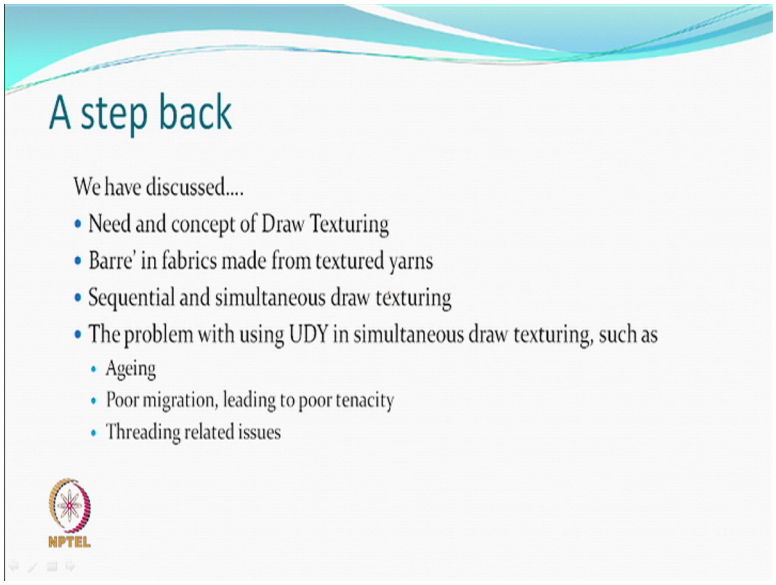
Textured Yarn Technology
Prof. Kushal Sen
Department of Textile Technology
Indian Institute of Technology, Delhi

Lecture – 14
Simultaneous draw texturing with POY

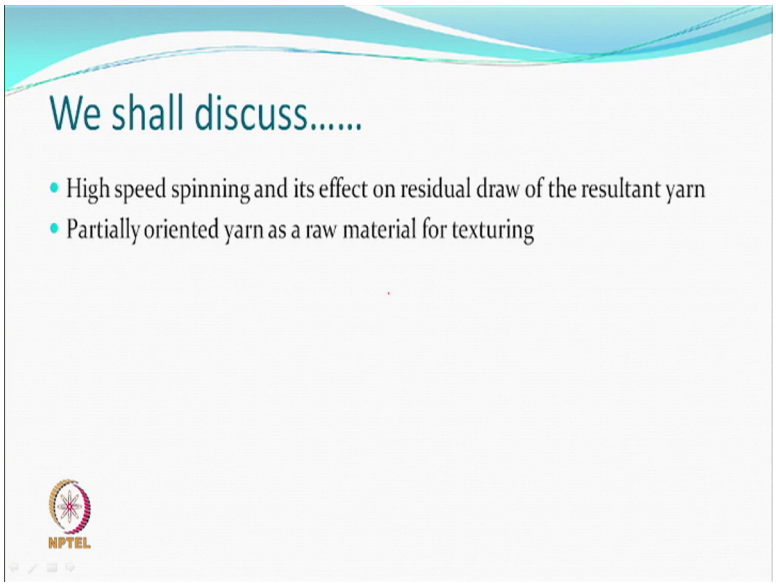
So, we continuing with the draw texturing and we did understand that why the draw texturing was needed and what actually is the draw texturing? The bar a which actually result after you make some fabrics, after dyeing why does it happen, what type of bar a v encounter, sequential and simultaneous draw texturing. And in the case of simultaneous draw texturing problems associate with using an undrawn yarn.

(Refer Slide Time: 01:01)



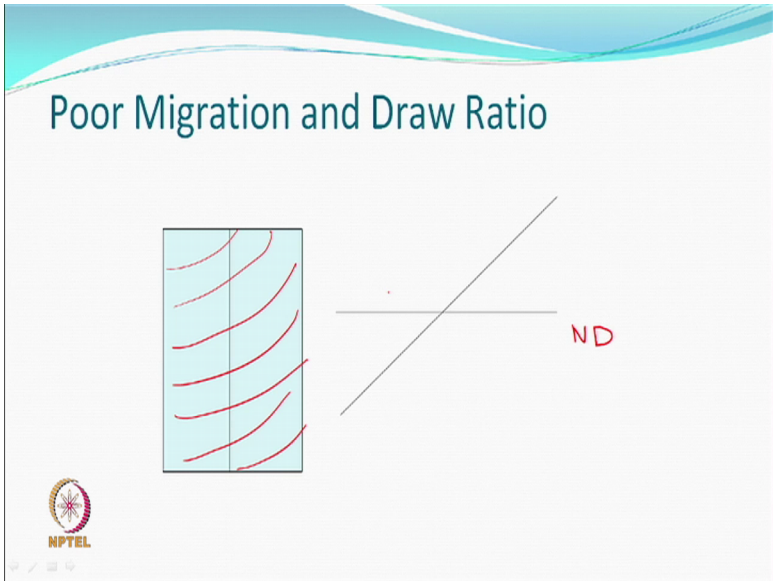
The aging migration leading to poor tenacity and threading related issues.

