Textured Yarn Technology
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Lecture – 9
Influence of process parameters

So, we are still on false twist texturing and we have covered material Parameters and their Influence. And today we will concentrate on Process Parameters.

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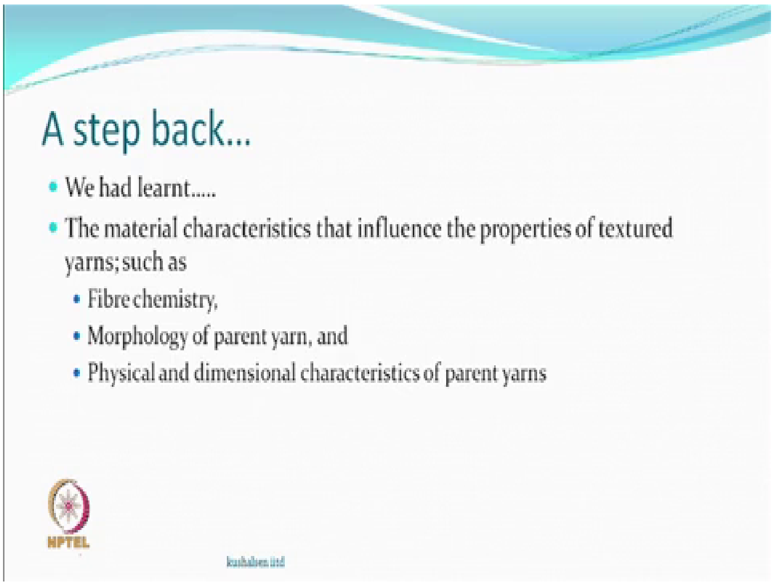

So, we had seen the effect of fibre chemistry morphology of parent yarn and physical and dimensional characteristics of parent yarn and their influence on the properties of textured yarn likely influence. So, we come now to the process parameters, process parameters are those parameters which we can control definitely, in the case of material parameters if somebody wants you to texturize polyester we cannot help it.

If I want 200 denier then that is it. So, you know the influence of a totally denier or denier per filament or the material characteristic, but you may or may not have much influence on the material, you may not be change. If there is a history that it was already drawn and texturized drawn and heat set.

Then the crystallinity will be different and because it will be different, then you have no choice except to understand if it is more what will go do if it is less what will you do.

And how will you optimise this is the way you will act optimise that you will choose some process parameter, which you have complete control and then based on the material you would optimise those.

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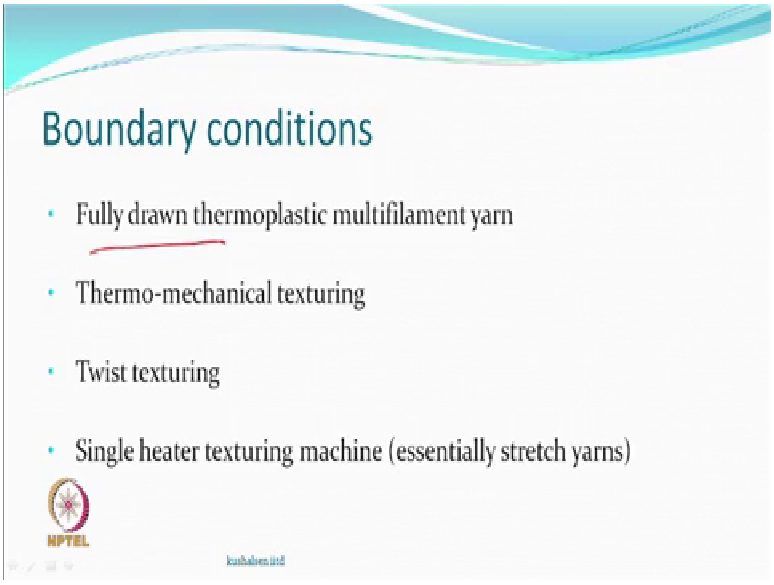

So, we still remember that we talking about fully drawn material alright, because one which is fully drawn behaves in different way and that is what is our constraint at the moment of course, they are thermoplastic thermo mechanical, twist texturing and single heater machines and the products based on single heater machines is what we talking about.

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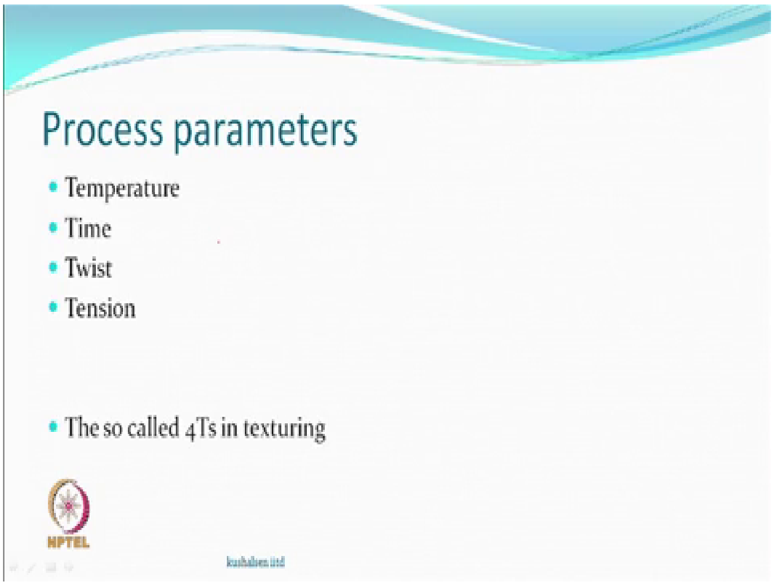

So, we look at the process parameters there are 4 Ts of texturing; the temperature, time, twist and tension. So, you have a possibility of changing any one of these on the machine and therefore, optimise the process. So, temperature, tim,e twist and tension the 4 Ts of texturing.

