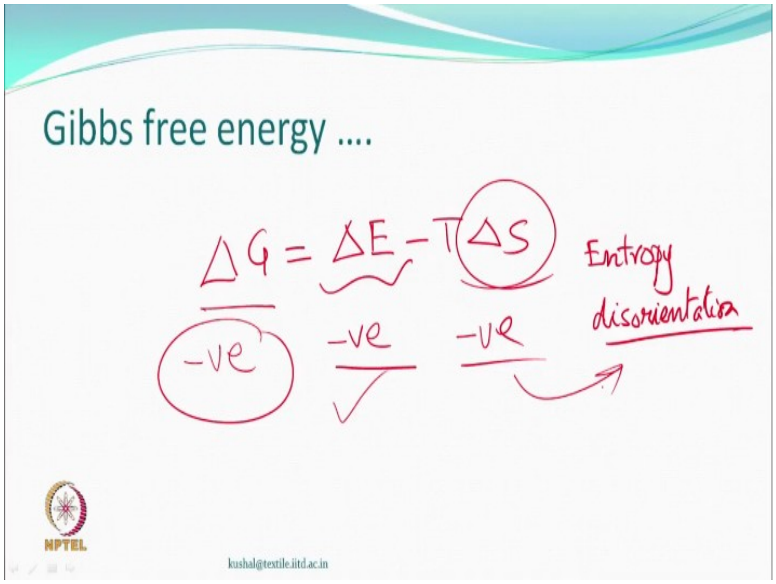

You heard about this famous equation there is a very important equation which is thermodynamic equation for various types of thing that happened in the world. Even in the so called domain of synthetic fibres, which do respond to heat, for example, so, what this and says that if a material is in one state, whichever state it is that wants to go to the other state, it will happen spontaneously. For example, if you bend something, release the bending forces in become straight because by going to this, it is releasing energy.

So, what it says is if this change in the free energy is negative that is delta G is negative then whatever change we are talking about will be feasible, will be automatic thermodynamically feasible process. What it means therefore is there is this term which is related to let us say internal energy. If this is negative, it is a good idea then it is helping the state. This is another term which is here, which is called the entropy which represents the disorientation.

So, entropy of the universe always increases that mean delta S is always going to positive or more randomness, if more and more randomness takes place, more and more disorientation takes place, because of our action like taking material to a little higher state, higher temperature right by heating then this is going to be positive. So, if delta S is positive this term also is negative, if both the terms are negative then the delta G is negative.

And now depends on what is happening. You know, if one of them is positive, the other is negative, which is more negative which is more positive. Finally, delta G if it is negative, then this process will be spontaneous. Now, in our case, what does it represent delta E for example, in the case of fibres and this heat setting or thermo mechanical setting could represent crystallization process.

Do you know the crystallization is it exothermic process or an endothermic process crystallization, so crystallization is an exothermic process. So, that gives a negative so, whenever any material after heating and goes through crystallization process will be going towards a stable state okay that mean dealt G will be negative and as we already mentioned, this is like entropy increase that means disorientation.

So, whenever there is a chance so, fibre will shrink, if given a chance it like to crystallize both the things happen, then you will go to a state which is stable purpose of heat setting is to make state stable. If you form a crease it should remain like a crease if you form of you make a surface absolutely smooth, it should remain smooth. That is what the thermo mechanical setting will do for you.

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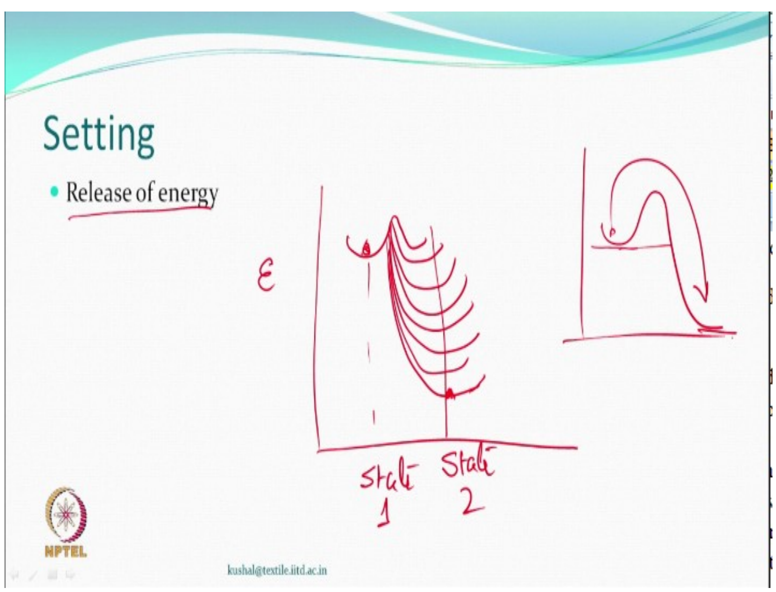

So, setting is by release of energy. Okay. So what does it mean by release of energy? If we just understood the delta G, so let us say we have a curve, which has got some energy state, let us say state 1. We have not done anything let us say a fabric as it is, after that, it was stable, because it will not change this position. So it was stable. But you let us say put a crease and then start heating. As you start heating crystallization can start.

