New Spinning Technologies
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Lecture - 08
Rotor Selection

So, let us now discuss Rotor Selection.

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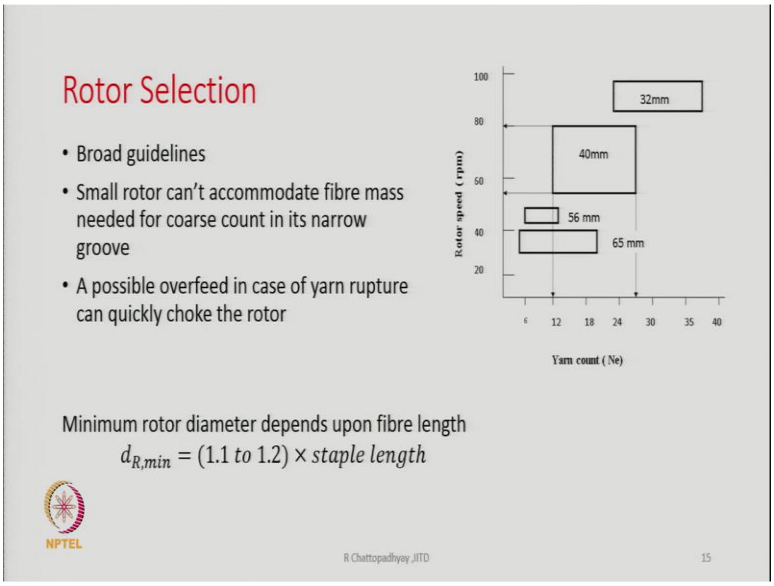

You see a diagram on the right hand side where on the 'x' axis we have count of yarn and on the 'y' axis we have rotor speeds. And then, what we also see here is this rectangular blocks which are showing the diameter of the rotors, and the speed range, and the count range in which they can work.

This is a very interesting picture. The broad guidelines for the selections are small rotor cannot accommodate fibre mass needed for coarse count in its narrow groove. So, we have to think that when the fibre mass is more; when the fibre mass is more? When you try to spin coarse count, then you will have more fibres in the cross-section of the yarn or that will also be in the groove of the rotor.

So, this small rotor, large number of fibres cannot be accommodated because the grooves are narrower also. And the other thing is a possible overfeed in case of yarn rupture can quickly choke the rotor. This is another danger that we have. When the yarn ruptures and we restart the machine again, put a seed yarn, but before that we know switch on as we switch on the machine, the when the opening roller side, the fibre starts going inside the rotor little earlier than the time the yarn end actually reaches the rotor groove.

So, if the fibre feeding rate is very high. That will be high when the yarn is coarse. I have to feed more fibres per unit time. If the rotor diameter is less, the more fibres can choke the groove very easily. So, that over feeding possibility is there in the case of yarn rupture which will case cause the rotor choke.

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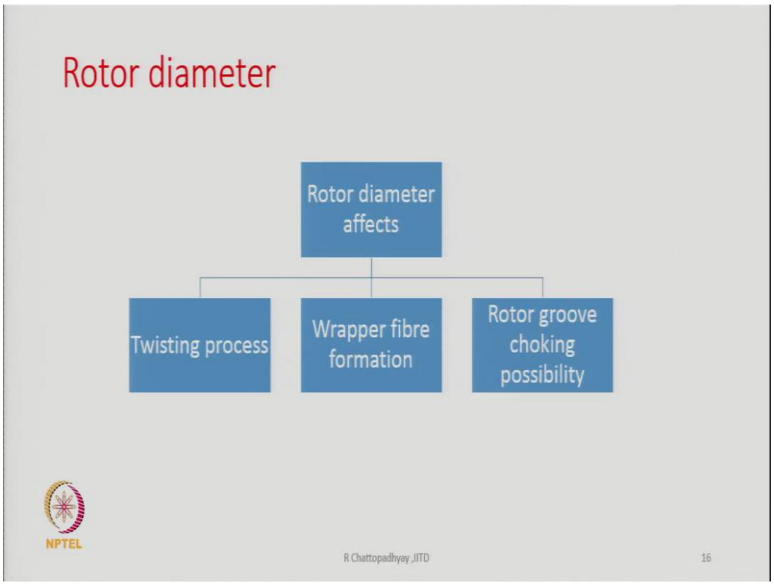

So, we have to therefore, understand that though we have rotor starting from 32 mm to 65 mm, all sort of rotors are there, but we have to understand which rotors to be used for what purpose.