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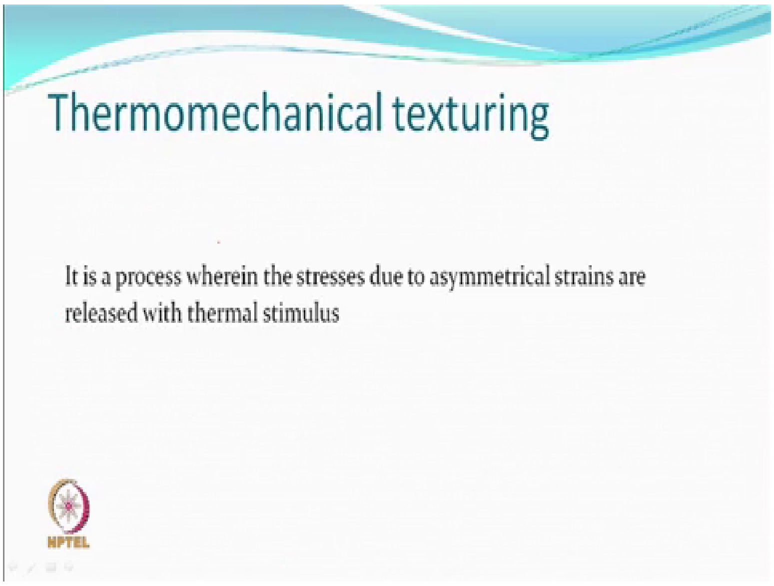

So, what is thermo mechanical texturing? It is a process this sentence you may just try to remember, it is a process wherein stresses due to asymmetrical strains are released with some thermal stimulus. Asymmetrical strains; obviously, different portion of the filament different filaments within the yarn may not be strained to the same extent. And therefore, the asymmetrical stresses and these are being released and therefore, the setting is because of release of energy. You already seen the mechanism therefore, this is just one interesting part.

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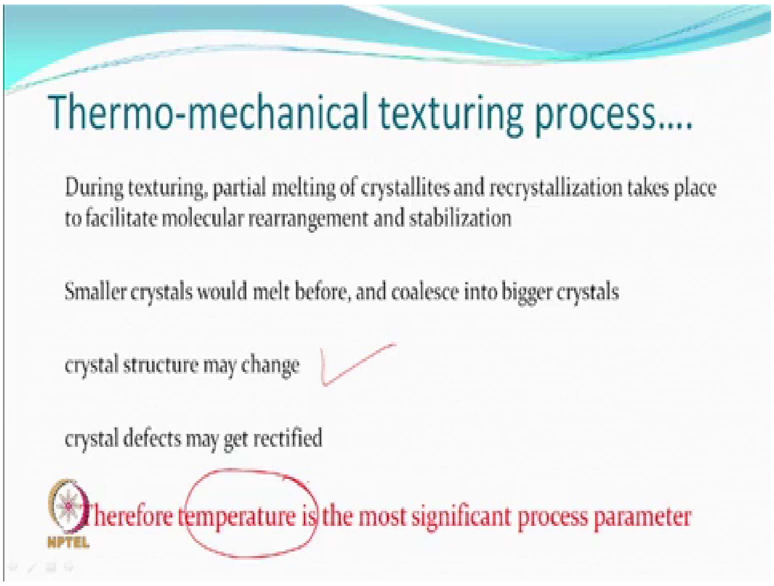

So, first sentence we had already talked about that during this process, during this texturing process, there will be partial melting of crystallites and recrystallization this would be required to facilitate rearrangement of molecules and also will involve stabilization. During this process also we can expect smaller crystals, if suppose there is a history of let us say heat setting or drawing, some crystals may have been already formed, you can appreciate that all the crystals would not have the same size same dimensions like all molecules in a polymer also do not have same length or degree of polymerization.

So, smaller crystals; obviously, may melt before and may also during this process collides into bigger crystals. The crystal structure may also change which we said maybe if there are structures which are less stable, they may go into a more stable structure. And if there are crystal defects they may get rectified during this process as well. So, the most important parameter therefore, is temperature because all these things are going to happen at a temperature which is optimum for that material for texturing. So, temperature becomes an important process parameter.

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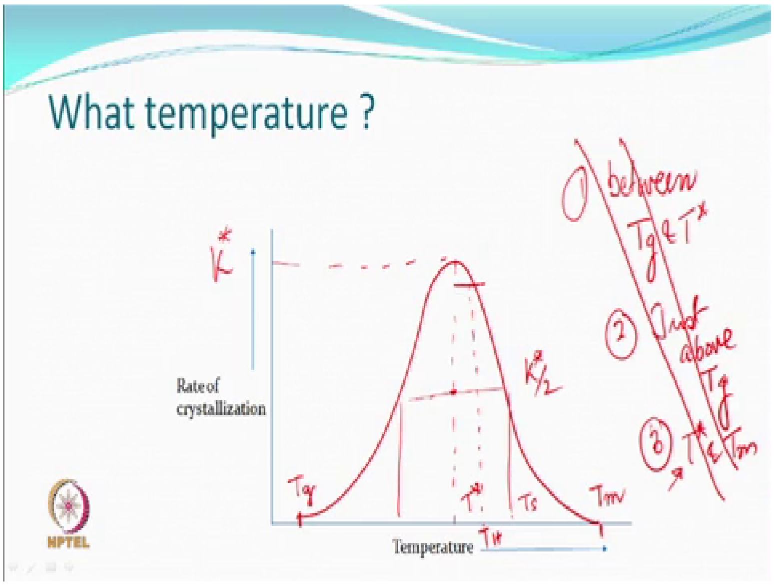

So, we talk about temperature of texturing. So, at what temperature should we be working on? This is very clear that if you have polypropylene chemistry is different against for example, the polyester the nylons and therefore, the temperature optimisation would definitely depend on what material you are going to texturize. So, that will be for example, the melting temperatures you are quite aware, someone melts around 250 to 260, one melts at 215 to 220 the other melts at 170 and therefore, all the temperatures that you will use for texturizing and optimisation will be different and therefore, temperatures are there.

But let us say we try to plot rate of crystallization, versus temperature, rate of crystallization is also chemistry dependent for example, when we said we have polyester which has got aromatic rings in the macromolecule versus nylon 6 which is aliphatic and more flexible versus polypropylene, they all have different rate of crystallization. So, even if we do not talk about the value of the rate, we can look at a generalized curve of rate of crystallization versus temperature.

