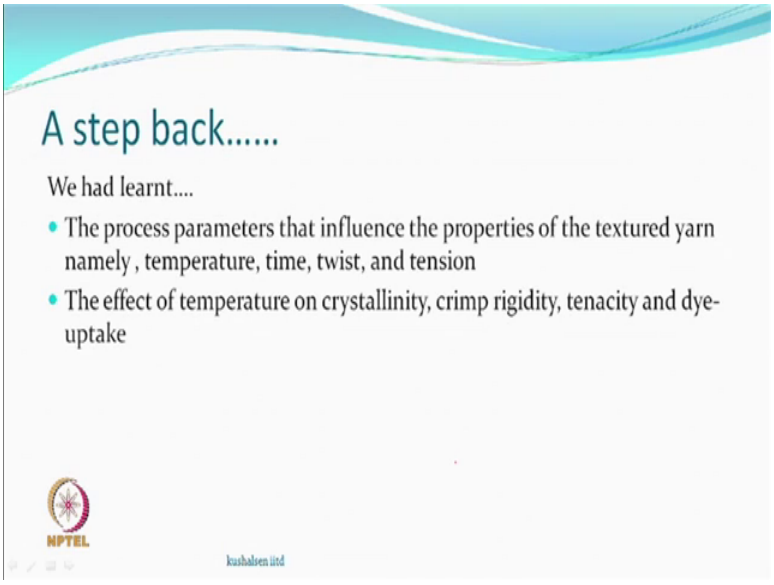
Textured Yarn Technology
Prof. Kushal Sen
Department of Textile Technology
Indian Institute of Technology, Delhi

Lecture - 10
Influence of process parameters contd

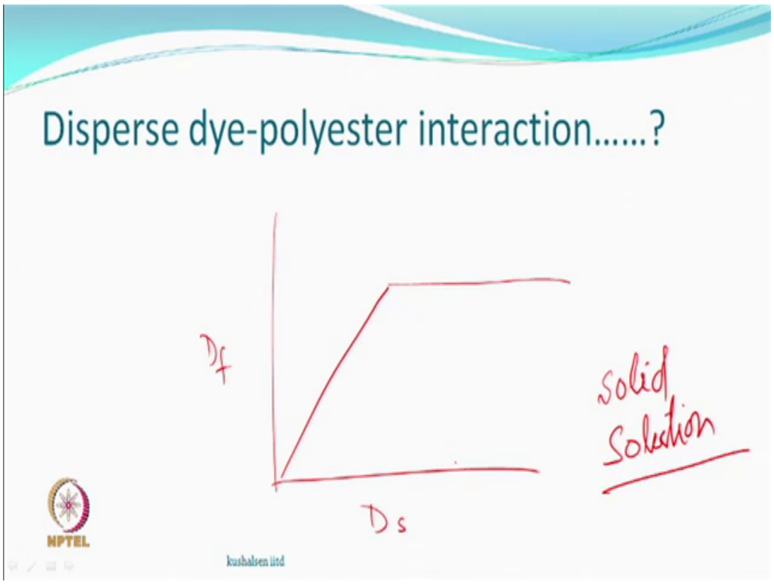
So, we are continuing with the False-Twist Texturing, Influence of Process Parameters. We are continuing this as we had only covered part of the effect of temperature.

(Refer Slide Time: 00:35)



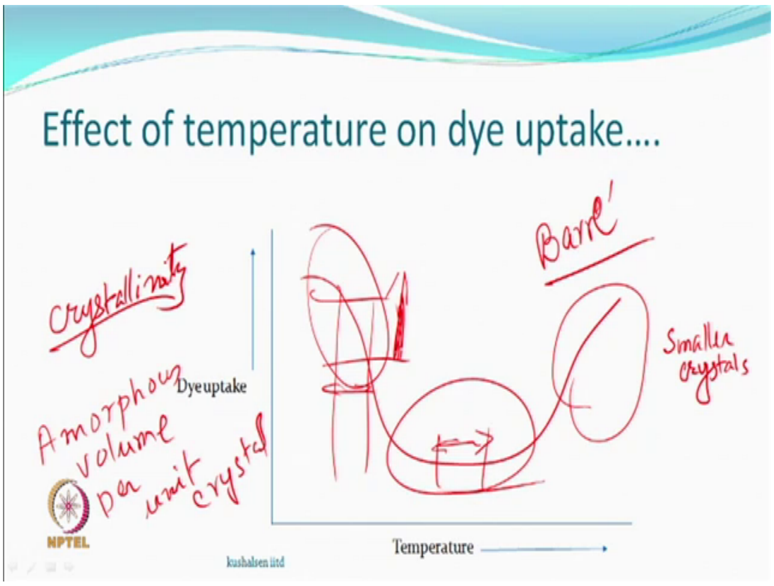
So, process parameters which we understood over temperature time, twist and tension. And we did study the effect of temperature on crystallinity, crimp rigidity, tenacity and dye uptake.

(Refer Slide Time: 00:55)



As per dying is concerned, we were talking about a dye like a disperse dye on a polyester where the interactions are in a manner there which is not dependent upon the n group ionic or cationic nature, with basically dependent on how much amorphous content is there. And that is what we believe happens during texturing, the changes in the crystalline content and the amorphous content and so does it have any influence. This is what we wanted to learn.

(Refer Slide Time: 01:37)



And after some discussion we came to state where we said the dye uptake initially decreases because the crystallinity is increasing and the dye can go only in the amorphous region. But thereafter it again starts increasing, and we left it at this point saying that maybe you would like to say something on it. Anybody would like to say something on this?

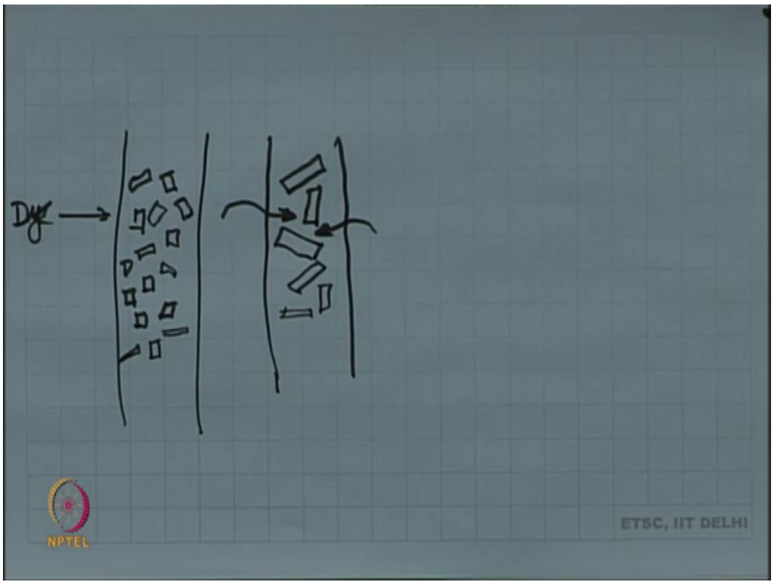
Student: Sir, due to recrystallization the more free space will be created. So, dye uptake increases up to certain temperature around after 180 degree or you can say that after 160 to 180 degrees.