Minimum rotor diameter depends upon the fibre length that we want to use. So, diameter, the minimum diameter of the rotor is going to be 1.1 to 1.2 times, this staple length of the fibre. That is if the fibre lengths is fixed, the rotor diameter should be 1.1 to 1.2 times, the minimum diameter. If the diameter is more than that there is no problem. That is the minimum diameter that we can go for.

This is all because of the fact of again the wrapper fibre generations. If the rotor is too small, smaller than 1.1 or 1.2 times the staple length; that means, for a 30 mm staple length, 33 to 36 mm rotors should be chosen. If it is 32 mm or 30 mm, then there will be too much of the wrapper fibres and the yarn quality will suffer.

On the maximum side, we can go for still bigger rotors for 30 mm, not 36, we can go for 45 mm rotor also or 40 mm rotor also or maybe 56. So, on the higher side, the restriction is not there in this particular equations, but from the lower side the restriction is stated, that this is the minimum that you should have which is a function of staple length of the yarn.

Rotor diameter affects twisting process, wrapper fibre formations and rotor groove chokings possibility. These are the three things which are affected by the rotor diameter. And we will discuss them now.

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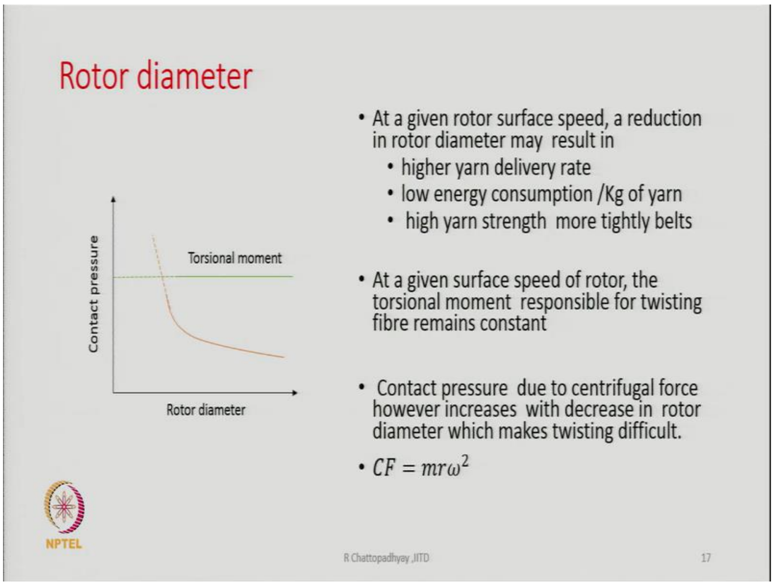

At a given rotor surface speed, a reduction in rotor diameter may result in what a higher yarn delivery rate, low energy consumption per kg of yarn, and high yarn strength more tightly belts.

These are the advantages, for a given rotor surface speed a reduction in rotor diameter basically would mean increasing in rotor speed because the surface speed I am keeping constant. And because of increasing in rotor speed rotor yarn delivery rate is going to increase because twist is same.

Low energy consumption per kg of yarn productions because productivity is going to be more now. And in some cases, we may find strength to be more because of the wrapper fibres, we will see that when you discuss in more details about the type of wrapper fibres or nature of wrapper fibres in the rotor yarn.

Some of the wrapper fibres are tightly wrapping the core. The tightly wrapped core the you know wrapper fibres has a beneficial effect and they can strengthen the yarn also. They are like, that is why they are known as belts. Anyway, these possibilities exist. This may be sometimes true, sometimes may not be true also.

Now, at a given surface speed of rotor, the torsional moment responsible for twisting fibres remains constant. The contact pressure due to the centrifugal force; however, increases with decrease in rotor diameter. See, here on the right left hand side there is a diagram. This is contact pressure versus rotor diameter. So, either rotor diameter increases, the contact pressure is decreasing.

Why it is decreasing? This is true for a given rotor surface speed. So, as the diameter increases for a given surface speed, basically means I have to reduce the rotor speed. Diameter is more, rotor speed will be less, because if the surface speed of the rotor is constant.

So, if the rotor speed is less than the centrifugal force which will be acting, 'ω' is representing the rotor rotational speed. So, if that reduces the contact pressure will be less because fibres within the groove are compressed against the rotor wall because of the centrifugal force.