If we take any polymer which now we are talking about thermoplastic material which melts. So, you heat it up or you cool it from the melt. So, it is going to follow a certain uniform bell shaped curve, where at a particular temperature the rate of crystallization will be high, let us say a temperature called T star, where the rate of crystallization is high. At some temperature somewhere here, this may be the melting temperature, where everything is in molten shape condition and so, you cannot expect crystallization to take place.

The kinetic energy is too high, molecules are vibrating and therefore, they are coming together to either orient or coming together to crystallize is almost 0, because you said is all molten. The other side also is a temperature which can be considered as the glass transition temperature, below which we believe the material which is the polymer behaves like a glass means, it is frozen the vibration levels are very low the molecules will not have enough freedom to do anything alright.

So, roughly all the material like this with give a rate of crystallization curve with temperature which is a bell shaped curve. So, it is clear the texturing temperature cannot be glass transition temperature and the crystal the texturing temperature cannot be melting temperature all though. So, it has to be in between and somebody wants to ask what will be the crystal texturing temperature we will have to say something else.

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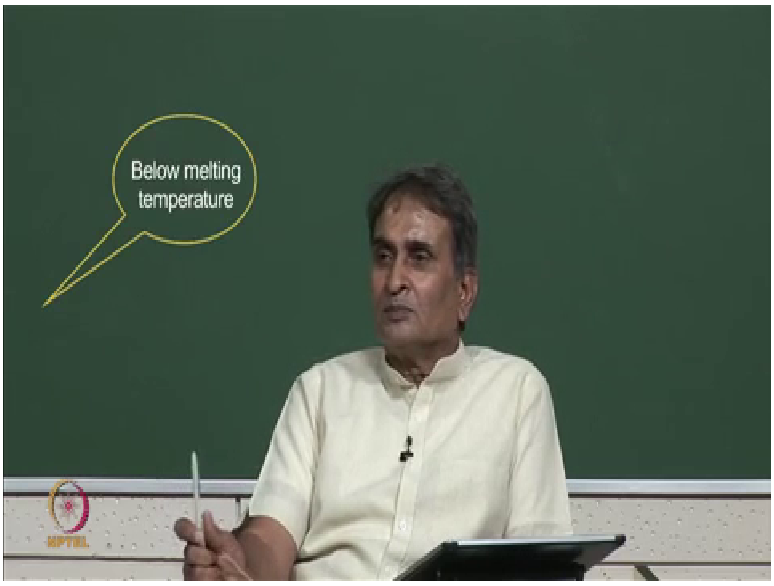

So, what you think should be the temperature of texturing for any polymer, by look at and just looking at this curve.

Student: (Refer Time: 10:02).

Yeah.

Student: Below melting temperature.

T star.

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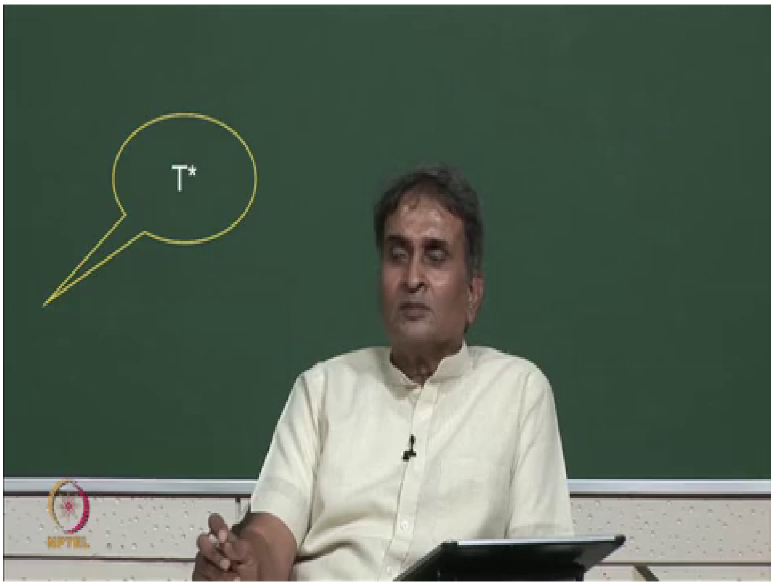

Student: T star.

No, so not the T star, anyone else would like to comment on this.

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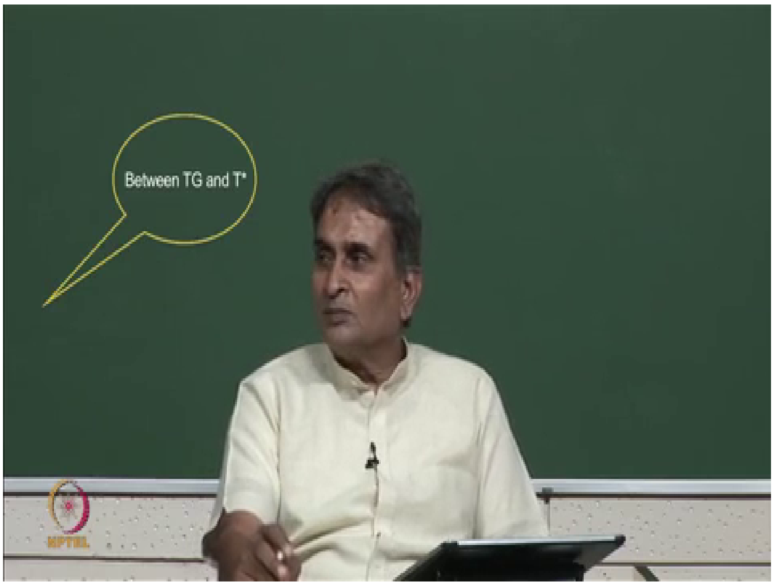

Student: Between TG and T star.

So, I am just writing something one option that has come to us is between TG and T star, other option was just above TG any other option there is another one also between.

Student: Between T star and T m.

Between T star and T m between between T star and T m good. So, we have large range we have covered everything, for somebody may like to understand why should it not do at T star. What are you likely to lose if the temperature of the polymer is actually at T star what are you going to lose? Before this let me just also say, if that at T star if the value of the rate is let us say K star. So, at K star by 2 you get a temperature which is also close to softening temperature, the material is still solid, but it is softened.