Disorientation can start and it can go to a state which has got a lower energy, let us say a state 2 and then you cool it now, the tendency of this fabric which has attained this state to go to this state will be very low because you have to go higher the energy later, which the fibre may not like. So, what you are doing is creating a barrier energy barrier. So, if this has to go from here to here, it can go which will call it setting you know from a higher state of energy to a lower state of energy, which will finally make delta G are negative this is what will be happening?

And why will it happen? Either it will be crystallizing or will be disorienting. Other thing that we had talked about for setting which we are done earlier is setting everything in position which means cross linking which we have done the non thermoplastic material okay. So, the non thermoplastic material can be cross linked like we have done DMDHEU on cotton for that matter, right. So, but for synthetic fibre is the release of energy by thermo mechanical means.

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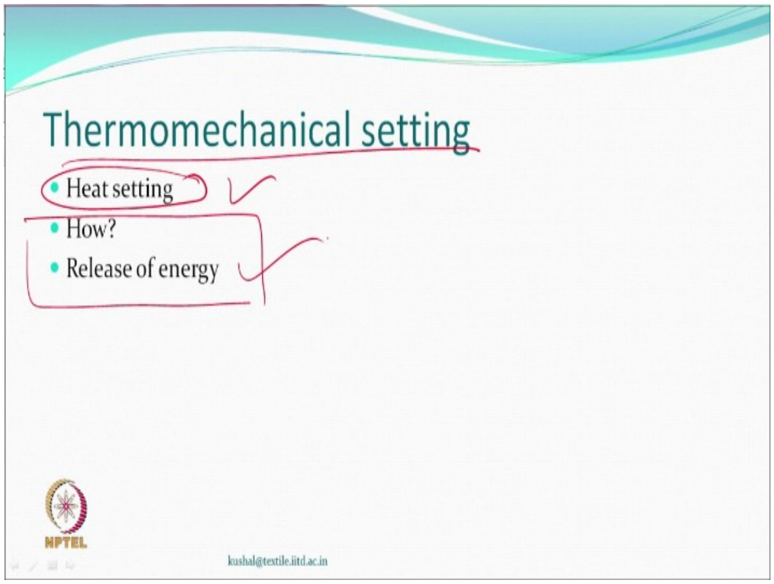

So, this is thermo mechanical settings sometimes it is also called heat setting and how the setting takes place is by release of energy, release of energy means, it may be crystallizing, as well as getting disoriented based on how much tension and what temperatures are kept.

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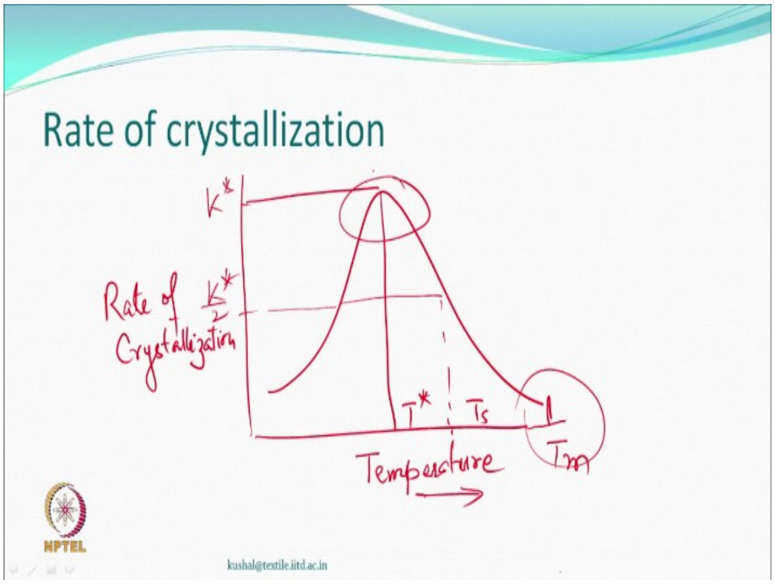

Now, what temperature should be used for during this process if you draw a plot of a temperature versus let us say rate of crystallization right. This curve is something like this. That is at as the temperature would increase the rate of crystallization. Crystallization means molecules coming together making a nice beautiful crystal that every atoms in a certain specific position etc etc will increase. So, these synthetic fibres to crystallize and rate of crystallize increase.