So, anything that will reduce centrifugal force means pressure will be less. So, keeping the rotor surface speed same, if we go for bigger diameter rotor the contact pressure will be less. When the contact pressure is less, the benefit is twist can flow easily. In the groove, we will see that the twist that remains in the yarn arm.

We have already discussed it earlier that the yarn arm means the portion of the yarn between the rotor centre point and the rotor periphery. This is called yarn arm. This yarn arm contains twist, it remains twisted always. But part of this twist flows back in the groove of the rotor, not the entire groove.

Only the fibres which are remaining in the groove only part of them gets twisted because part of the torque which is there in the rotor arm, in the yarn arm will flow. And this part of the twisted part of the fibres which are deposited in the groove is known as peripheral twist extend or PTE.

So, how much length of the fibres which are there in the groove will be twisted depends upon how with what pressures the fibres are pressed against the rotor wall. If the PTE zone is too small, the end will break. If the PTE zone is too long, again the end may break, but the reason for breakages are different.

The mid point here is that by due to reduction in pressure, there may be an advantage, that twist flow will be little easier and therefore, you may have advantages in terms of stability of the spinning. And the reverse will be true, when the rotor diameter is reduced because if the rotor diameter is reduced, basically means my 'ω' value is going to increase for the same surface speed. So, contact pressure is going to be rise, is going to be more and more.

The twisting torsional moment that you require to twist the bundle of fibres depends on the fibre itself only. So, that remains constant. So, that remains constant. But the torque that I require to twist the fibres may increase when you go towards this side, that I select rotor which are smaller in diameter.

In that case, the 'ω' value is going to be more, contact pressure is going to rise, twisting will be difficult. So, within this smaller diameter rotor you can now understand twisting of the bundle of fibres which are there in the groove is becoming more and more difficult. So, that is the influence of rotor diameter and this is going to affect finally, the spinning stability that is whether the end is finally, going to break or not.

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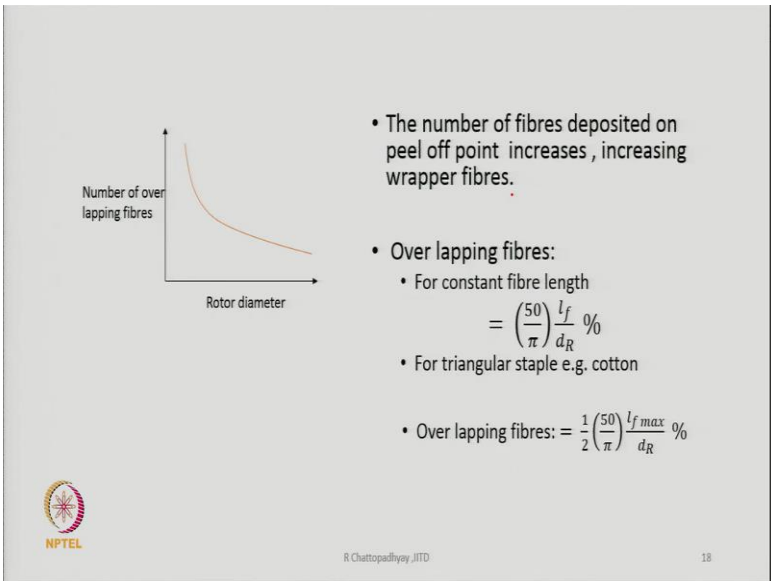

The other thing that is affected by this is number of fibres deposited on the peel-off point increases the wrapper fibres. See the diameter of the fibre is low. We have, I think discussed it earlier that the possibility of a fibre falling on the PTE zone is be more and more. And as a result, the number of overlapping fibres is going to be more and therefore, more wrapper fibres is going to be formed.

Because every time the rotor comes under the fibre feed point, as a possibility the fibre which is ejecting from there may come into contact with the yarn itself, the yarn arm or it may get deposited where the PTE zone is there. That possibility will be more and more if the circumferential length of the rotor goes down.

So, rotor diameter reduction means reduction in circumferential length of the rotor itself. And as a result, possibility of wrapper fibre formation is going to be more. So, that is another disadvantage with the rotor, small rotors. And overlapping fibre lengths, for constant fibre length this has been shown to be,

$$= \left(\frac{50}{\pi}\right)\frac{l_f}{\mathrm{d}_R}\%$$

And for a triangular staple length example cotton overlapping fibres has been shown to be,

$$= \frac{1}{2}\left(\frac{50}{\pi}\right)\frac{l_{f\ max}}{\mathrm{d}_R}\%$$

So, these are where 'l_f' is the fibre length, maximum fibre length in the case of triangular staple cotton and 'd_R' is the rotor diameter. So, they gives you some estimate of the proportion of fibres which will ultimately form wrapper fibres. And what we can say that the overlapping fibres which are likely to form wrappers depends upon 2 parameters, one is the length of the fibre, another one is the diameter of the rotor.