So, there is no doubt that above glass and sand temperature, there will be an activity above T m there will be no activity as far as the crystallization is concerned, but as you keep reducing the temperature. The opportunity for the molecules based on whether any kind of a nucleation is possible, they may start coming together. So, theoretically there should not be any reason for someone to say that I want any other temperature than T star theoretically. Similarly if you go above softening temperature the difficulty levels may come that the material is softened and the individual filaments may start fusing with each other.

So, they are still solid, but there is a compressive stress you have twisted, there is a compressive stress softened material, it may get fused a some filaments get fused with each other, then they are aim of texturing which said that it is a twist free bundle of twist lively filaments and we actually believe all the filaments are free to do what they want to do a 50 percent of them can do something and the other 50 cannot do, then you will not get a better thing. So, one thing which can be quite we can be sure is that we do not want to go below go above the softening temperature.

So, why should we not be at T star which is the rate at which this happens, there is no reason actually except that we must be sure that actually you are at T star, what does it mean when you say I am controlling a process parameter called temperature, what are we controlling we are controlling the temperature of the heater plate, if it is touching. We may have difficulty in measuring the temperature of the yarn at any given points in the heater, 3 you can also appreciate that the yarn which enters the heater is at room temperature and its temperature keeps rising as it is moving in the heater. As it is moving in the heater so, which temperature are we talking about, the yarn temperature or the heater temperature?

So, if we talking about heater temperature, then we actually do not have any measuring controlling device, which is measuring the temperature of the heater and then saying, let us say we are at the optimum crystallization temperature. If this curve is true so, the polymer definitely will have the highest rate of crystallization; highest rate of crystallization means, the time required to finish the process will be less, why should anybody not be interested in this alright. But there is also an important factor that first we have no control on the temperature of the yarn we only hope that this is it, this is going to be it at some point of time in the heater because temperature is continuously rising. So, you have control only on the heater. Then the rate of transfer of heat from the heater to the yarn will depend on the difference in the temperature.

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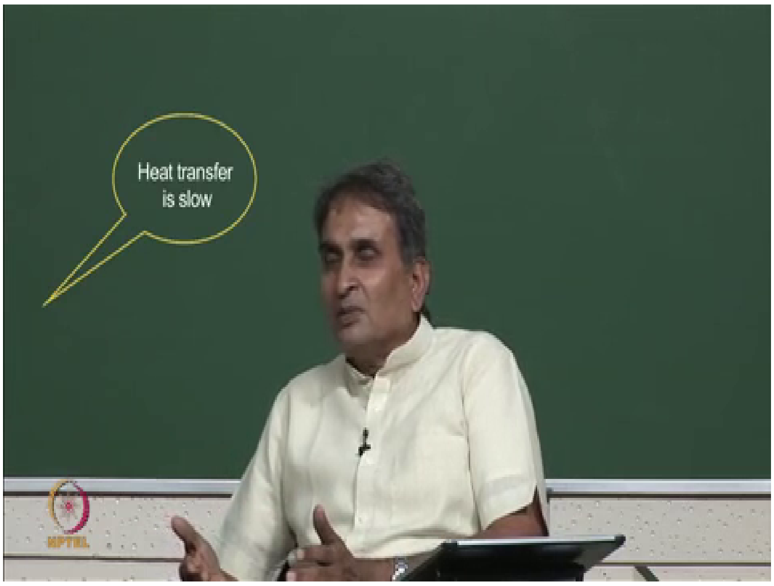

So, as the temperature difference will keep on going down obviously.

Student: Heat transfer is slow.

The rate of heat transfer will be slow, when somebody said we can have between T star and TG. So, you can probably get to that temperature, but which will always be less than T star; is that true? So, you are actually designing an equipment saying well we will be below T star always, but possibly you should design an equipment saying that I will be likely to be near T star and so, in a situation where the temperature of the yarn is rising from room temperature to a particular optimum temperature, we are wanting to set the temperature of a heater which would; obviously, transfer the heat and; that means, its temperature should be higher than the expected temperature.

If is less than that then; obviously, that expected temperature will never be reached so, that does not mean a good design, or an optimisation. So, if we look at the temperature of the heater this definitely will be so, these things we are for the time being saying no we are not happy with this. So, in some sense it will be between softening temperature and the T star, generally maybe let us say this maybe the temperature of the heater which we can control how do we control of course, we like to measure some characteristics of the textured yarn and say well is good is not good.

If it is not good then you will do something take an action and then worry about it, but the control tell us heater. So, one can say well oh you are going at this point therefore, the rate of texturization is a slow therefore, the time required maybe higher yes that maybe true, but it is much less economically burdening a little bit of extra time versus actually not reaching the optimum temperature.

So, the optimum temperature of the heater will be near T star above it maybe 10 degrees above, maybe 15 degrees above based also on what is the denier so, is a very heavy denier then; obviously, it is not just transferring of heat from the surface of the heater to the surface of the filament it must; obviously, heat the inside the filament also inside the yarn also. So, if it is a thicker yarn; obviously, optimization maybe different have a temperature. So, this will be optimised and if you say well I exactly know every day every time you come you are given a polyester 100 and 90 degree is a 95 degree is the good thing or 210 degree is a good thing is not fixed.

So, if what you fixed is that you will try to optimise your heater temperature, versus let us say one interesting property called the crimp rigidity all right. So, based on the dimensions of the material and also the history of the material your time temperature could be different.