So, you are saying that the recrystallization is taking place because of that. The whole thing is recrystallization that is why the temperature dye uptake is going down, because if there is more crystal formation amorphous content goes down. So, why would it start increasing?

Student: Smaller crystal became bigger.

Alright. So, this is one interesting thing is that after certain temperature, the crystallinity may not increase too much, but smaller crystals can collies and become larger crystals. So, there is a concept of amorphous volume per unit crystal. And if for whatever reason is not the total amorphous content, but the amorphous content associated per crystal if that increases then there is a possibility that the dye may defuse more. And so, something like this one can assume.

(Refer Slide Time: 04:19)



So, there is a fibre, in this fibre you have smaller crystals of various types, let us say arranged in any manner. A large number of small crystals oriented or disoriented in a fibre depends on what is the percentage. And the dye has to go inside the fibre, and we understand that you would not see any dye inside the crystal structure. So, if you have large number of such smaller crystals, then they do offer some resistance to motion and diffusion. If in the same thing it changes that crystals become less in number and larger in size, I will just, then you have more opportunity for dye to defuse in having less tortuous path and so one sees that the dye uptake actually starts increasing because crystal percent is not increasing so much, but the rearrangement is happening.

Now, this curve which we were looking at how is it important to us. If this curve is true then how is it important to anybody who is texturizing. Whenever we do any texturizing we optimise the temperature in this case for that matter, there is going to be a variation. You set it up at 200 degree centigrade; you will have 200 plus or minus some degrees. Now, depends on how much accuracy that you have is it a 0.1 is it a 1 or is it 2. So, based on that at any given point of time as the fibre or yarn is moving in the texturizing machine sometimes it may be actually having a temperature higher than the average, sometime it may be having lower than the average.

And if the dye uptake of this material depends on the morphology, morphology whether larger crystals are present smaller number of larger crystals or large number of smaller crystals are present or crystallinity is less or crystallinity is more, then when you finally, dye the textured yarn the yarn or that part of the yarn is going to take different mono dye at equilibrium.

Even whatever temperature that you have fixed the parameter that affects for dying. So, it does not matter so much, but the moment you make a fabric outfit. So, depending upon which type of yarn and which portion of the yarn is coming near the other portion you can start seeing variations in which people referred to as barre. So, as a customer you would like to reject because it does not look good you wanted uniform dying and the textured yarn is not uniformly dyed.

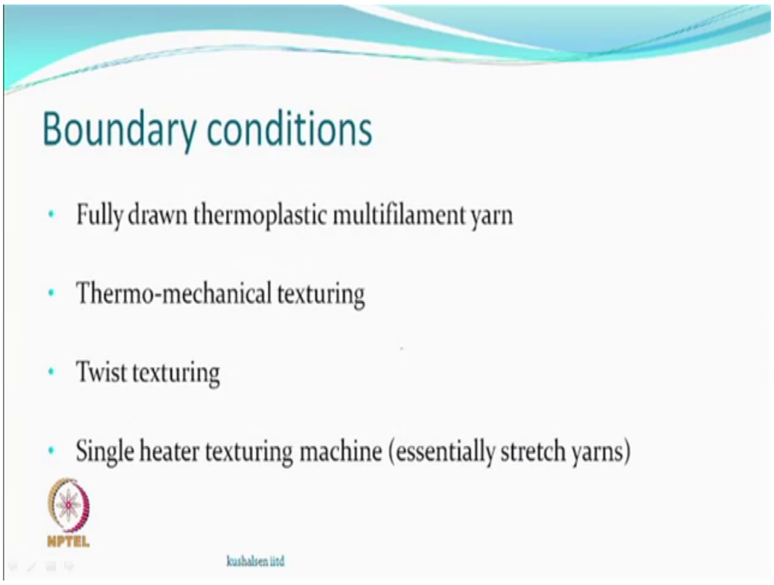
And so, somebody who is optimising the temperature the first parameter that you were looking at was the crimp rigidity because your preparing a textured yarn. And, suddenly you find no their maybe something else also you must look at it and which is not tensile strength or abrasion resistance. You look, want to look at a something if somebody says if you have to setup your machine temperature, suppose this is the curve the curve may be different for different fibres fibre of the different histories that is ok. But you will get a dip what temperature the machine temperature would you like to fix. At temperature which could be somewhere here, at temperature to be optimized here, the temperature to be optimized here, yes.

Student: Yeah.

Flat region. So, now, you suddenly have another reason for you to do optimisation because if you are in the flat region if some variation occurs in temperature and also whatever is happening as far as the dye uptake is concerned which is visible thing it is going to be less. Compared to a situation here where the same variation in temperature can give you variation in dye uptake of this type all right, this much variation and dye uptake which will be more visible. And after all people reject things on the first look, if you can just look see from your eyes and say this is a defect then you are not going to buy. So, a texturizer should not be bothered only about the crimp rigidity and tenacity and what so or crystallinity which of course, most people do not even know how to see it from eyes, this can be more dangerous. So, that is what we thought will be important.

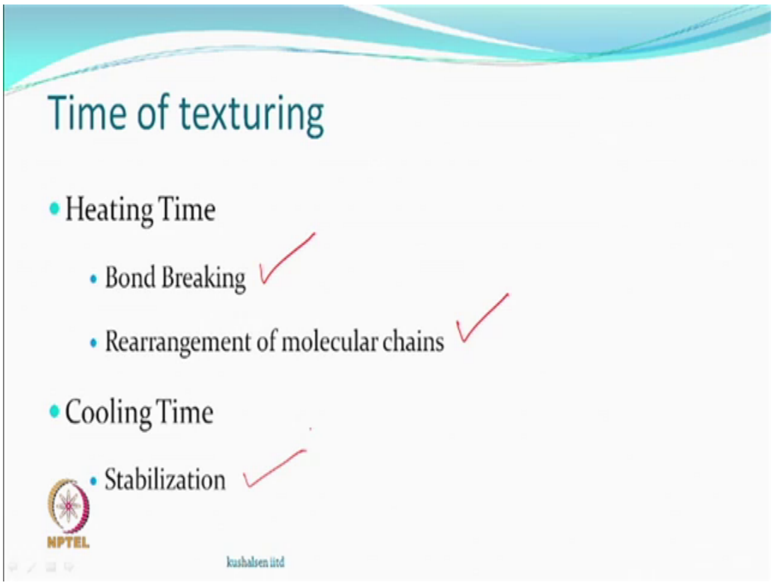
So, the next parameter is the time of texturing. So, we had temperature the next parameter which you can optimise by changing the machine speed. If you can change the machine speed the time of texturing can be changed because the length of the heater is going to be constant for that machine. It can be a different machine with a different length of heater, but as far as one single machine is concerned this is what will be available to you.