So, when 'd_R' reduces, obviously, the overlapping fibres is going to be more. And hence we should be careful about choosing the rotor diameter, keeping in mind what is the length of fibres that I am using.

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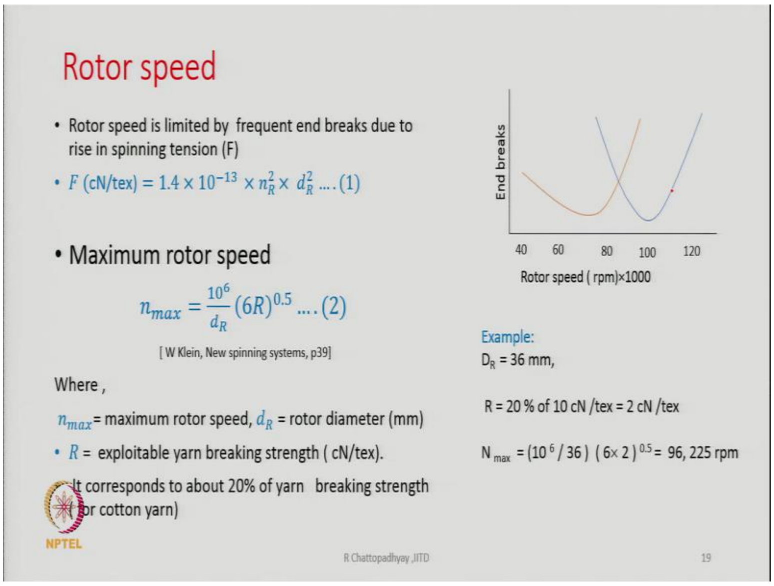

Next comes rotor speed. Actually, rotor diameter, rotor speed, there are interconnected. We have to, no, we cannot sometimes see them in isolation. Length of the fibre, count of the yarn, diameter of the rotor, the groove speed everything has to be seen together.

Anyway, for the rotor speed we should see for when other things are constant, rotor speed is limited by the end breakage possibilities. Because we have to choose a speed, so that the breakage remains within tolerable limit. The breakage is too high, we will not be able to spin the yarn properly, the yarn will break frequently and it will lead to more and more you know joints and therefore, quality of the yarn will suffer.

So, there are two equation which have been suggested to find out the type of speed that we need. One is the calculation of spinning tension, how much tension is acting on the yarn, because ultimately the spinning tension is going to decide where the yarn is going to break or not. So, the first equation states about the spinning tension.

And the second equation is giving you idea about the kind of speed that we can keep. If we know certain parameters which are stated here,

$$n_{max} = \frac{10^6}{d_R}(6R)^{0.5}$$

where 'n_{max}' is the maximum rotor speed, 'd_R' rotor diameter (mm), 'R' is exploitable yarn breaking strength.

And how much is the yarn exploitable yarn breaking strength. That is 20% of the yarn breaking strength for cotton yarn. Otherwise, the yarn will break frequently. So, this is a typical you know equation which has been illustrated. And if I use this equation to find out the 'n_{max}' value, we can see that for a 36 mm rotor diameter, for a yarn of 10 cN/tex tenacity, the typical speed that we can keep is 96225 that is what a speed we can keep, that is what we can get by using these equations.

So, this equation can be an initial estimate for the speed of the rotor. Then, one can really start the machine keeping this speed and check whether I am getting the desirable end breaks or not, is it really practically feasible in a given situation or not.

On the right hand side of the top, there is a diagram, rotor speed versus end breaks. And what we see here that the when this there is a minima, that is at a certain speed we get the minimum breaks. If the speed you go on the higher side, the end break sizes. If we go to the lower side, also end break sizes.

So, this is a typical curve that has been you know seen. That means, for a given situation type of fibre and the you know the kind of yarn that we want to spin for a given diameter of the rotor, there is an optimum speed at which possibility is best. But any speed more than that will be detrimental, any speed less than that is also detrimental. Both way my breakage rate can go up.