But after a certain temperature it will start decreasing because the kinetic energy will be so much that whatever little opportunity that they get to come together they also have equal opportunity to stay away because you are giving a lot of energy at some stage we may have a situation where the rate is almost getting 0 right, which may be melting temperature for melting this temperature if we call it T star is the temperature where rate of crystallization is maximum alright.

So, theoretically we would be if we go somewhere at the if this is rate of crystallization K star, if you go to somewhere around half the length which is K star by 2 as approximately this temperature is maybe a softening temperature we may not go even to this point because there may be some addition fusing of fibres, there is no point going up to this temperature, there is no point in going up this temperature somewhere around this temperature is the one that will be an optimum setting temperature where the rate of crystallization will be high.

So, you go up to this temperature hold it for certain time and then cool it. So, that comes back to room temperatures the new structure, new morphological structure will be stabilized all right and this will happen thermodynamically, if you have gone beyond a certain temperatures what will happen reduction in free energy means it will crystallize. And of course, at the same time, molecules may get disoriented also.

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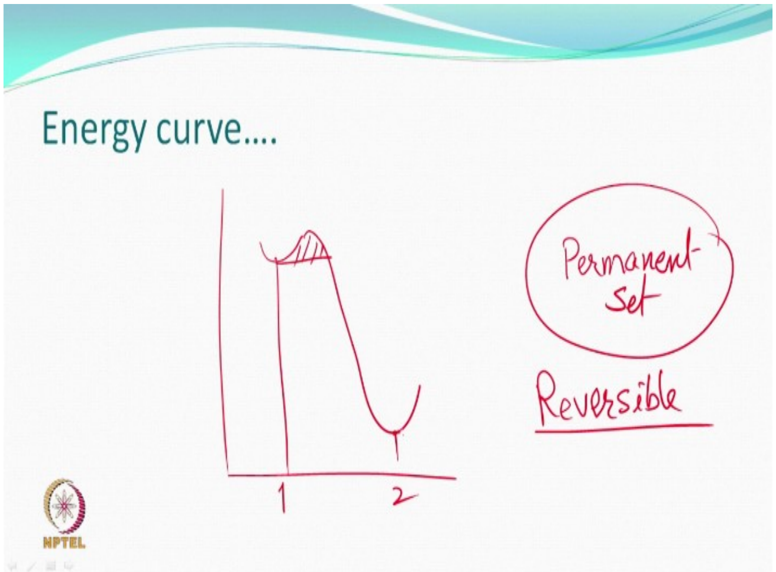

So we have seen the energy curve, the energy curve is that you happen to be state 1 in one, and then you come to state 2 all right. If you come from state 1 to state 2, it will be called, let us say, a permanent set. Nothing is permanent as such. But if you somehow are already in this state and you want to go to this state, let us say there was a crease state, which we are quite stable now you want to go to another state. Well, if that is what can happen then you can change. So, we did say that from any state to any state it can go this setting will be reversible, right.

And so, you can have crease if you do not want crease next time you go to the same temperature to the reversal, it can go to the other state. So, from one state to another state can go and that is what we can call as an energy state okay. But if suppose you wish that you do not want to increase the temperature at all, automatically, this will come to the state it will not happen because even at fully drawn yarn which has not been heat set is also partially crystallite textile materials or semi crystalline materials, the right okay.

So, during the setting process, both crystallization and this orientation will take place all right and both are thermodynamically favorable the energy will go down in both these cases, what can we set well we can do the setting of yarn like heat setting a yarn can be done no problem that. So, drawing and heat setting of the young can be done if you just draw will shrink more tendency if you draw and heat set, which means you are stabilizing.

So, process of heat setting basically makes the system more stable by bringing the energy of the whole system down alright, so, stable system. of course, we can do fabric that is the finishing for example, fabric you can iron, you can pass it through a stenter at a different temperatures and so, you would be able to finish the fabrics you can crease make pleats, all that can be stabilized by thermo mechanical process.