(Refer Slide Time: 10:55)



Remember again that the boundary conditions remain the same thing we had all talking about fully drawn thermoplastic multifilament yarns. Twist texturing, single heater. So, that does not change because all understanding is to be within this constraint.

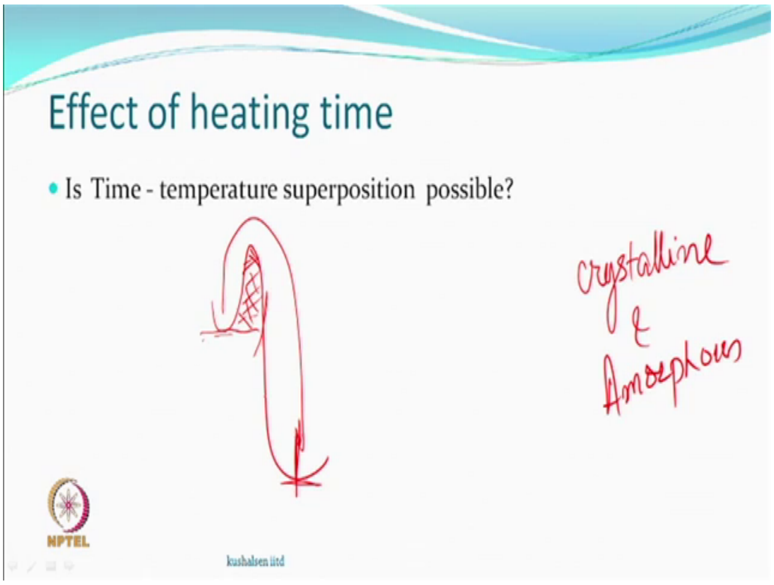
(Refer Slide Time: 11:11)



So, time of texturing can be now talked about as either a heating time or a cooling time. So, that is why we said in a texturing machine you have a heater and then after the heater there is a cooling zone before you do de twisting. So, what is happening? During heating as required a bond breaking is taking place that is you have intermolecular bond breaking so that you get more freedom which could be as you said partial melting or recrystallization and then we have rearrangement of molecular chains in the energetically favourable configuration. So, either they would crystallize or they may disorient, both are energetically favourable. So, this is what will happen.

So, during heating as we can now recall the bond breaking and rearrangement will take place, right. So, crystallization can take place during the heating itself. And cooling is the time where you are interested that the new configuration which have been achieved gets frozen as soon as possible. And therefore, you want to get to the temperatures which are lower than glass and transition temperature so that no further change occurs, so that is that is kind of a permanency, relative permanency that you want to achieve.

(Refer Slide Time: 13:01)



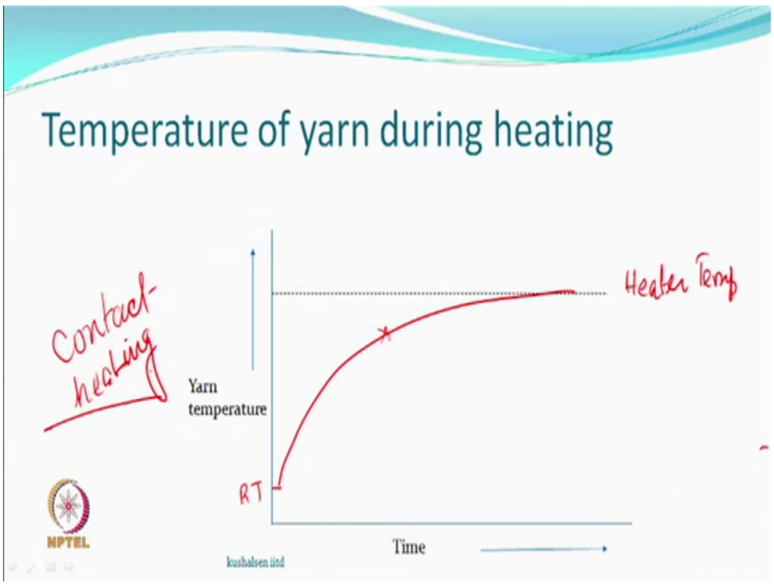
Now, this is the interesting question with somebody you would like to always know. Time-temperature superposition what it means in a process environment is that if I am working at a higher temperature I can reduce the time or I can work at a lower temperature and increase the time. So, from that point of view whether this type of superposition is possible, in what we are considering as a textile fibre, right.

The textile fibre has crystalline and amorphous region that we now understand. If a material is totally amorphous, totally amorphous and has no chance to crystallize in such situation the time temperature super position is absolutely possible but if you have a crystalline region. So, we understand during this process there is one minimum and another minimum and you have to go from one minimum to another minimum for a setting operation. And what therefore, it means also is that you got to supply certain amount of energy before anything can take place.

So, suppose tomorrow you decide that I will like to do texturing, texturing at room temperature leave it for one month after twisting and come back and see the effect you may not see anything; unless and until you give enough energy to overcome this barrier this barrier. If you can overcome this barrier then it is spontaneous. If you are operating in this zone then maybe yes time temperature superposition be possible, but not every time. So, you are got to be in a range and therefore, this optimisation is, that if you are in the range of let us say in a polyester from 190 to 210.

Well, you can play reduce temperature increase time etcetera, but not in a large range where you will say that the partial melting is not taking place is not complete so how will the rearrangement take place. So, in the textile material with a useful textile material which have crystalline and amorphous regions this time-temperature superstition will not be possible in the standard math sense.