(Refer Slide Time: 01:11)



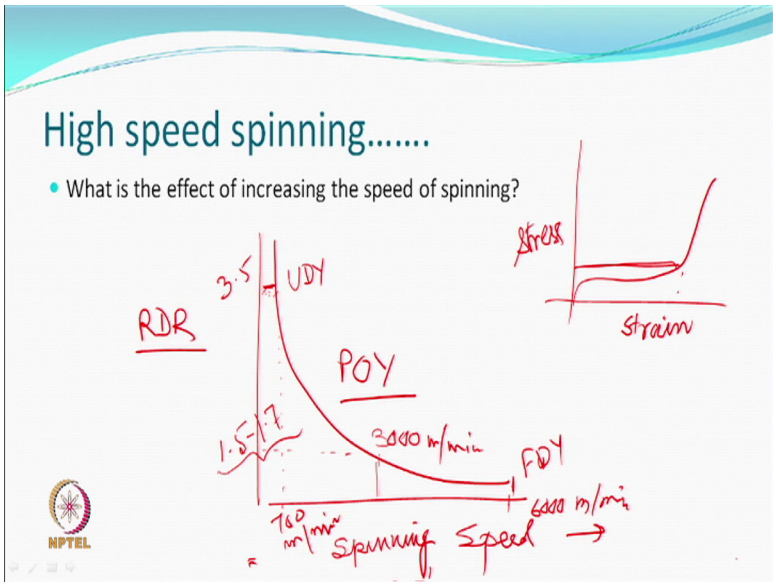
We will try to see if we use high speed spinning we said the last time we were using fibers being spun at around 500 to 700 meters per minute. If, instead of that we use high speed spinning what happens to the residual draw of a resultant yarn. And also the yarn that is produced, which is not fully oriented not fully drawn, but probably has been oriented more how does it behave for the purpose of texturing. So, looking at simultaneous draw texturing with a POY called a Partially Oriented Yarn.

(Refer Slide Time: 01:57)



So, we remember there was a poor migration. And if the draw ratio in a undrawn yarn remain the same, some of the yarns were getting drawn more than the others. So, one thing people had suggested in generally that, the draw ratio could be reduced, let us say by 5 7 percent or maybe 10 percent. So, that none of the filament is overdrawn. Otherwise, you can actually have a broken filament also. So, that is as far as the simultaneous draw texturing was concerned and we had the problems related to that.

(Refer Slide Time: 02:55)



If we increase the speed of spinning alright and plot spinning speed versus residual draw ratio. Residual draw ratio means, that if you have an undrawn yarn for example, whatever and you were trying to work and then this finally, takes up the shape.

So, this much draw you have to give. Before a useful product is made, because this change is a permanent change. And you will not allow any textile material, which is useful material to have this type of a change, which is permanent and you always want change which a recoverable change right. So, that if you extend a yarn it should be able to come back. So, the same type of stress strain curve.

So, this is the draw ratio which you may have to give, if suppose you want to make a fully drawn yarn after your spun the material. So, that it becomes like a regular usable material. So, that is what if you plot versus spinning speed. Let us say this is about 700 meters per minute, the draw to be residual for example, in this type of a yarn could be close to 3.5 or more. So, this is not an absolute value that I am giving, but approximately.

Because based on the molecular weight based on everything else all these things can change. You start increasing the speed, around 3000 meters the residual draw is less; that means, when you increase the spinning speed the melt that is coming from the spinner it is being pulled faster. And because of this there is some amount of orientation taking place, during this process spinning itself. And if orientation takes places means that, if you really want to extend there is a limitation. And the limitation is that you will be able to not able to go up to let us say 300 percent stretch not a stretch extension value.

And so, that extension value or which we now also approximately say as the residual draw will keep on getting reducing, because the material is getting oriented during spinning itself. So, that is what this curve shows, that if you start increasing the speed the residual draw can go down somewhere around it maybe 1.5 or 1.7.

So, this could be the range based on whatever kind of material will produce, that the draw ratio required to make it fully drawn we will reduce. Why, because some of the molecules during the spinning have been oriented. Of course, if you still increase the speed almost up to 6000, you can actually get almost a fully drawn yarn you do not need to draw it further.

So, those experiments have been also done, but the material that has that is produced at this speed probably is not considered to be as good as a material which is drawn after spinning alright. So, the development of a morphology is slightly different, but what was interesting was from a stage which was almost like undrawn yarn, to a fully drawn yarn, you were getting reduction in the residual drop.

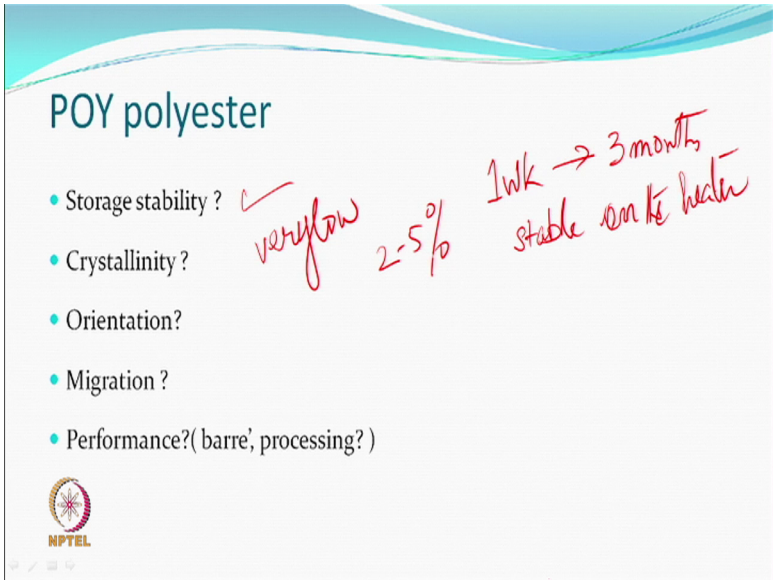
So, one can stop anywhere for that matter. And this type of a curve is for almost all melt spun fibers, because this kind of speeds are never used for wet spun fibers or solvent dry spun fibers. So, this was melt spinning. So, if you are somewhere around 3000 meters you get a material, which has a residual draw quite reduced, but not fully drawn about 1.5 to 1.7 alright.