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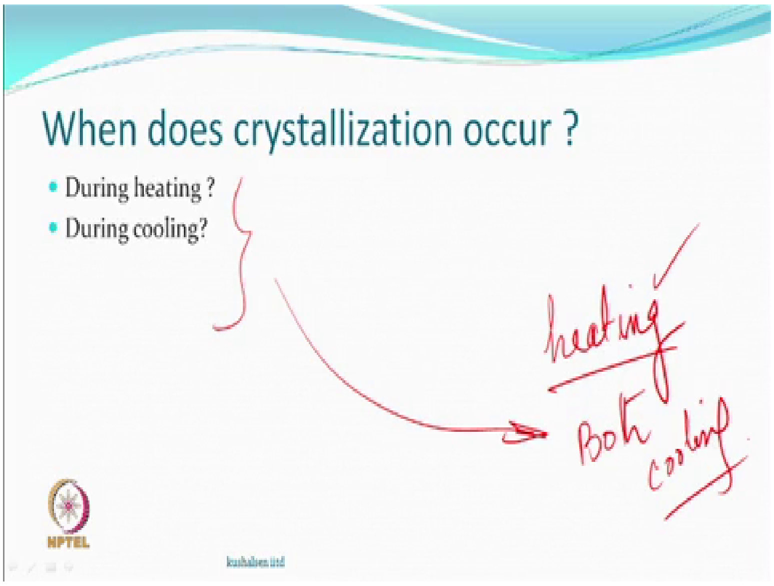

So, another question you may like to understand and maybe you know it already, when does the crystallization occur we said above melting point; obviously, there is no crystallization before glass transition temperature there is no crystallization. And what is our texturing process? Twist, set, detwist and what is set you have to heat which we said we will heat and after that we cool also.

So, before untwisting you have heating and cooling right. So, somebody says at what time or part of a process the crystallization occur, heating or during cooling.

Student: Cooling (Refer Time: 21:50) will increase.

Yes, heating and somebody said both. So, anyone else, so we see our curve crystallization happening. So, rate will keep going down as you cool and you may actually go below the glass sensitive temperature we said after that you will be safe, no more change can take place and you may like to cool as much as possible.

But we definitely must say that during both these processes crystallization can take place, during heating decrystallization also takes place; did we say that you have to do partial melting? So, it does not mean that crystallization not taking place where is the melting happening and there maybe recrystallization also happening, this curve is wide and the melting is not taking place at one particular temperature only, it may start before alright. But smaller entities are melting is not the whole fibre is melting because when all the crystallites melt, it is melt.

So, it happens during heating, it happens during cooling rates maybe different and then we can get a textured yarn. So, that is the crystallization part of it which is important, randomness and disorientation will happen, but a good amount of stability that we say dimensional stability recovery from deformation, all those are going to be more governed by how much crystallization we have done.

So, this good amount of crystallization and that is how the fibres were also the problem is also selected for texturing, would depend on how much crystallization takes place after or during texturing and it will help to make the crimp rigidity better and maybe stability also better under repeated loading unloading stress and recovery cycles.

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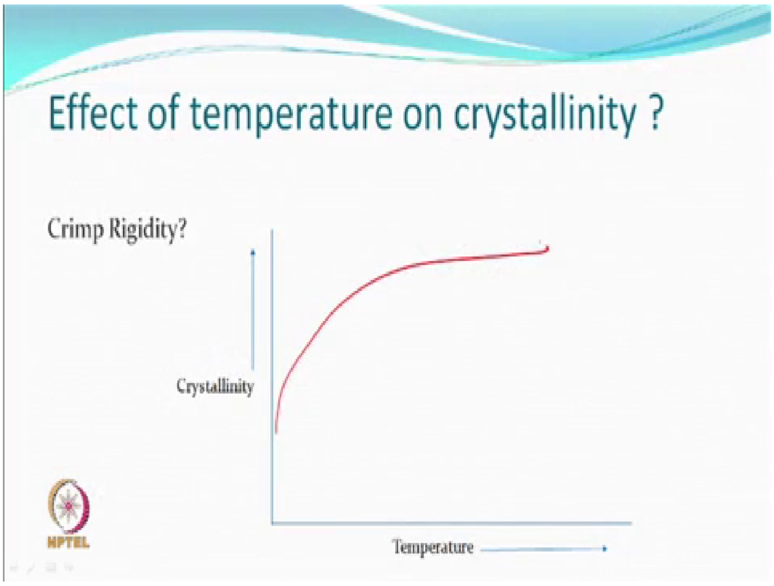

So, we come to the most important thing when we want to optimise any temperature or heat and temperature, the effect of temperature on crystallinity alright. So, we know something about rate of crystallization. So, let us talk about the crimp rigidity, remember the rate of or the effect of development of crystallinity would also have something do with the crimp rigidity. And therefore, let us first understand what would be the effect on crystallinity. Let us also appreciate that when we talk about variation in temperature, we would not be saying well I am varying the temperature from 0 degree centigrade to 260 degree centigrade in texturing.

We already said below glass transition nothing happen; obviously, and then we also have a ballpark figure of what temperature of heater you like to use. So, let us say you get yourself a margin of 30 to 40 degrees in which you will optimise, this is no point in getting a margin of 80 degrees to optimise, because then the experiments will be too many all right. So, let us say without talking about a polymer, because this temperature will be different for different polymers.

Let us say I am interested in measuring crystallinity texturing has been done and after that I have taken it and measure the crystallinity let us say wide angle crystallinity wide angle X-ray crystallinity.

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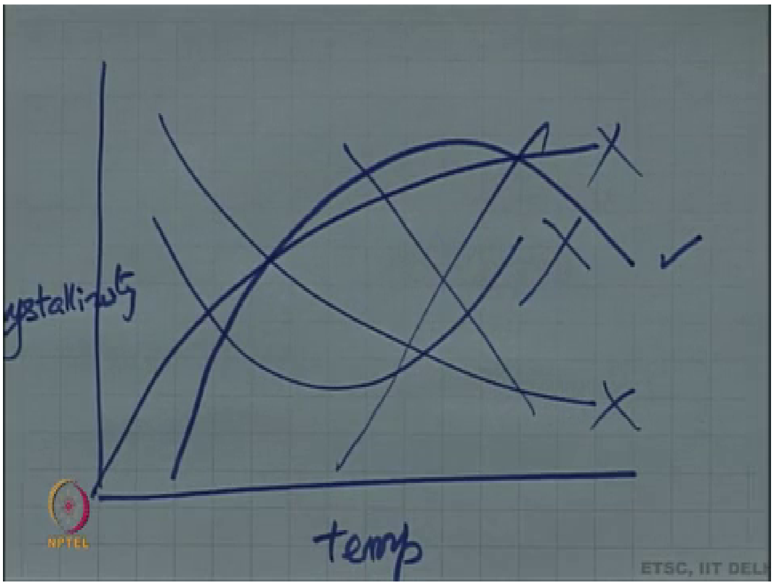

So, what do we expect is a curve, any guesses? How do we think it will go like this, yes or no, like this? no and then this way this is also no this way yes yes no.