(Refer Slide Time: 16:05)

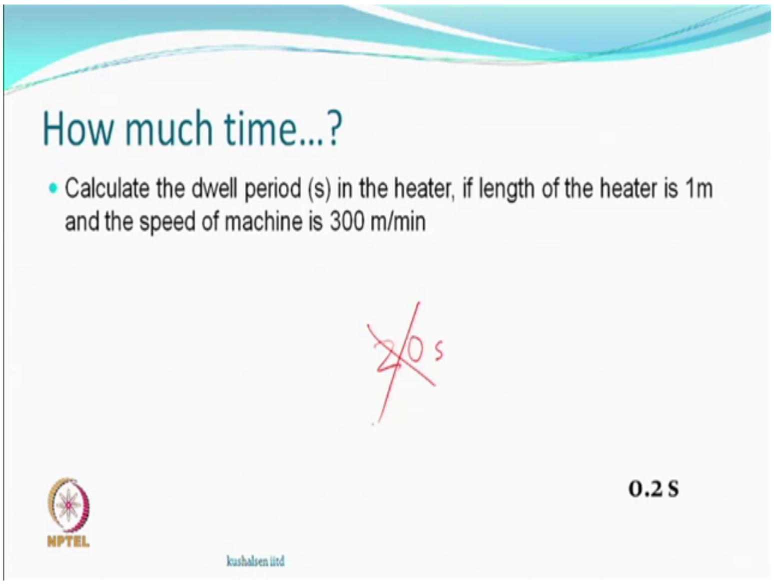


So, we know that the yarn is at room temperature when it enters the machine. So, when will the bond breaking take place? The bond breaking can take place only if the yarn has achieved a certain temperature. So, the time of texturing would have to account for that time as well which is taken to raise the temperature of the yarn from 0, I mean from the room temperature to a certain temperature after which all these things. So, if the time required even to raise the temperature is going to be interesting. What kind of a curve we are going to get here? Let us say this is the room temperature. The yarn temperature will start rising and at best it can be equal to heater temperature.

And suppose this is equal to heater temperature, and somewhere down the line here the bond breaking may also start, rearrangement may also start, and the optimisation can be that yarn temperature is equal to heater temperature and therefore, we say there is no point, no there is a point. You may actually give more time than this also because you are not interested in raising the temperature you are also interested in bond breaking and rearrangement. Therefore, the heating time would be also time required to take it to a certain temperature. And this will also depend on what? The dimension of the yarn also. If it is very fine yarn, find denier then the time taken may be different. And so, this is dependent on the yarn characteristics which may be specific heat which may be the overall denier. And of course, that all is the first part is something to do with the chemistry; the second part is something to do with the dimensions of the material itself.

So, one will be, we are of course, as we said we are doing the contact heating the machine that you have seen and so, should be most efficient way of heating you could have done non-contact heating also. But that is in your control when you design the machine, but after that it is the material how it responds.

(Refer Slide Time: 19:15)



And now this question was important in a sense. So, let us say we have a machine which is a heater length of 1 metre which is the primary heater we are talking about and you want to run the machine at 300 metres per minute, all right. So, how much time the yarn is likely to spend in the heater. So, 1 metre heater, 300 metre per minute. So, how much time will it likely to spend?

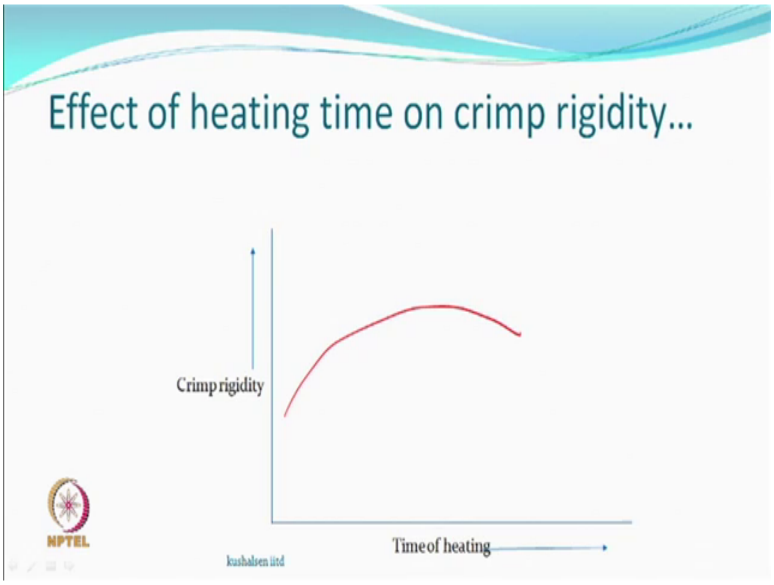
Student: 20 seconds.

20 seconds. I am just keeping writing. Anyone else? Any other figure?

Student: 0.2 seconds.

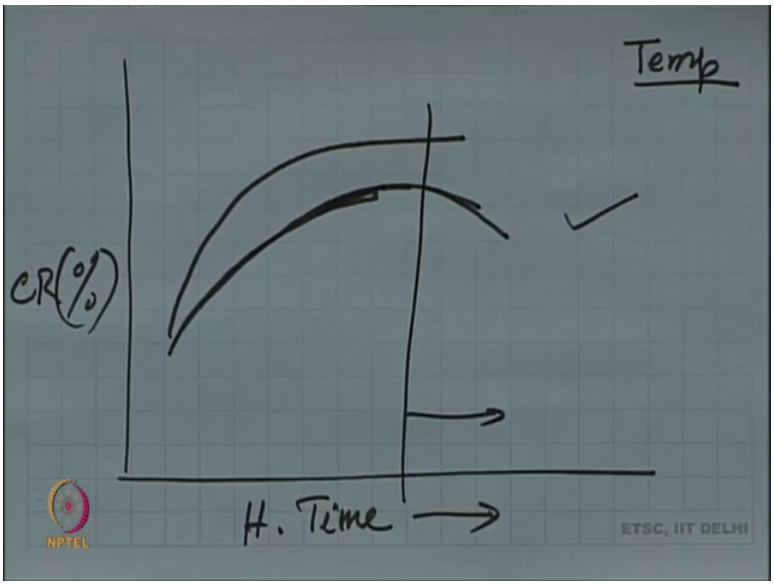
Alright. So, this is not there 0.2 seconds you understand this time. 1 second itself is considered a small, now you are only looking at the machine which you want to run at 300 metres. The modern machines maybe running at 1000 metres or more how much time are you giving in the heater. Look at the expectations. The expectation is that from room temperature the yarn will attain a right temperature and also within this time all rearrangements will also take place. And this is what happens also that means, your material responds. But you have to be as a as efficient as possible that is why the transfer of heat is concerned energy transfer. But this was not to check your calculation, this is or you know this is to appreciate get an appreciation as to this is the smallest so much less time that you have and you are supposed to optimise this.

(Refer Slide Time: 21:21)



So, we would be obviously, interested in learning to what happens when you increase the heating time, I am riding heating time because we have something called cooling times well on crimp rigidity. What do you think?

(Refer Slide Time: 21:41)



Let us have some guesses. Heating time and crimp rigidity. So, what do we think? What will be the thing? What kind of a curve are we looking at? If time is very low what do you expect? High crimp rigidity, low crimp rigidity? You must know what you expect to happen during this time. Any guesses?

Student: It will increase then decrease.

It will increase then decrease, all right. Any other thing? Any other thing that you want? The time you know required to do raise the temperature of the yarn allow bond breaking and rearrangement means either crystallization disorientation what have you so, all right.