So, nylon may have different, polyester may have different, different types of polyester may have different thing, but you are getting some this type of a yarn was therefore, called a partially oriented yarn that is it is not fully oriented, but during spinning some orientation is taking place it is interesting that this yarn. Obviously, one reason is that

you want to have more production. And therefore, you want to get to this yarn has beautiful properties, much better than the undrawn yarn UDY.

And therefore, the people from the texturing industry liked it very much and you will be surprised that at this during this time the research and development units and research universities, as also the machining manufacturer spinning, as also the machining manufacturer texturing they were all collaborating. So, there is one of the very successful stories of collaborations, where everybody respected the others viewpoint and the limitations.

(Refer Slide Time: 09:39)



So, what happened the moment let us say I am talking at the moment of polyester? The storage stability of this material called a POY, which may have been spun at 3000 or 3200 3400 meters per minute improved tremendously. That is from 1 week to 3 months, that is this material could be stored at the normal temperature humidity conditions which are available.

And so, you would not see any deterioration of properties during this storage, which means that after spinning you can supply to anyone who wants to use this. And that was a big thing and the stability has come from the morphology which has changed and instead of being totally unoriented structure it is an oriented structure. And therefore, it is more stable to be environmental conditions and right.

Not only that this material was also stable on the heater, like when you are threading the yarn over the heater it would not fuse it was stable. So, you can very easily thread this system, machine and then run and after that everything happens like a draw texturing. So, 2 important things happen; one that it would not fuse on the heater and also you could store it for a longer period remember you talking about polyester the moment.

The crystallinity as we said stress induced crystallinity of this material was very low 2 to 5 percent remember the crystallinity of a fully drawn yarn is somewhere around of a polyester about 27, 25 percent. And this material has only 2 to 5 percent crystallinity, if we recall our earlier discussions, that lesser is the crystallinity of a parent yarn because this will become the parent yarn now it is better for us.

That means, total energy barrier is less and you can do the things better and immediately go to a next stage, which will be more stable stage state because of low crystallinity. The orientation of this yarn is relatively higher, which is evident from the reduced draw ratio, residual draw ratio. And therefore, compared to the undrawn yarn is performance is likely to do better. After texturing because starting with the material, which is better oriented material. And that also we said that higher is the orientation better for us, but we will never say that this orientation is equal to a fully oriented yarn this is less definitely, but compared to the undrawn yarn is much better.

Then, we did talk about migration because of this orientation that happens, because the fact that the residual draw is less. Therefore, the migration is improved; this is the migration of filaments during twisting you will never say that it is become equal to again with a fully drawn yarn. So, it may not be equal to fully drawn yarn, but it is much much superior to an undrawn yarn, which just extends at a very very low stress, this requires more stress to get extended. And therefore, the chances of migration of surface to the core filaments is higher.

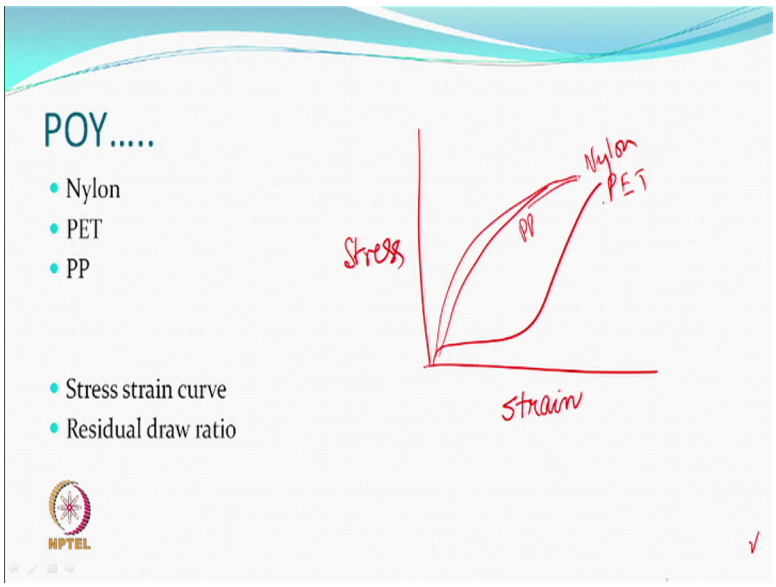
So, from that point of view again this proposition was a good one, that you have something called a POY, polyester yarn, which can be used for texturing polyester texturing and that also draw texturing and that also simultaneous draw texturing. Performance from the bar a point of view improved because again you are dealing with large trough coming straight from the spinning.

So, it is a POY it is a large draw of 5 kilogram 7 kilograms big trough and so, that issue of position to position variation or every hour every 2 hours variation those kind of things; obviously, get reduced as long as you have some control and; obviously, you should have control on your machine. In fact, the interesting thing was that the movement POY came into picture. The texturing industry which was texturizing nylon as also polyester, nylon is a fiber which came earlier. And obviously, it was predominating after this scenario is changed completely. It was polyester all the way and one of the reason was this and of course, this.