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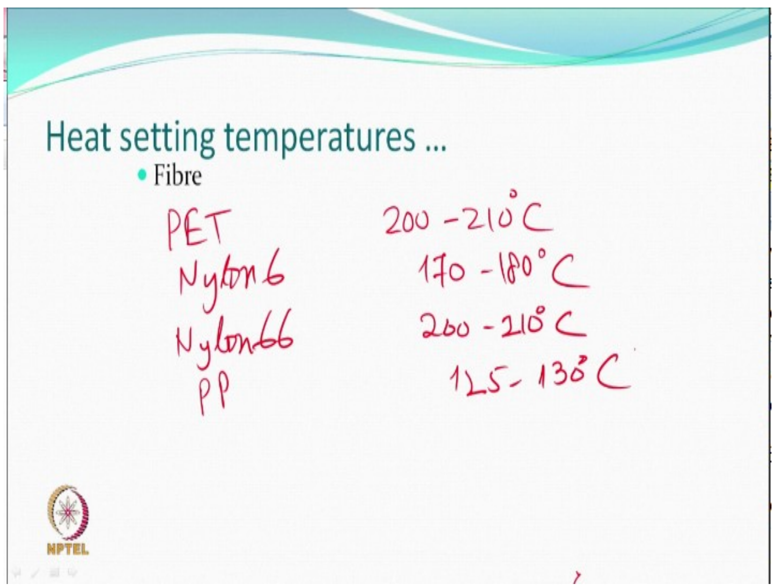

So, what temperatures some guidelines we can get it from that rate of crystallization curve. And in general, if we have polyester for example, fibre is polyester polyethylene di sterlite from above 200 to 210 degrees centigrade could be a heat setting process temperature nylon 6 may be around 170 to 180 all right degrees and centigrade, if you have nylon 6, which obviously is a different fibre nylon 66, it can also be from 200 to 210 you can set it.

If you happen to be handling polypropylene then maybe 125 - 230 degrees centigrade is what may be required now, it could be 30 seconds to one minute depends on what kind of thickness of the fabric is there so, you pass it through let us say a stenter everything will be done nicely. Do we allow for shrinkage to take place during this process? Of course, to make it more stable, it is better to allow it to shrink a bit.

So dimension control can be done harm or shrinkage process would like to do that you decide 5%, 7% shrinkage in any of the direction. Let us say in the behalf direction you allow that to happen and then finally the fabric will be more stable, okay as far as that is concerned.

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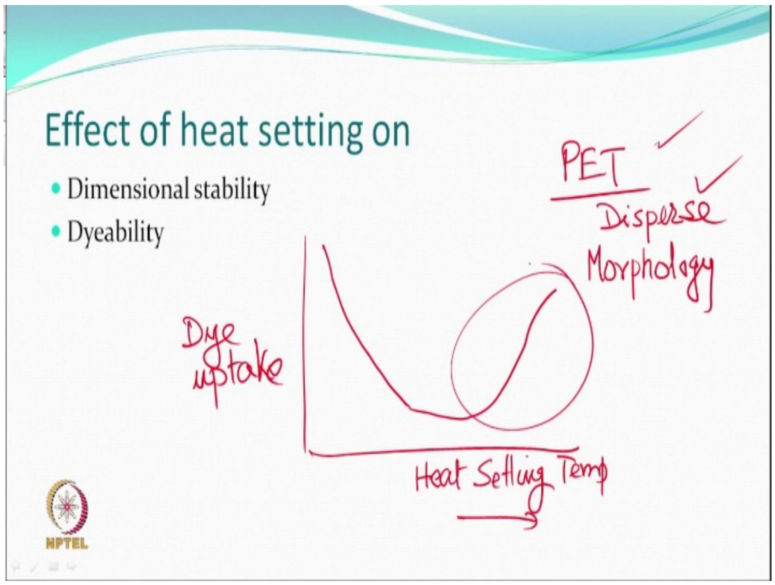

So, what is the major effect of heat setting? Major effect is dimensional stability, the dimensional stability is coming because you are taking by this thermomechanical process the whole system to a lower energy state and how is it happened by increase in crystallinity and possibly decrease in orientation as well. All of them they are not exclusive in the sense that only one will happen the other will not happen in both can happen.

That is one important so dimension stability occurs because of this so it will not show when you do hot water shrinkage measurements will not shrink to any significant effect like you do laundering in a higher temperature the garments will not shrink this is what will they if they have been set in a flat state they will not crease also so that is also very important thing as far as we were concerned, will it affect dyeability?

Let us say we talk about polyester with dye it is dyed from disperse okay, disperse dye, dyed from disperse dye, they right good now the disperse dye goes into the these spaces that are available you know, this is when the dyeing is done let us say higher temperature there is molecular mobility some space between the molecules is created and then dye defuses inside disperse dye, it is not dependent on any functional group.

So, what is dependent on? It is dependent on the morphology, how much is the crystalline region, what type of crystals are there, what is the space available because the dye is going to go to the morpheus portion, remember we said the textile fibres are semi crystalline. So, there is crystalline portion which gives the dimension stability but the un oriented or a morpheus maybe oriented morpheus regions are non crystalline will allow dye diffusion to take place is good for us.