Let us say this is, ok. Why does it increase from here to here crimp rigidity? Why? Why does it increase? It should increase because you are allowing time for breaking of intermolecular forces and rearrangement. The more time is allowed the more of this can happen and therefore, more we can say the energy level or the free energy is going down is getting into the most stable state, more stable state means more set and that means, a better crimp rigidity, right.

What is go down then? It should keep increasing or could have become constant when there is no scope for further improvement in let us say crystallization. Why does it decrease?

Student: Melting of crystals and after that sudden cooling, so maybe.

No, no this is heating time.

Student: If temperature (Refer Time: 24:15).

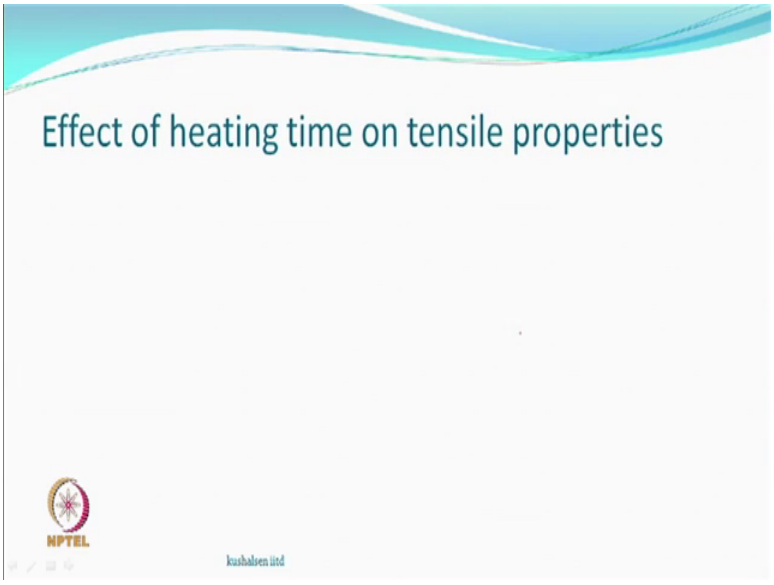
We had not gone into the cooling part as yet. And you can appreciate that we are saying that we have already probably optimise temperature and we are working at a constant temperature which has been optimised, the constant temperature. So, now, the temperature of texturing is constant only the time is varying.

So, have you ever kept any material which is called a polymer fibre in an oven for a longer period of time? Have you ever seen what would happen I never had got a chance to say any material in a oven or a hot environment kept for a long period of time? If you see it becomes yellow, it starts becoming yellow. If any material which was approximately white starts turning towards yellow. You can appreciate that there is some degradation starting. Something which was white it is becoming yellowish that means, certain types of groups which can absorb something from the visible radiation you have start growing when you start looking at something which is different. So, you can keep anything for a long period of time at a temperature which is which the material is susceptible then you will start seeing degradation.

So, in the temperature case also we will looking at the degradation after certain time. In the time case also we will be looking at a degradation starting, although this rate of degradation we will be slower compared to the rise in compared to the behaviour that we saw when we look at the temperature increase because here temperature is constant. So, time has an effect that is not something, something not happen. So, it has a positive effect as well as negative effect and therefore, although you may be lucky that you say well this is my time, but if you go beyond this you can get some degradation also which would mean result in loss of crimp rigidity as well.

So, you obviously, have reason to optimise. You do not go beyond. And who wants to increase the time? You increase the time means machine speed is slower you want more productions. So, actually have a tendency to go for the faster speed rather than the slower speed, but when you are doing research to do obviously, something like that as well.

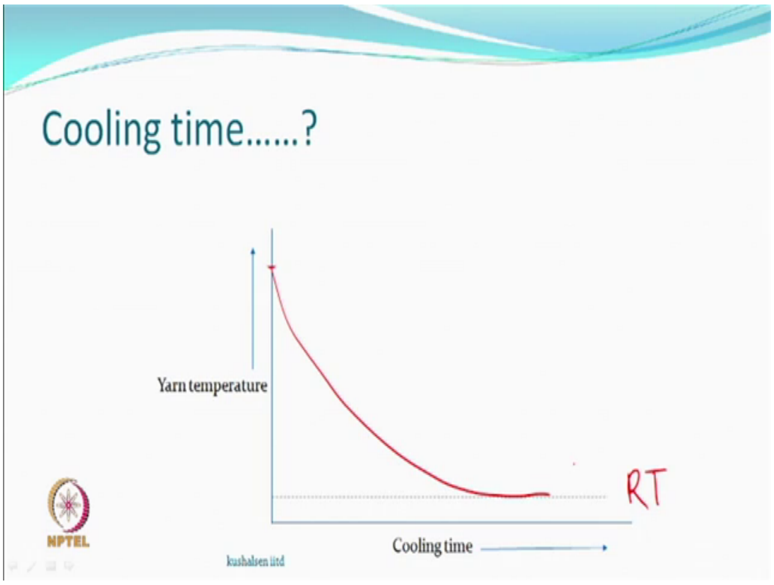
(Refer Slide Time: 26:59)



So, what will be the effect of heating time on tensile property like? Tenacity. So, remember because we are setting a twisted yarn and therefore, the orientation of the yarn is going to go down, so when you test any of these properties it will only go down. Now, the question that remains is it so important that you should worry well depends what are you doing with it.

Generally, during use because you will be in a stress zone rather than in a real extension zone. So, some losses may not matter. So, you can expect some losses will always be there because texturing is basically a disorientating process, so tenacity will go down. If it goes down by 10 to 15 percent nobody bothers. If you do something wrong and goes down below 50 percent, then somebody we will say what are you doing. And so quite possible the fibre may not actually look white in case you are doing a white, using a white textured yarn.

(Refer Slide Time: 28:27)

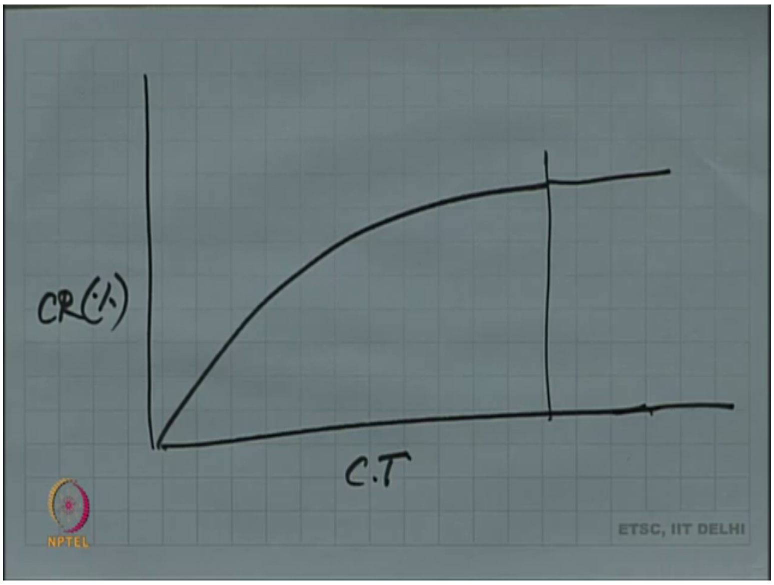


Come to the cooling time and what did expect? We are expecting that during this cooling the new configuration which probably is at the lowest energy levels is going to be stabilized. So, this is important in some ways.