Because unless and until you are going towards melting temperatures going close to the melting only then you can expect crystallinity to go down, because then the crystals that I have been generated will also melt alright. So, if we are looking at temperatures which are in the range in which material is softened off rates are high enough, crystallization can take place and if we just recall as to what type of temperature that we talking about heat and temperature, which is quite close to the rate where the temperature where the rate of crystallization is higher alright.

This is how? So, what we expect then? The expectation will be that it will like to go and take up a curve and rate of crystallization rate of rise in crystallinity will keep coming down as the temperature is moving, because you are getting the highest values, after that the molecules may not have you know they get jammed and then getting more freedom from some other part of the molecule to come back and again crystallize will keep on reducing, so, will come to a state which may be quite jammed up state.

And after that increasing it further will be difficult, because after a long molecular chain absolutely not free it is held up somewhere else also, held somewhere else also as long as there was a possibility of chain folding it could, but then after it may not be possible. So, it is like jamming, as far as the crimp crystallinity is concerned; as far the crystallinity is concerned, it will start from the parent yarn which may have whatever level of crystalinity you can appreciate that a fully drawn fully drawn polyester yarn may have crystallinity of the order of 25 to 28 percent. A fully drawn nylon let us say yarn may have crystallinity 35 to 38 percent which is not been heat set.

And a fully drawn polypropylene may actually be having crystallinity of the order of 70 to 75 percent or even more; are you getting the point? So, all of all the 3 fibre which are typical fibres are very responsive to texturing and the heat therefore, but the rate of the crystallization the very high and therefore, during preparation itself you can have a good amount of crystallity generated and during drawing also. And then you texturize so, from that level I will go to whatever higher level it can go. So, it will go to a level and then stabilize unless and until you say while I am going to keep on heating till you melt well that is it.

But then there is no texturing, even you cannot go up to softening point no melting there, but is still bad because the fibres are going to get fused and get stuck with each other which is not good that so. So generally in the range in which will be interested in optimisation, you will see the crystal and crystality rising of a parent yarn going up to a certain level which depending on what can do for example, in the case of polyester you may actually go up to 55 percent to 60 percent, starting from almost 27 percent which is quite a good amount of rise. And therefore, structures becoming more stable, but we expect in this range this will not happen.

Then we look at this value which of course, the whole reason why we are texturizing is we want crimp characteristics to be improved.

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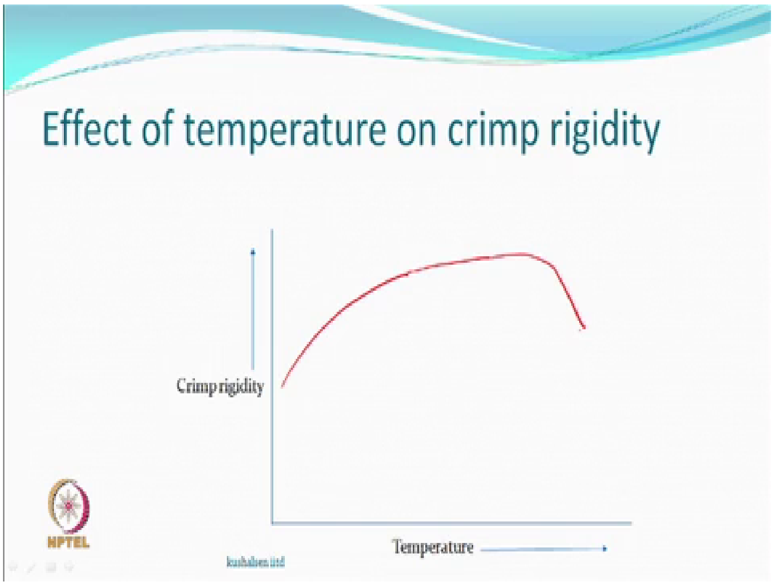

So, you remember what is crimp rigidity by definition so, basically it is a recovery how much it can recover and how much recover after defamation which is fully extended state of the fibre right. We are not talking about fully extended state of molecule, we talked about a filament yarn, the crimps have gone when you put point gram per linear load, molecule still have are enjoying freedom alright. It is very difficult to orient all the molecules in any direction. So, that is the crimp rigidity part of it.

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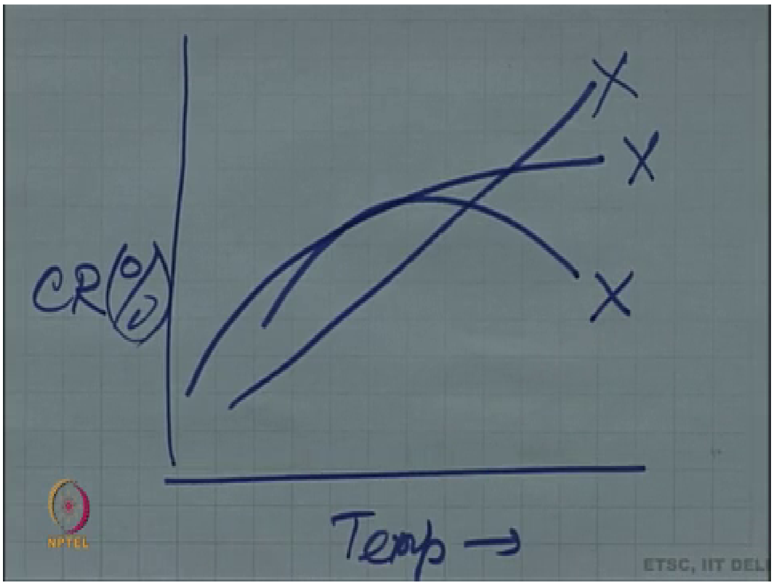

So, let us see what kind of expectations do we have temperature and now crimp rigidity percent, you now aware is to how what is happening to crystallity alright. And then now way say what happened to crimp rigidity, some guesses; will the curve is similar to the crystallization curve?