So, not sometime that the breakage rate is high; and if I am working in this range, let us say more than 100 in the case of blue curve if we concentrate, if at 100 I get the minimum value. If I go for a value let us say 110 the breakage rate is going to be rise, going to rise. So, one can say, obviously, it will rise because tension is high, so more breaks are required.

But if we go for a speed at 95000, again breakage rate will be high. So, when I am, if I am working on 95000 and breakage is high, and I feel if I you know make a wrong decision thinking that at 95000 the breakage is high because the tension is more. So, let us go for lesser speed 90000 because it will further increase. If I go for 80000, this breakage rate will further increase.

So, if I am working on the left hand side of this blue curve, a reduction in speed is going to increase breakage rate, even though I may be thinking that the tension is going low and low why the breakage rate is going to rise. And so, that will go against the normal logic because there are some other reason for this.

So, in some cases therefore, you may find by increasing the rotor speed I can bring down the breakage rate, when I am on the left hand side of the blue curve. If I am on the right hand side, then increasing speed is going to increase the breakage rate.

It is therefore, very very important to choose, to find out what is the right breakage rate for a given, fibre, the preparation of the sliver, how uniform the sliver that will also matters, how much trash is there matters, what is the orientation of fibre, how many passages has been given to the sliver. Because that decide the fibre parallelizations. Everything will affect the final selection of speed of the rotor.

When the speed is low the breaks may go high due to some other reason. And what it could be? Possibly the tension in the yarn is going to decrease in the yarn arm and therefore, the flow of torque, twisting torque in the fibres which are there in the groove may not be adequate.

So, as I said that we need to have a certain length of PTE, Peripheral Twist Extend to have a stable spinning operations. If the PTE is not there, spinning will be impossible. To have certain length of PTE, the torque must flow. So, whatever torque is there in the yarn arm, part of it must flow.

How can I make more torque to flow? Either by increasing the twist or by increasing the tension in the yarn arm, and that is possible by increasing the rotor speed. So, therefore, by raising rotor speed in this zone, I may gain because more torque is flowing and therefore, an adequate length of PTE is going to develop.

Whereas, as I go beyond 100, already I have no proper PTE. Now, if I still increase the speed, one is the tension is going to be high, the yarn is going to break. The other thing is PTE is extending too much, and more too many wrapper fibres are forming which is weakening the yarn as a result and therefore, the yarn is going to break. So, therefore, one needs to be very very careful here.

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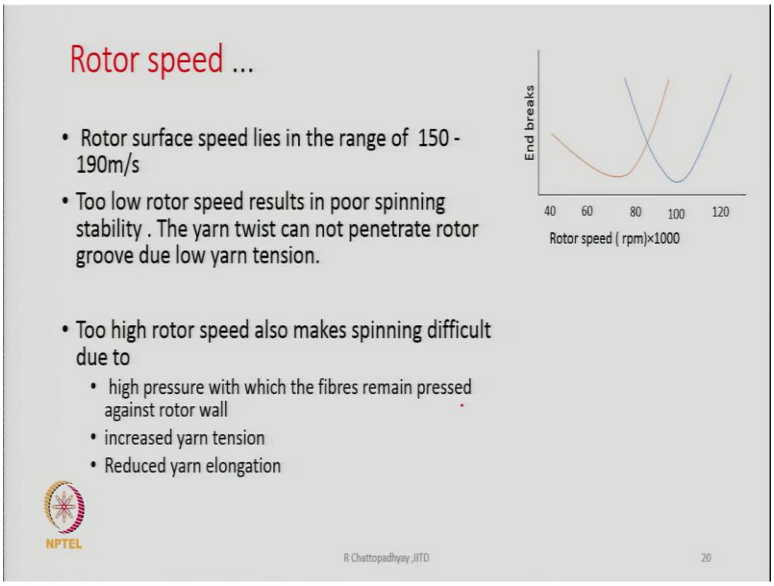

Rotor surface speed lies in the range of 150 to 190 m/s. Too low rotor speed results in poor spinning stability. The yarn twist cannot penetrate rotor group due to low yarn tension. That is what we discussed. The same curve is also there in the present slide.

Too high rotor speed also makes spinning difficult due to high pressure with which the fibres remain pressed against the rotor wall, increased yarn tension, reduced yarn elongations. And also, may be because of lengthening of the PTE which may cause more wrapper fibre formation and therefore, which will weaken the yarn, yarn will break. So, these are the reasons.