Suppose this is your room temperature and you want to measure the temperature of the yarn. What kind of a curve will be? What type of curve we are expecting? So, it will come down. This is let us say the temperature of the yarn as it exists, then it will keep coming down and after room temperature obviously, there is no reason why it should go down because that is a room temperature no further loss.

Now, both these times can be also important because they should have a role to play in determining what kind of a final property you are getting particularly the texturing also. Let us say you want to say the crimp rigidity in the cooling time, what kind of a curve are we expecting?

(Refer Slide Time: 29:45)



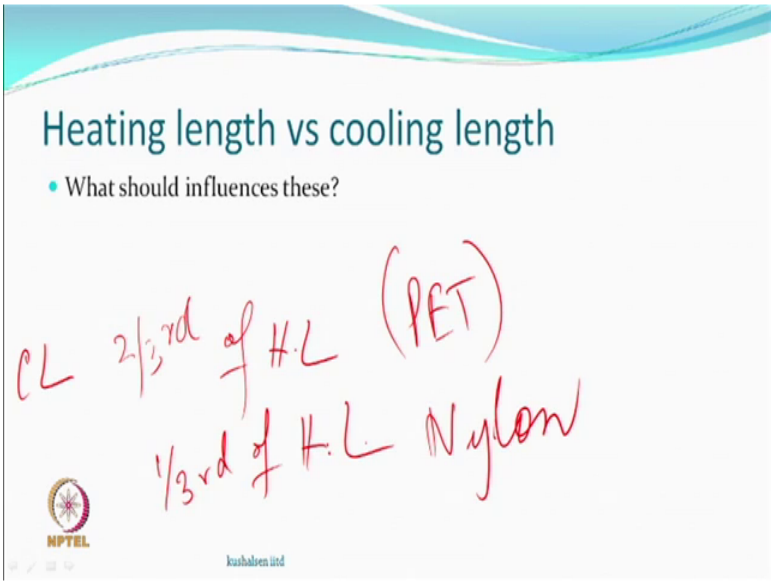
In the cooling time and let us say we are still interested in crimp rigidity. What do we expect? Sorry, no cooling time, zero cooling time and we increase the cooling time, difficult question. Any guess? Increase like this.

Student: Increase and then constant.

No. Like this, right. Will it go down? If you keep increasing the time is there any reason. It should not go down, because no degradation can take place if you keep the material at a low temperature for longer period because that is how the materials are stable and we could happy to use them here after year. If so, cooling time is important, but if you keep increasing the time there will be no further improvement in the crimp rigidity.

So, the problem that remains always therefore is, can we change the cooling time and the heating time independent of each other. That is I increase heating time reduce cooling time. Can we do it? At least not in the same machine. If you know the line diagram that if you remember I mean the machine speed if it is increase both of them going to reduce or vice versa. And therefore, people talk about texturing time and generally they say well heating time and so obviously, cooling time will either go up or down.

(Refer Slide Time: 32:11)



And therefore, people talk about heating length versus cooling length, now this is something do with the machine. But, how will you decide? Let us say I have to texturise two fibres of same denier one is the nylon the other is polyester. The crystallinity of polyester is around with said 27 percent, 28 percent of a fully drowned yarn via a viz the nylon would be having about 35 to 37 percent. Now, what of the effect of this on the heating? Effect of this on the heating time. Which will require more heating?

Student: Nylon.

Right. So, nylon be require more heating compared to polyester. So, irrespective of whatever you do, so it will require less. So, you can yes, well I can reduce the heating length or I can increase the machine speed, all right. The cooling length actually is if you are what are you doing the yarn has is at a certain temperature it has to cool down. And this rate of cooling will depend on the temperature difference and also the property of the material.

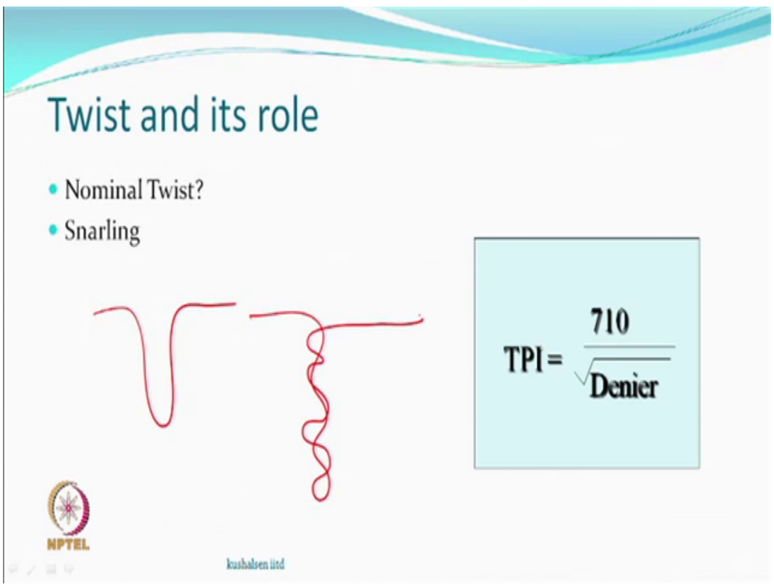
If the conductivity of fibre is poor thermal conductivity then it will take more time to cool down, and so it was understood that the thermal conductive of polyester is poorer compared to nylon. Which mean polyester will require higher time compare to nylon. So, a somebody say that thumb rule, the cooling time for polyester, cooling length let us say the cooling length of polyester or polyester fibre yarn is about two-thirds that of the heating length two-third of heating length, so cooling length is two-thirds of heating length. While in the case of nylon this is for let us say polyester for nylon it is one-third of the heating length.

And suppose you have a machine which as which is designed for polyester which is two-third is a cooling length will it harm if you texturize nylon there. Will it harm? It will not because if you increase the cooling length there is no deterioration to going to take place. The same machine therefore, can be used you do not really have to make a machine for polyester and a machine for nylon and a machine for polypropylene. Thermal conductive a polypropylene also is very poor, all right.