So, people said well this is it so, happened that the POY polyesters were made early then the nylon. And one of the reason why it was difficult for them to immediately make an commercialize nylon a POY was that, whatever polymer that they were spinning at that time and the whatever the machines they; obviously, were spinning on had difficult controlling the thread line stability of a melt.

So, as a molten material which is coming, which has to solidify somewhere in between and then wound. And winding at higher speed means vibrations and so, additional vibrations, the polymer being whatever it is the stresses developing in the melt thread line would cause breakages instability. And that was something which delayed the commercialization or commercial product of a POY nylon for that matter.

(Refer Slide Time: 17:35)



More than that in our group we have polypropylene also. Polypropylene is relatively much easier to spin compared to nylon and polyester, if you happen to see any of those spinning units. In nylon polyester may almost be on 2 to 3 story spinning systems, while this could be done in one single story. Because of the properties of the polypropylene that loves to crystallize very easily. A rate of crystallization if you look at it these 3 fibers from the melt polyester is the slowest, because of its aromatic structure the rate of crystallization is very slow.

So, for some it may be looking at a negative point for the POY production people it was the most positive point, for the people who were wanting to texturize it was a very positive point. Compared to polyester nylon crystallizes more the rate of crystallization is higher. Here, we talked more both nylon 6 and nylon 6 polypropylene which of course, is an isotactic polypropylene which is the textile grade material. The rate of crystallization is very high, if you remember we said the crystallinity also is very high of a fully drawn material polypropylene, because the chain folding takes place very easily.

So, good for something, but if you look at the stress strain behavior of the POY. So, this residual draw ratio; obviously, reduced and then finally, you can get this material as far as if you want to flat yarn to be do that. The same yarn, we can use it for the simultaneous draw texturing, but when they checked the finally, of course, you could handle all these instabilities in spinning line spinning thread line. And you start making nylon.

They found the stress strain curve of a nylon is like this. Residual draw may be still there you still have to draw it, but look at the difference of the two what did it show? It shows that it is taking the resistance from the word go, there is no so, much of a pre free plastic flow. Of course, if you stretch or extend to the final point, it will get extended to the extent of whatever residual draw is.

So, this indicates that this material is already crystalline, while it is being spun. And therefore, people also said well if it is crystallizing even a 2000 meters per minute, if it starts crystallizing at such a slow speed. So, you do not want to go to low speed. So, they started also spinning nylon at a relatively higher speed not, even 3500, they could go even to 4000, because it has to crystallize anyway.

So, and that type of material could be used for another process, which is called a spin drawing that as you are spinning couple the drawing with it spin draw technology and get a fully drawn fiber. At this point you may just remember that, it is assumed or believed that you first do make a POY and then do the drawing is a better idea, than a fully drawn yarn by increasing the spinning speed.

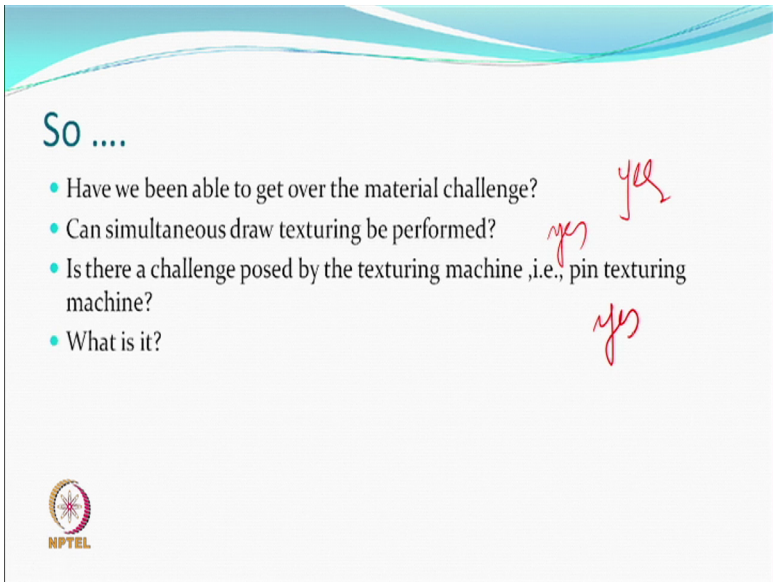
So, nylon people (Refer Time: 21:59) well we will go and for a higher spinning speed, but not 6000 4000, it is crystallizing does not matter, but we can get a spin draw yarn, normally a spin drew yarn is used for tire cords also. Similarly, when they saw a curve for polypropylene also was a similar curve.

So, it was also not showing any. So, the first common sense issue was that, let us use polyester. Polyester today is; obviously, used maximum for all kinds of things. And so, from the point of view of texturing, this is the material, that you want to use. And from this point onwards if you look at the history it is the POY polyester, which is the maximum use and is number 1 as far as the texturing is concerned.

Of course, you can texturize POY polypropylene, you can texturize nylon, because some advantage in terms of the barre was there in all the cases nylon definitely. So, POY has come to stay as a material and another advantage people also thought that when you are drawing during texturing itself. So, whenever even if the necking zone is not the best necking zone, neck point is not the best necking point, still there is a pull and a push which happens. And because of that some adiabatic changes in terms of temperature rise right if you do any kind of a pull.