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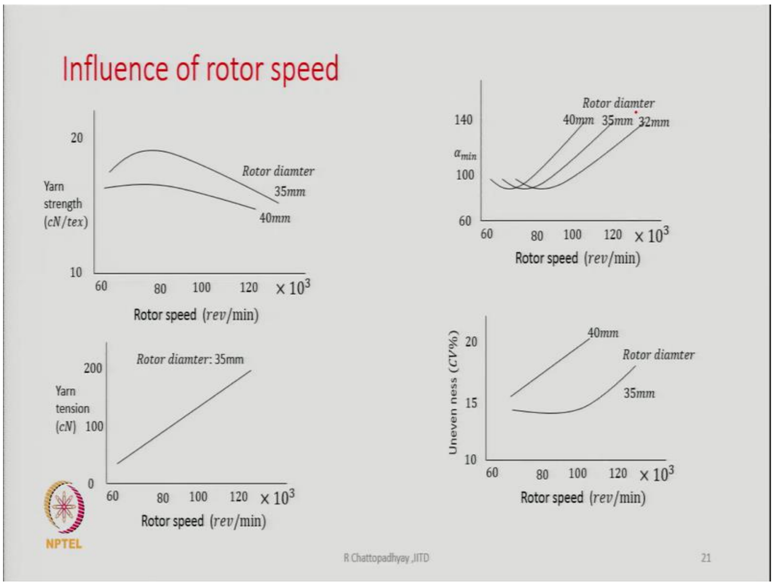

So, there are few typical diagrams are shown here about rotor speed versus yarn strength, rotors speed versus the minimum twist multiply with which we can spin the yarn, rotor speed versus yarn tension and rotor speed versus yarn unevenness. So, for two different rotor diameters, this diagrams are shown here. So, with the increase in rotor speed initially the little rise in strength, after that the yarn strength is going to go down and down with the increasing rotor speed.

The minimum twist with which we can spin the yarn is going, see little decreasing and then is going high. Initially, there is a decrease, but after that it is going to increase continuously. And 'α_{min}' is the minimum twist multiply required to spin the yarn successfully. We want to spin the yarn successfully means basically with the tolerable you know breakage rate.

So, when you go for higher speed, the minimum twist that we require to is multiply that you require to spin the yarn successfully will be more and more. If we keep the twist below that, then the yarn is going to break. So, if we go for higher rotor speed, in order to you know increase the productivity, the minimum twist requirement or minimum twist multiplier requirement is going to increase.

So, if we want to spin a very soft yarn, I go for very low twist multiplier. So, now I have to go for lower rotor speed, that one has to remember. Rotor speed and yarn tension are directly related, so more the speed more the tension is very obvious. The other thing is unevenness is going to rise with increase in rotor speed, because as we go for higher speed, there may be some turbulence created within the rotor and the fibre deposition may be disturbed.

The other thing could be the, there may be rotor fibre the wrapper fibre formations also may increase which can also create problem and it can also go for you know it can increase the unevenness of the yarn. So, selection of speed therefore, is very crucial in rotor spinning.

And you have to keep in mind all these factors, unevenness, strength, especially these two and the end break is rate we also want to see. These are the important you know factors that we have to keep in mind while choosing the rotor speed.

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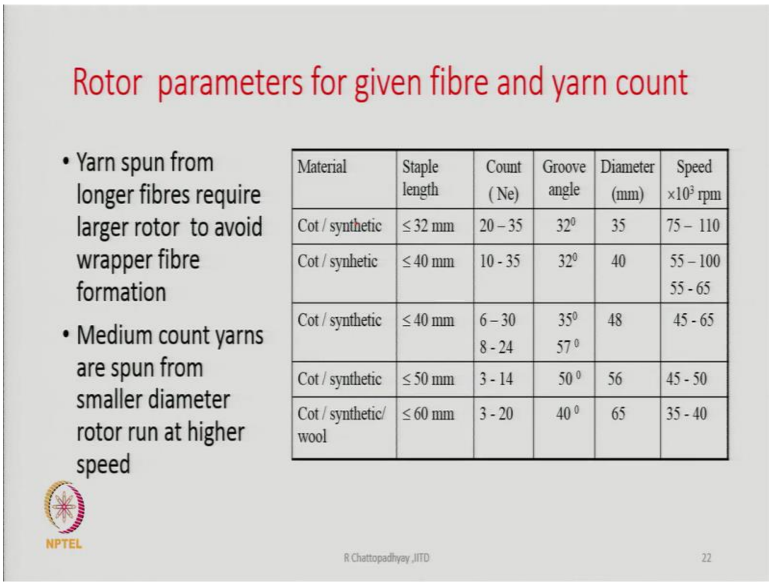