And the crystallinity of a fully drawn polypropylene vitamo polypropylene the polypropylene thermal conductivity is also poor and the crystallinity of a fully drawn polypropylene is also very high. So, you now have a material which require high heating time and also high cooling time. Now, it so 3 different kinds of classes of material require in different kind of things. So, what will machinery manufacturer do? It just make a machine and you say well does not matter at least cooling time should be sufficient. But if it is insufficient in any case then you are going to get a better result.

The next parameters that we have is Twist. So, when we talk about twist you can assume that we have already said that this is the speed at which we are running the machine time is fixed, the temperature is fixed and now we see what is the effect of twist.

(Refer Slide Time: 36:45)

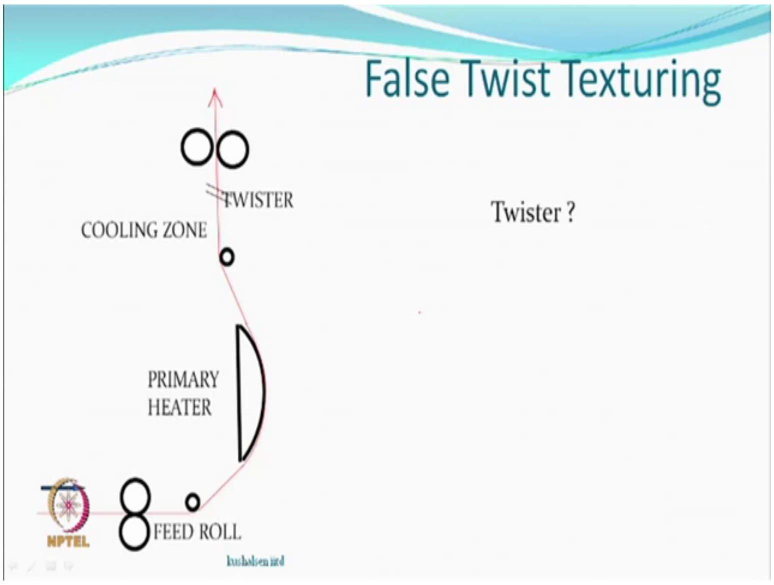


When you look at any textile yarn, less spun yarn you say there is some nominal twist we have inserted for whatever purpose, purpose maybe to hold the fibres together. So, what is mean by this a normal twist or a nominal twist? What it means is that if you take the fibre or a yarn and bring the two ends together it will make a loop, all right, this will be normal twist.

If you have more than the normal twist then you should expect snarling, right. So, it is more than normal twists. So, the yarn whenever given a chance that you bring two ends together and starts snarling. So, in a normal textile processors we are not interested in snarling to take place right. But in the texturing our twist levels are very high, much higher than this level that we talking about and this is a thumb rule you know. If this is the final rule then life will be very different there is thumb rule, that depending upon the denier of the yarn the twist can be decided. And around this value you will optimise, because your heater may be different, your number of fibres may be different, whatever it is talking about total denier only, ok.

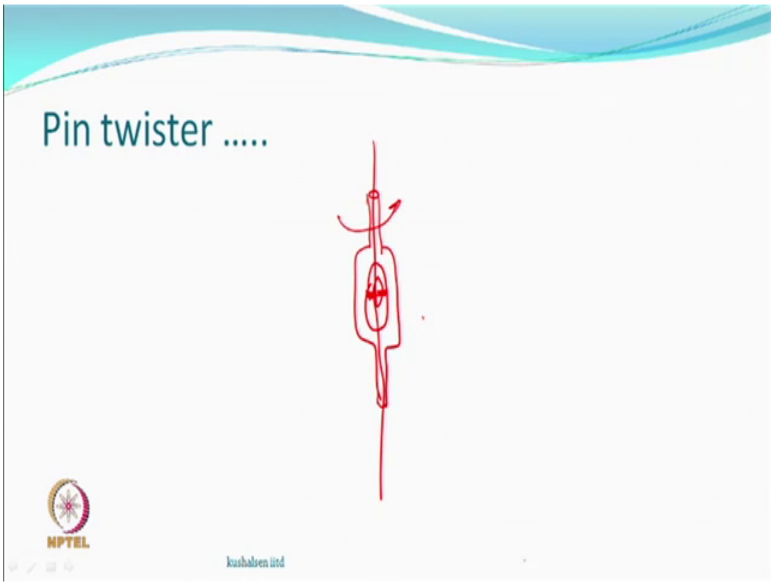
Now, what it approximately says is, approximately that inspective of whichever denier you use the helix angle at least on the surface the helix angle is approximately going to be same, approximately, where the optimum is going to be coming or around which you are going to be doing the experiments. So, that is what says. Empirical formula or thumb rule, all right. So, higher is the denier, lower with the twist required and vice versa, that is quiet high.

(Refer Slide Time: 39:07)



So, just to get feel the false twist texturing obviously has a twister other than everything else, right. So, you have the same line diagram, you have feed roller you have a heating like a primary heater, we talk about cooling zone. So, we talk about heating cooling zone and temperature and now we have a twister. Now, you just want to I want you to appreciate something, you what is a twister and how does happen.

(Refer Slide Time: 39:41)

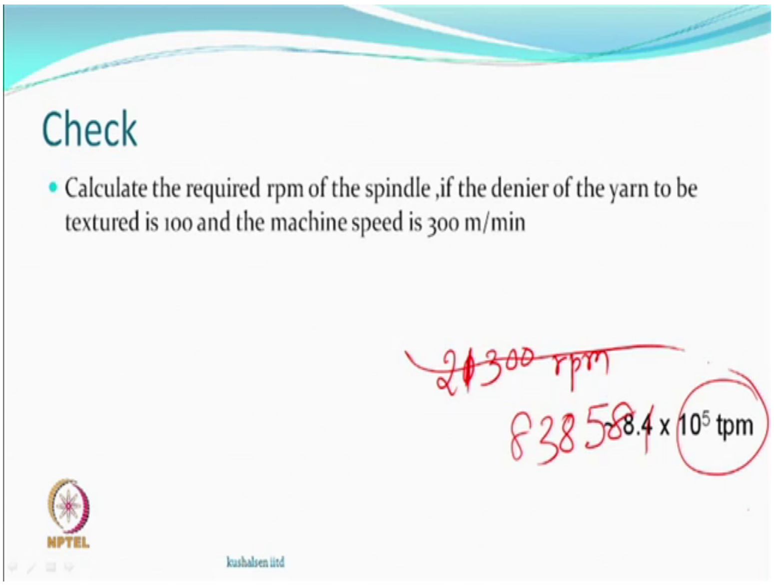


There something called a pin twister. A pin twister a obviously looks like a pin, but this is hollow, all right, and this bulb is also hollow. So, there is a tube and there is a bulb, and here somewhere there is a pin. So, what happens is if suppose you have the yarn which is let us say going inside the tube it is taken one round here and comes out.