Student: (Refer Time: 33:11).

No ok; if it is no then there must be some curve, can (Refer Time: 33:19) the riser like this, yes no ok, then follows this curve; yes no? I can only see some heads moving so, I am just guessing no. Then what? Yeah this one so; that means there is nothing. So, we will have to go to the lab and do whatever experiment we have done.

Let us say you want to actually measure obviously, it should rise; do we believe that should rise when we increase the temperature of texturing, or no? That should rise, because by increasing temperature you are going to be facilitating the partial melting there is an important thing before crystallization so, partial melting and then recrystallization alright.

So, when you increase the temperature, then you increase the temperature then the crimp rigidity should improve because crystallization is also going to take place possibly reorientation rearrangement also has been facilitated. And therefore setting is better, if setting is better then you should expect that the texturing is better means crimp rigidity should be rising, its rate also should keep going down, because you may not be able to increase the crystallinity and therefore, more things mere may not happen.

But it is seen that the crimp rigidity can start falling after certain temperature; obviously, which you will say will it in did not appear to be bad temperature why it is falling so, you will stop, somewhere there and that is the time when either molecular degradation can become also significant factor you are giving temperature and time. And; obviously, this texting is not being done under nitrogen environment, the environment is normal air environment. So, there is oxygen anything with you heat in oxygen for a certain period of time there can be after little work you can stay well there the crimp rigidity goes down.

So obviously, you at least have some reason to stop somewhere and this will happen much before the softening temperature, sometimes in the case of polyester it is also been seen, that polyester has crystallized quite a lot, it also has developed enough crystallinity. And therefore, when you untwist, there is a lot of resistance to untwisting, but machine is stronger than the fibre and during this process people have seen cracks being developed on the surface alright.

That means, you are becoming so, rigid then you want to do the untwisting which is against the wishes and so, beyond the certain point there can be degradation, there can be mechanical breakdown of surfaces and therefore, because of rigidity.

And therefore, much before when we expected that the crimp rigidity go down and any other reason which may fuse the fibres will also make sure the crimp rigidity is not good enough. And so, crimp rigidity would fall beyond the certain temperature, although crystallinity has not fallen and right, it can still happened.

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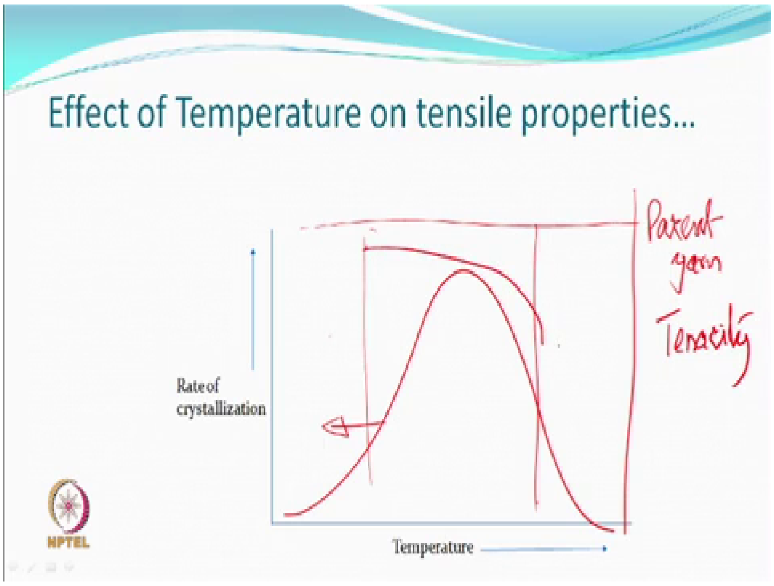

So, on a tensile property although we said tenacity of a textured yarn is not so, important, but at least it should know what is happening ok. So, is the same kind of temperature range in which we want to work, we quite sure as to what is the rate of crystallization which we may let us say want to plot this will be always like this, but let us say I am interested in tenacity.

So, what would happen to the tenacity of a textured yarn? We recall crystallization will happen it gives you stability rigidity, but what is the texturizing process? During this process the textured yarn or the yarn under which is being subjected to heat treatment is not a parallel bundle of elements, it is not a parallel bundle of elements; what is it? It is a twisted bundle. So, the texturing is taking place or heat setting is taking place while the yarn is twisted.

Now, would you like to say what is the tenacity effect of temperature on tenacity yeah decreases alright, will it be lower than the parent yarn or increase and decrease what it will be lower than the parent yarn. So, let us say the parent yarn tenacity is this. So, if we look at the same kind of range let us say we are working on a range of this type because that is a optimisation. So, the textured yarn tenacity will be always lower and this will only fall.

So, while the crimp rigidity can increase and come down the tenacity of the textured yarn will be always lower than the parent yarn and by increasing the temperature whatever happens the crystallity may be increasing, but the tenacity will go down. So, one thing you probably can now appreciate is that increase in tenacity is not related to tensile strength in a direct manner right, if it is not crystalline it will behave differently, but you can always have an system which is more oriented.

So, when we talk about tenacity it is the orientation of the fibre which is more important place important role, than the crystallinity which we have seen now that the crystallinity could be high, but the tenacity can go down and keep going down. And you go further and further it will keep going down further molecular degradation, all kind of other things fusing a filaments everything will be responsible for decrease in tenacity.

I am not talking about elongation so you can try and appreciate what will happen to the elongation of the fibre, when you are doing all this. So, at kind of a when you sit down at home and trying to revise, try to see what happens to the elongation of a textured yarn.