So, the molecular level there is a friction and because of that adiabatically the temperature can rise which will be advantage to during the heating process also. So, no one has any doubt that POY should be used. All of them have residual draw despite this stress strain curve being different. So, they are not fully drawn yarn.

(Refer Slide Time: 24:39)

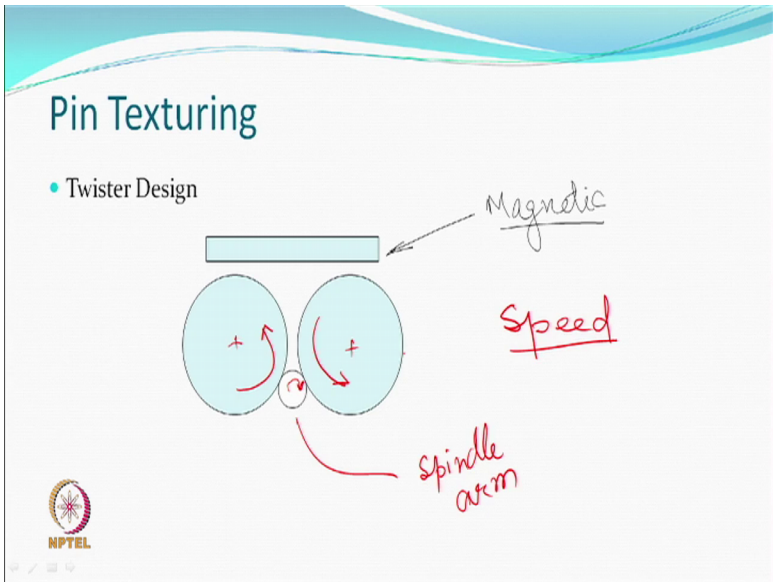


So, there was a material challenge which came because we want to do simultaneous draw texturing and we wanted to avoid barre and so on so forth. Some material challenge which was creating difficulties in texturing has it been solved, we will say to yes to some extent to actually large extent yes. Can we now perform simultaneous draw texturing? Yes.

So, this is where also we are there is there a challenge posed by texturing machine, machine at that time the POY had already come machine was spin texturing machine. So, remember when we did agree to go for simultaneous or sequential draw texturing, we were aware that the drawing speeds are higher around 700 to 1000 meters per minute. The texturing speeds were not so, high. So, at least simultaneous draw texturing had reduced to one process and you going through the whole process.

And so, people have stop thinking about sequential draw texturing, where you are actually going fully drawn and after that more crystallinity and then more time and all thing was stopped and so you go for this machine, this material and the machine was mean texturing. With this machine posing a challenge yes, the material challenge and now the machine challenge and what this challenge? Just for varying a perspective.

(Refer Slide Time: 26:39)

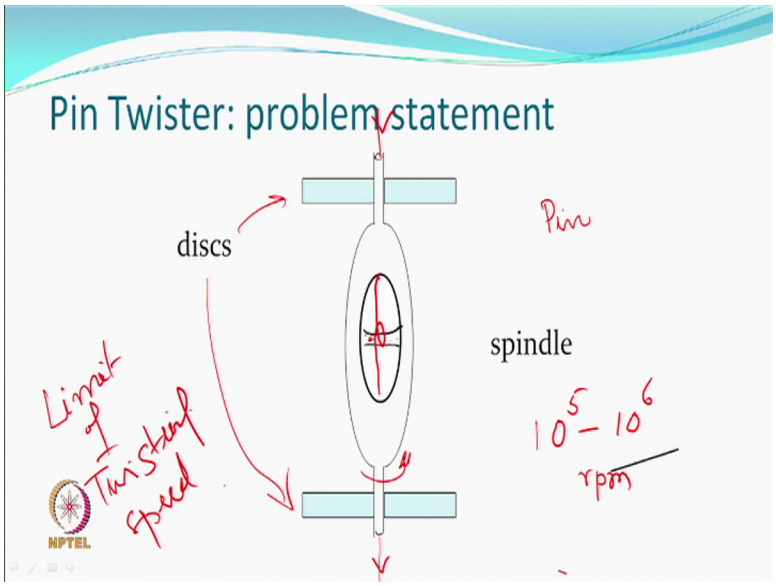


So, this is a pin or a spindle and this is spindle arm of the twister, but the twister is the whole assembly. So, your spindle is twisted and the twister assembly has this arm is resting on to disks. So, one disc moves, the other disc moves and because of that the spindle arm also moves. So, like we said last time that well it rotates at the same rpm the pin and the same rpm would be of the yarn at that particular point.

But, the control is happening here there are no gears right, you probably will have difficulty in finding getting 10 raise to 5 and 10 raise to 6 kind of an rpm. So, we are using some kind of a gear it is a floating spindle it is a floating spindle and how is it being held?

So, there is a plate which is let us say magnetic plate and this is a magnetic material and. So, it is being pulled towards that plate and so, it is held in position that is floating.

(Refer Slide Time: 28:15)



Other side you look at so, there are 2 pairs of disc; one holding the top arm, other holding the bottom arm of the spindle. So, these are the discs and the pain of course, is here as we had seen before this is the pin and you are rotating. Now, how you can think that they were actually working on the machines at 300 320 25 meters per minute and the spindle supposed to have been rotating at the speeds it tends to 5 tends to 6 rpm, its a very high speed that 2 of material we just floats.