So if you want to measure the dye uptake versus let us say heat setting temperature. Remember we are not talking about disperse dye, let us say any synthetic fibre like polyester. So, what is happening by heat setting? We said crystallization will take place. So, as you increase temperature more and more crystallization will take place true. So, what will happen to dye uptake? Will it increase by setting temperature or decrease?

So, we expect to decrease. If more and more crystallization takes place, the percentage crystallinity in a fibre increases then we can expect the dye uptake to go down compared to the without it said let us say a fabric or a yarn, after that what happens when one notices that the uptake of sometime then start increasing does it mean the material is becoming less crystalline have you gone to a temperature which is much beyond the temperature of heat setting.

No, even without that, what people have found is that as we increase the temperature that crystallinity it increases may be not to same rate because the space may not be there enough large number of molecular segments have already crystallized one which are non crystalline portions of the molecule, how do they come close because they are being hindered by the already crystalline portion because invariably you may have been told that the molecules fold on each other during this crystallization process.

And then they pass on and go to the next crystallite region. But, during this heat setting process other than crystallization, as we move further other thing which happens is smaller crystals can merge into a larger crystal. And, if that happens, then even in the same crystallinity level, this space available for dye to diffuse starts increasing what people now term this as a morpheus volume available per crystal this increases and therefore dye can go further.

And that is how we see this type of behavior right very interesting behavior and synthetic, particularly for the dyes which are more dependent on the morphology right the internal crystalline morphology, it has an effect, mechanical properties of course, it can effect if disorientation takes place maybe the tenacity is can go down, but if you keep on stretching and then heat setting the tenacity can increase.

So, mechanical properties would depend more on the orientation. If more orientation takes place along the direction of the axis that we are interested then the mechanical properties can increase, if more relaxation is allowed, the mechanical properties can go down a bit that will resistant go down a bit, that is okay. That not going to affect anything too much.

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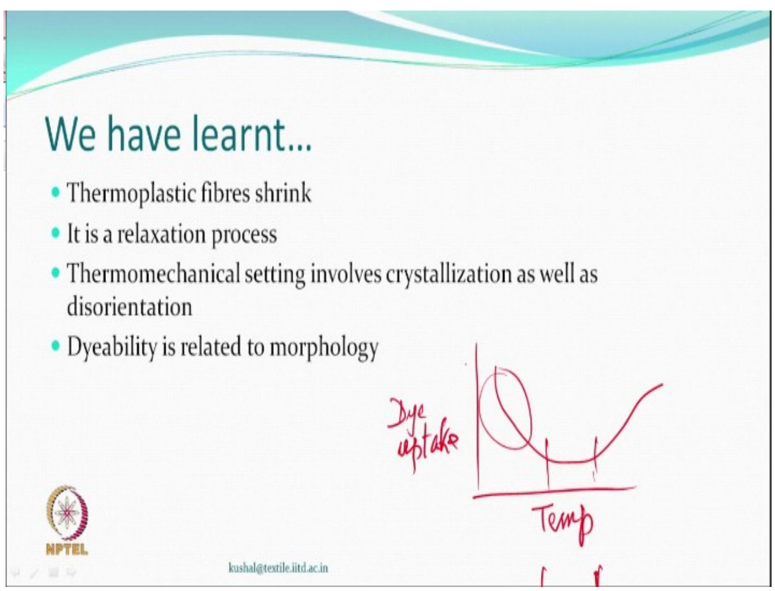

So, what have we learned? We have learned that the thermoplastic fibres shrink and that is akin to a relaxation process, where the molecule which was already stressed quite a lot and now shrinks to relax, which is thermodynamically feasible process where as we say, the entropy increases. It also involves development of crystalline structures, which in some sense, is responsible for reducing the internal energy which is also good a thermodynamic process to make systems more stable.

And this morphology which develops during this process of heat setting can affect the dyeability in one way or the other, if somebody asks a question at what temperatures you should be dyeing for example, you got a very interesting temperature go curve, a curve like this, what should be the nice temperature is art of the dyed is concerned, dyed would you prefer a temperature range from here to here, where if there is a variation in temperature, the change in the dye uptake will be least.

If you start dyeing here then a small change in temperature can change the dye uptake more and you can have known in uniformity in the dye uptake and so that may not be a good idea. So, that is one simple command. Next time when we meet, we shall talk about the other important property or finishing treatment which is antistatic, which is specifically required for the synthetic fibre fabrics. See you next time and enjoy till then.