Material	Staple length	Count (Ne)	Groove angle	Diameter (mm)	Speed $\times 10^3$ rpm
Cot / synthetic	≤ 32 mm	20 – 35	32^0	35	75 – 110
Cot / synhetic	≤ 40 mm	10 - 35	32^0	40	55 – 100 55 - 65
Cot / synthetic	≤ 40 mm	6 – 30 8 - 24	35^0 57^0	48	45 - 65
Cot / synthetic	≤ 50 mm	3 - 14	50^0	56	45 - 50
Cot / synthetic/ wool	≤ 60 mm	3 - 20	40^0	65	35 - 40

Rotors parameters for a given count some. You know table is here just to give you some idea, that if you look at this table, yarn spun from longer fibres required larger rotor to avoid wrapper fibre formations and medium count yarns are spun from smaller diameter rotor run at higher speeds.

Ultimately, from commercial point of view, we want productivity to be more and if productivity we have to increase, we have to go for higher rotor speeds. So, somes, the idea about the type of material, staple length of the fibre, count that can be spun, and the groove angle of the rotor, the diameter of the rotor, and what kind of speed, that can be chosen. Some guidance are given here.

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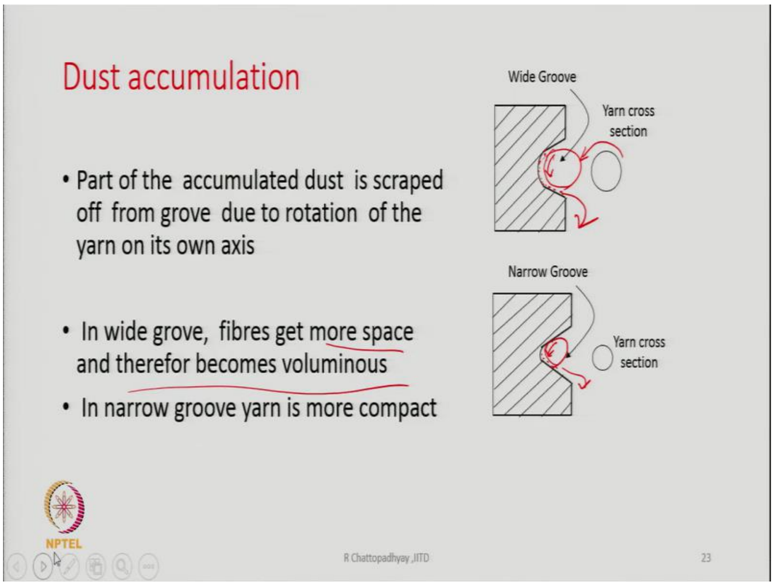

The other important factor with the case of rotor spinning process is the dust accumulations, especially with cotton; that could be fibre debris in the case of synthetic fibres also. There could be accumulation of spin finish, when you process polyester fibres or other similar fibres, if you want to process.

Though dust is not there, but some of the spin finish will be scraped off from the surface of the synthetic fibres which can go inside the rotor and will be depositing there. In the case of cotton, lot of micro dust which are still left in the cotton sliver, will go, and they will be deposited in the groove itself.

Generally, there are 2 types of grooves are there, wide groove and narrow groove. So, wide groove as we see, can accommodate a larger yarn diameter. A narrow groove can accommodate, a small yarn diameter. So, narrow groove automatically means suitable for final count yarn and wider grooves are required for coarser count yarn.

The wide groove, see what happens, part of the accumulated dust is scraped off from the rotor groove due to rotation of the yarn on its own axis. So, there is a possibility of rotation of the yarn. See, the yarn cross section within the groove is rotating also because I am twisting the yarn. So, the yarn is rotating.

So, the yarn is here, the cross-section is here. This is rotating here. If there are some dust particles which are settling here, they will be ejected by the rotating yarn. This is called self-cleaning action by the rotating yarn. The yarn rotates on its own cross-section around its own axis. This is because the bundle of fibres is getting twisted.

So, if the yarn rotates within the groove therefore, because it is in contact with the groove the fibres the not the fibres the dust which are here, the dust will be scraped out and there will be coming out from the groove. Hence part of these dust particles will be sucked out because suction is there within the rotor.