So, if there are vibrations of any kind it can jump off, if jumps off there is a break how fast can you rotate this? You can rotate it, by reducing the diameter of the arm or increasing the diameter of the disc, if you increase the diameter of this there is a position the whole spindle will take somewhere on the machine will keep increasing, its a number of things that you can place in one line on one side will reduce. And of course, there is a mass which also will increase.

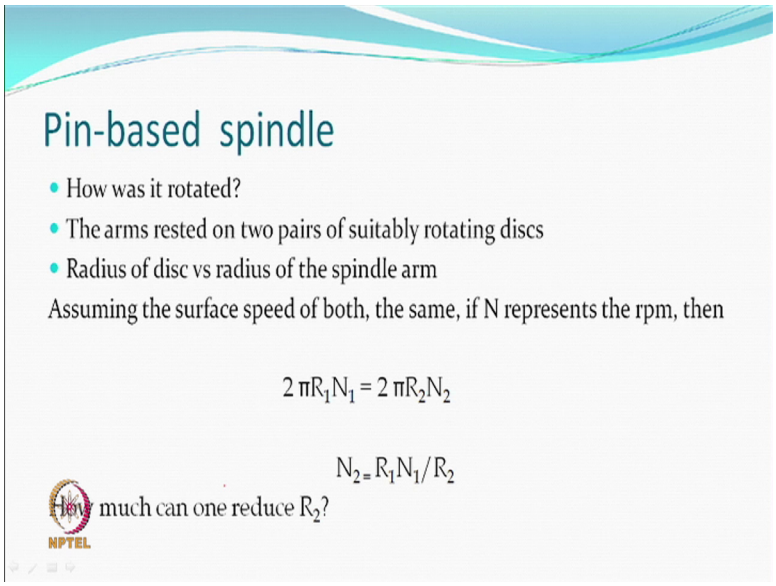
This spindle actually was a engineering marvel. A, very sturdy material with a hollow arm, which is rotating at a very high speed and running for hours together. So, reducing the hollow tube further, the bulb is alright. The hollow tube further was very very difficult. And if you make it thin yarn still has to pass through its not solid. So, you got to give some space, you would not like to have too much of friction between the yarn and the arm of the spindle because, but in any case they said this is the limit of twisting.

So, the machine was not giving a problem that you cannot wind it faster, you cannot feed faster, but you cannot rotate it faster. And what speed we still talking about is 300 meters per minute. And you say we would like to match up with the drawing machine, which were running at 100 meters or 700 meters, you try to do that then you are looking at values which are higher, lot of vibrations spindle jumping off at the whatever limits that could make. And therefore, we said those speeds cannot be increased.

So, that is the limitation. So, you go for a simultaneous draw texturing material is the one which responds very well, a slow crystalline material or even if nylon polyester we a nylon polypropylene we are talking about, the crystallinity developed during the spinning is not alpha crystals right. They are crystals with less stability less stable crystal crystalline form. And therefore, they are still good right. So, nylon would form large amount of gamma crystals right. Polypropylene will form more symmetric type of structure which of course, will go to the alpha as you heat it up and work around.

So, the materials were good as far as all the POYs were good some material challenge was taken off taken care of, but the machine challenge was there, that is the time and people started saying talking about friction texturing.

(Refer Slide Time: 32:55)



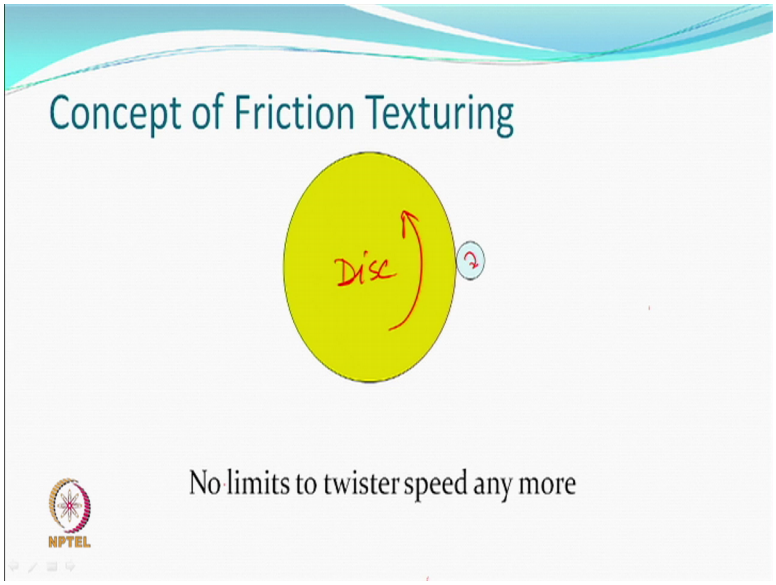
So, just to recall again how is the pins spindle rotated, they were true they were rested, the arms of the thing were resting on 2 pairs of suitably rotating discs, disc of course, were rotating on pivots and some drive positive drives, radius of the disc versus radius

spindle was an issue. So, you could reduce as much as you could and this simple equation which say that the ratio of the radii would determine the rpm of the spindle needless to mention the disc are rotating; obviously, at low rpm and the spindle rotating at a higher rpm. In some sense this is also friction because there were no gears.