Now, if you do one twist to this we expecting one twist in the yarn. This is called positive twisting. If you give one twist to this spindle, then one twist is inserted in the yarn which could be false twist on one and s the other end z. So, this is something called a pin twister. And the pin is rotated on a support which is magnetic support or there is a support in which it is there we will talk about it when we come to that. But my main interest is that there is a spindle which is going to be rotating an inside the spindle there is a pin and one rotation of a spindle means one rotation of the yarn one twist on the yarn and so that is it. So, the twist that we talking about.

If machines which use these type of twisters will be called pin texturising machines, all right, so the pin is only here, rest is spindle, this is a very interesting peace because hollow, then you have to designed everything else.

(Refer Slide Time: 41:53)



So, let us rule some little check and calculations, ok. Calculate the required rpm of the spindle that you have seen just above if the denier of the yarn to be texturise is 100, ok. You know the ballpark, way to calculate the twist. So, what will be the rpm? So, there is some little calculation required I like you to do whatever you can do to give me some answer; required rpm of the spindle. Now, you understand rpm of a spindle will also be equal to the twist that you insert. So, that is the correlation best part of it.

And based on the denier which is now 100 given to you and the speed is the same as 300 metres per minute you want to run the machine. So, would you like to do some quick calculation? You can use whatever you want to use to give me some value of the rpm, the rpm at which the spindle is suppose to be rotated. So, speed remains the same 300 meters, the yarn to be textured is the 100 denier total and we need rpm. So, are you doing some calculations there? How much? Any value that you want to give me? Please give me.

Student: 21300.

Just give me the number I will just keep writing and we will then decide right or wrong. What was the number first?

Student: 21300.

20300 rpm, right.

Student: 21.

21, all right, 21. Any other number? Any other number somebody is getting? You are using calculator I believe. Yes.

Student: 8 3 8 5 8 1 (Refer Time: 43:55).

Again give the number.

Student: 8 3 8 5 8.

838.

Student: 581.

51.

Student: 581.

581.

Student: 838581.

838.

Student: 582.

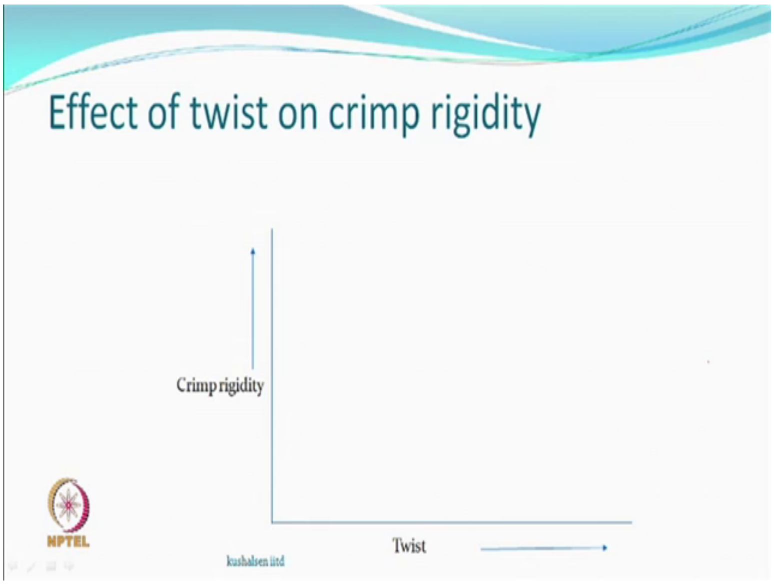
And there is one more, but it is ok, approximately.

Student: Approximately 7.

So, how much is this approximately coming? Look at this. So, this one definitely is little away. The question that remains at what speed again it is not to test your skills, please find out exact values whenever you want to find the value which will be required whenever we want it in examination. But at what are rpm you want to run this machine? You appreciate that, which spinning machinery the machine running at this rpm in textiles. Is there any machine? Any part of the machine that is running at this rpm? Right. So, interesting, is not it.

So, this is the kind of value that you looking at. 10 raise to 5 times, now you change the speed of the machine to 600, so it is not the time you are reducing you are also wanting the spindle to rotate that fast, all right.

(Refer Slide Time: 45:21)

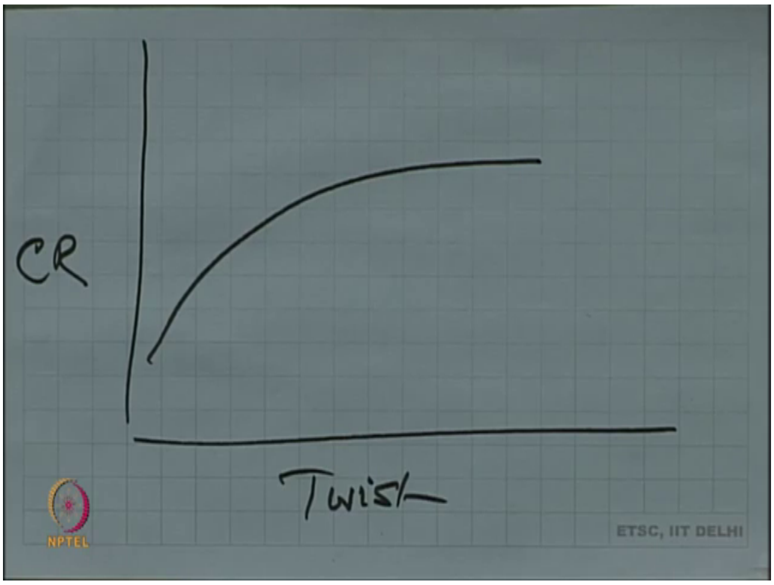


So, what do you think would happen if we increase the twist in the yarn? We know whatever twist now it means, you know what level are we talking about. We increase the twist in the yarn. Let us say twist per meter or whatever, at least twist in the yarn. What happened to the crimp rigidity?

Student: It will increase.

It will increase. We go back again, do some exercise.

(Refer Slide Time: 45:47)



We now a looking at twist and crimp rigidity, it will increase. Increase in which way? Level of all keep increasing. What will happen? Level of, it is a level of.

So, first question is why would crimp rigidity increase time-temperature is constant. What is the reason could be? Because the number of helices per unit length are increasing and is like a spring for example, then obviously, the resistance offered will also be more if number of helices per unit length are more. That is what the twist are going to do but when we keep increasing the twist why it is levelling off time, that we just stop here and think, ok. So, the number of helices per unit length are not going to decrease if you keep increasing the twist. So, we are not concluded this part, but we will like to talk about it when we meet again.

Thank you.