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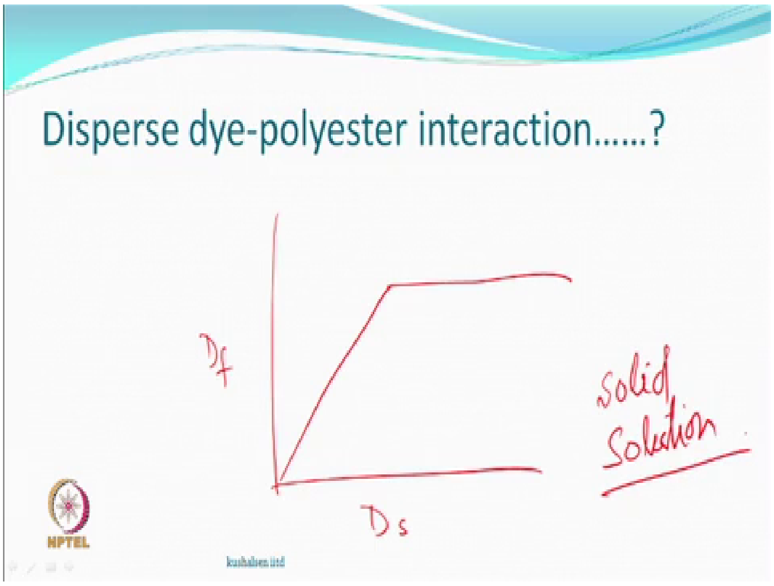

So, although this does not appear to be very interesting as for a texturing is concerned, but let us say we try to understand what it is; polyester I have just said, for an example disperse dye is another type of a dye. You understand what is the disperse dye?

Student: (Refer Time: 42:13).

Yes or no? Yes and a polyester you understand the disperse dye can dye polyester it can dye in alone it can dye under difficult you know (Refer Time: 42:7), it can also dye polypropylene under certain circumstances all right conditions have to be different.

But the important part here is the curve that you have relationship, if you have dye in solution versus dye in fibre, you are dying with the disperse dye some of these materials ok. Then we see a curve like this that there is some space; obviously, dye cannot go into the crystalline portions. So, there is a space which is the amorphous phase the dye diffuse in there and this curve; obviously, talks about something called a partition coefficient. So, die in a fibre at an equilibrium will always show this kind of a curve alright, this is the partition coefficient or some time it is also referred to add as solid solution ok. So, we will just try to see if we can complete this part today and at least get some interest in.

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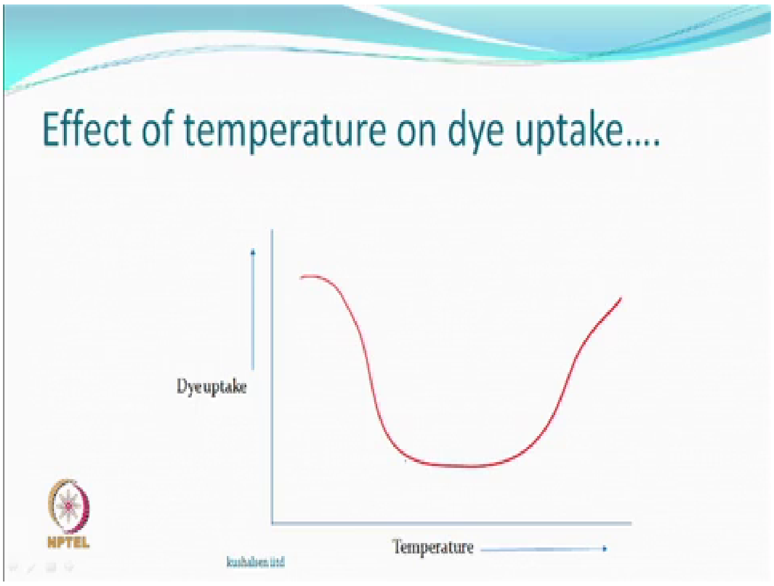

Suppose I am interested in plotting I am doing texturing at different temperatures and I also want to know what is a dye uptake of a textured yarn ok.

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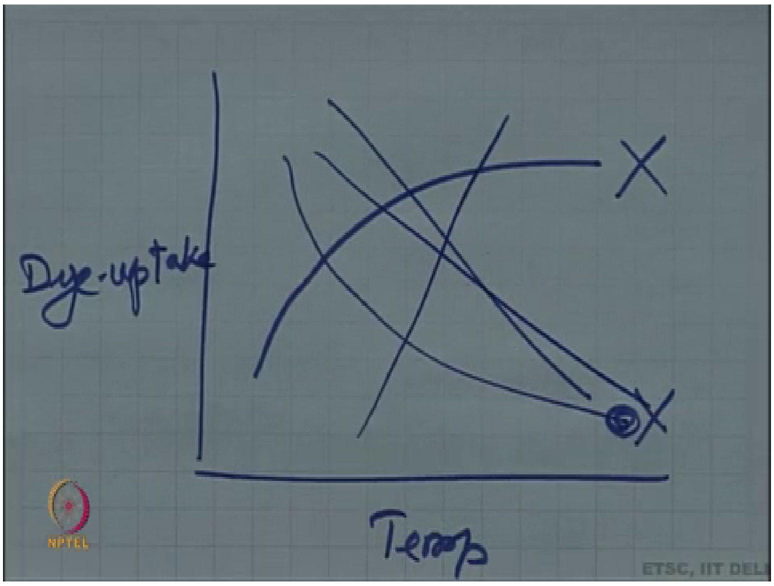

What do you think would be happening if I have to plot temperature versus dye uptake what type of curve have expecting.

Student: (Refer Time: 44:31).

Increasing and stable increasing and stable anybody else, because let us say I have some kind of discussion we have got two more minutes ago and we did say that the dye will go where in the amorphous region of the fibre. So, is this curve ok?

Student: (Refer Time: 45:03).

Yes or no?

Student: No.

No? No so, which is the curve would like to have? We will like to have this curve, is this ok? No this is also not ok, then what do we have this curve straight, will this curve v inverse of the crystallity curve yes or no?

Student: Yes.

Inverse of crystallity, then why we are saying this is no alright. So, anyway you rejected I am also rejecting, what people see is a curve like this. A curve where dye uptake is decreasing, is decreasing because crystallinity is increasing so, dye uptake is going down. Then there is some kind of a thing which is nothing is changing more or less depends on this curve can change a bit of a width and then starts increasing interesting. If it is interesting then we leave it here and if it is understood then anyway you will have the answer, if it is not understood then we will discuss it later. But this is a important observation and for practical consideration this is going to be interesting. So, let us see if you can find an answer so, we stop here today.