So, the surface of the disc the friction between the surface of the disc and the arm of the spindle is responsible for all rotation alright, but they are rigid bodies both are rigid bodies. And there was a force which is pulled up which is pulling the spindle and so, we called it a positive twisting mechanism.

So, the slippage between the spindle and the disc was considered or assumed to be almost 0, because the weight was not high and they are rigid bodies. Just, that we could not change the dimensions more and therefore, we could do, but this is not called friction texturing.

(Refer Slide Time: 34:37)

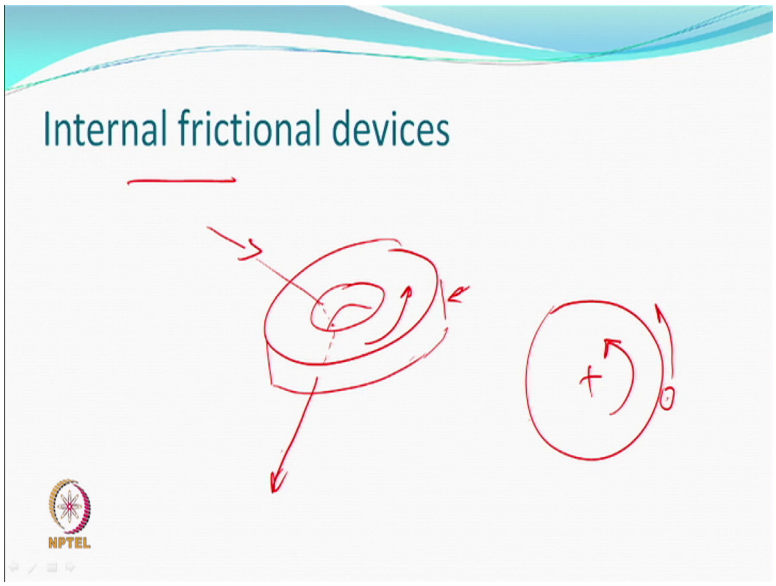


What people said is why have a spindle? We already know that the spindle also rotating because of friction, why should we not put the yarn directly on the disc? So, immediate advantages the dimension of a yarn, whatever the yarn issues versus that of a disc the difference is tremendous. And therefore, suddenly theoretically you almost said whatever limits of twisting you want can be done. So, do not have to worry about the dimension of spindle at all, whatever the yarn just put it on the disc they start moving. So, this principle was; obviously, loved and that is if you use this kind of a principle then you call

it friction texturing. Although, the pin was also rotating by some friction, but you do not call that as a friction texturing the friction texturing is the one where yarn is directly put on a rotating body.

So, principle was good people said yes, very nice this is how the machinery manufacturer were following the problems of the texturing machinery people, spinning machinery people had given a material, which is good. Now, texturing machinery manufacturers have to do something and also these kind of tests and experiments are also being done in the research institutions. So, that you do testing and say what exactly happens. So, suddenly you seem to be solving the problem.

(Refer Slide Time: 36:25)



There is something called internal frictional devices. So, initially people said that unfortunately a textile yarn is not a rigid body. And therefore, if you just believe that there is a disc and there is this yarn and this yarn will always remain at this position while the disc is moving in this direction, if not a good expectation not a rigid body flexible system. So, it can actually go in this direction also and start like a ballooning.

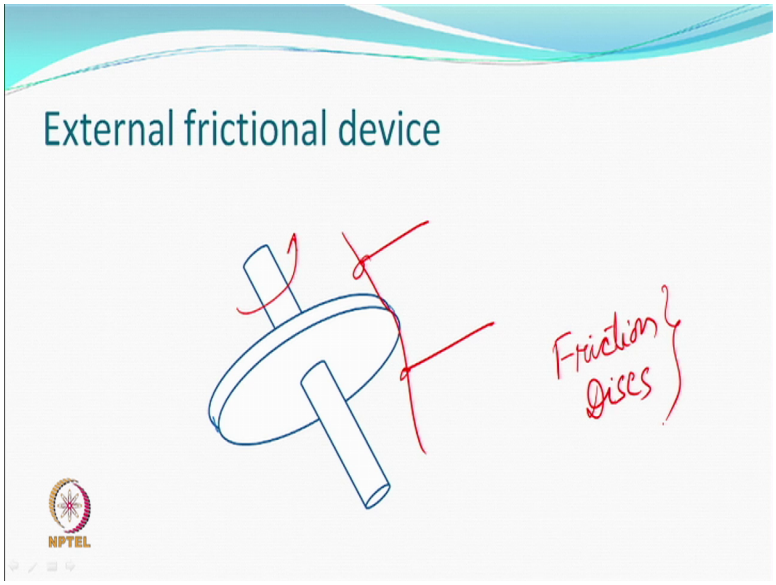
So, I said ok, we can have a device like internal friction device the various kinds of devices they will try. So, what says it cannot go out, because you will be drawing this yarn from one end to the other end through this orifice, which is good enough which has a friction. So, yarn will be touching that this rotate the yarn will rotate and hopefully you

have better control, they are not going to go anywhere else, because you are going to pulling in the other direction.

So, I am not saying this at the moment, I like you to just consider if this is the kind of a device that you have to run design a system, where this device will be rotating, the way you wanted to rotate alright it has to rotate. So, just you do not have to give answer just now, go back and see this is device which must rotate. So, that whatever you want can happen.

So, it is a engineering solution have to be found out for this purpose itself, you can do it at home these devices were given up earlier early in the day and thought that we should go for external frictional device only.