So, dusts which can accumulate within the groove, they can be easily removed if the groove is wide. When the groove is narrow in this case, the yarn may rotate, but the dust ejection by the rotating yarn will be less, because at the very corner groove being very narrow at the corner itself some dust is still there where the yarn cross-section may not be able to reach because the wedge shape of the groove.

So, dust accumulation one is the entry of dust. How much dust is going to enter per unit time depends upon the sliver feed rate, and what is the dust content in the sliver, that will decide at what rate the dust is entering the rotor. Part of the dust will be also we taken out at the you know cleaning done by the opening roller itself, but rest of it will go inside. So, every per unit time so much dust is coming inside. So, more of it will come.

If I want to produce a coarser yarn, now dust which are finally entered the groove, part of it will be removed by because of the self-training action of the yarn itself because the yarn cross-section rotating as I have said. So, the wide grooves gives a better opportunity for scraping out of the dust. A narrow groove does not facilitate the cleaning of the groove.

At the same time, the wide grooves gives more space and therefore, the yarn becomes voluminous. Wherein the case of narrow groove it will not be so voluminous because the space is not there. The yarn will be more compact. But sometimes we need compact yarn, sometimes we need voluminous yarn. So, depending upon our need, we can choose the groove.

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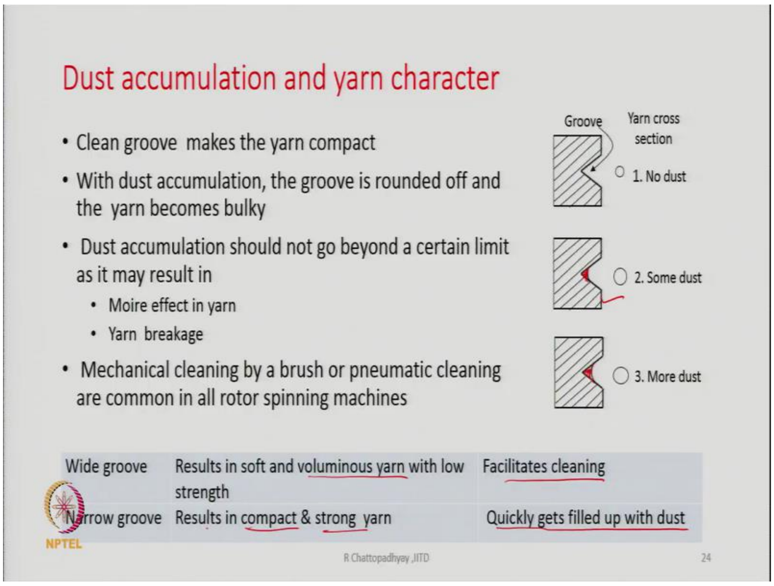

So, groove, different types of groove shapes are shown here and we see that when the groove is clean, there is no dust. This one shows, some dust is accumulated here, here, I see more dust and here there is no dust. Clean groove makes the yarn compact because fibres can go inside and get compressed.

With dust accumulation the group is rounded off. So, same group with time dust is accumulating it has become rounded off. More time means more rounded off. That means, the character of the yarn is going to change with time because more and more accumulation of dust in the groove.

So, dust accumulation should not go beyond a certain limit as it may result in Moire effect in the yarn and finally, it will lead to yarn breakage. So, before the breakage happens, the character of the yarn may change because of continuous gradual accumulation of dust particles in the groove.

So, what we do? Time to time that we mechanical cleaning is done by the brush or sometime pneumatic cleaning are also done. Whenever the end breaks, generally, nowadays the rotor box is open and the dust which have settled within the groove they are sucked out.

First, there is a brush which will go and you know simply it will go and try to brush the inner part of the rotor. Especially, the groove part, dust will be loosened and then this dust are sucked out. So, we clean the rotor. This is what is done normally.

Wide groove will always give you a soft and voluminous yarn and it also facilitates cleaning as we have stated. Narrow groove results in compact and strong yarn, but quickly gets filled up with dust. So, both types of groove has their own advantages or disadvantages. But there are we have already discussed earlier there are 4 different types of grooves which have been designs. They can be broadly classified into basically two groups, wide groove and narrow groove.

So, keeping in mind, the type of yarn we need, the dust particle which is there in the sliver, we have to choose the right type of groove geometry or the rotor with a right type of geometry. With this, we close this particular lecture. And after this we will discuss some other aspects of Rotor Spinning.

Thank you very much.