(Refer Slide Time: 38:53)

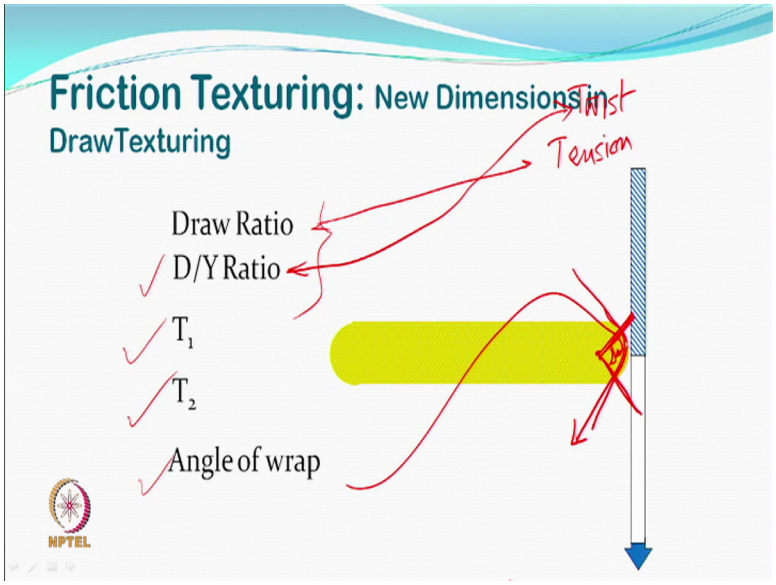


And the yarn can be here you say we will rotate no said we can easily provide guides, that the yarn is guided. Let us say here then it may not be able to go too much away from the positions this was interesting.

So, the external frictional devices, which are these days also called friction discs are the ones which are the twisting units in any modern false twist texturing machine. So, from a normal texturizing system, now you have simultaneous draw texting as also friction texturing. So, when you say friction texturing that mean the yarn is actually on the disc directly being rotated.

So, interestingly the difference in diameter is too much and therefore, how fast can you rotate is not a question at all.

(Refer Slide Time: 40:11)



So, this friction texturing, where hopefully the yarn is in contact, if the yarn is in contact then it should rotate, but if you look at this diagram you will not be very comfortable alright. So, one of the most important challenge, that came immediately the moment you said we are we have solved the problem of twist and limit of twist, we said well yarn is flexible whatever you do is fine we would have more problems.

But, even if the problems we solve at a later stage, what has changed.

Student: (Refer Time: 41:03).

Time would still remain a processing parameter, temperature will remain a processing parameter, but now there is a draw ratio the yarn is not fully drawn it is a POY. So, you have to draw while you are texturing. So, what are you doing you are drawing and texturing. So, there is a draw ratio. So, draw ratio is one of the parameter which has to be controlled process parameter.

Now, which is similar to tension not exactly, but similar tension after when you increase the draw ratio tension the yarn is going to increase, then they also said another parameter will be called D by Y ratio. The speed of the disc versus speed of the yarn ratio of these two, how fast you are running the yarn through the machine and how fast you are

rotating the disc. This was related to twist, that is you said why did you do that you just say twist, we said well this is called the friction texturing, I have no control on the actual twist being inserted in the yarn.

Because, I am not measuring I have no way to measure. In the case of a pin you had a something called a twist wheel, it has a number of gears something coming input from one side, output from the other side, it is driving something else, that surface speed is known, the disc surface speed is known, the surface speed arm is known. And therefore, I know, what twist I am inserting, that was called positive control on the twist. You come to this point you says, I do not know I am not twisting the yarn at all. So, there is nothing called a spindle yarn is rotating indirectly. Through the disc, but I am quite sure how fast the disc is rotating?

And I have a control, I also have a control that how fast the yarn will go through the machine? And hopefully the ratio of this would have something do with the twist, but I was still not talk about twist I will only talk about D by Y ratio. Some other parameters also came into play, tension was always important we say draw ratio we are doing tension, because you know you should measure it also. Now, measure the tension before you have fed the yarn to the disc on the twister and after it has come out of the twister. Is the tension same you can always calculate, but no they found this is not a simple case of a yarn moving over a disc.

The yarn is moving over a disc it is also rotating simultaneously. And therefore, you should measure T 1 and T 2 right tension, initial tension, input tension and output tension (Refer Time: 44:26). So, this becomes another parameter we should be worried about. Now, as I said if the yarn is going absolutely straight yes just like that the way it is been shown, the life will be very different. You may actually not see any twist, it is the point contact, but the point contacts are not good enough.

So, I say well we will wrap it around the disc. So, there is a wrap angle of wrap comes into picture alright angle of wrap. So, you have additional thing called T 1, additional thing called T 2, these terminologies have changed and you have angle of wrap. You can appreciate, if the yarn has tension and there is an angle of wrap, there is a normal force right. And if there is a normal force and friction then; obviously, a torque can be

generated. If, you do not have that you can have as much friction as you want without a normal force what will you do.

So, you have to do wrapping and wrapping means some angle of wrap, which could be this if the yarn is moving like this. So, wherever this is making this, this is the angle which can be called the angle of wrap. So, we are solving problems, where you also must understand one thing you have lost on the way you have no positive control on the twist, you have a indirect control which is not positive. So, we can stop here and next time we will move further from here.