New Spinning Technologies

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Lecture - 05
Rotor: construction, geometry and drive

Today we are going to learn about the Rotor, rotor is the most important element in the rotor spinning and we are going to learn about the construction part of the rotor, its geometry and the way it is driven, these are the aspects we are going to learn today.

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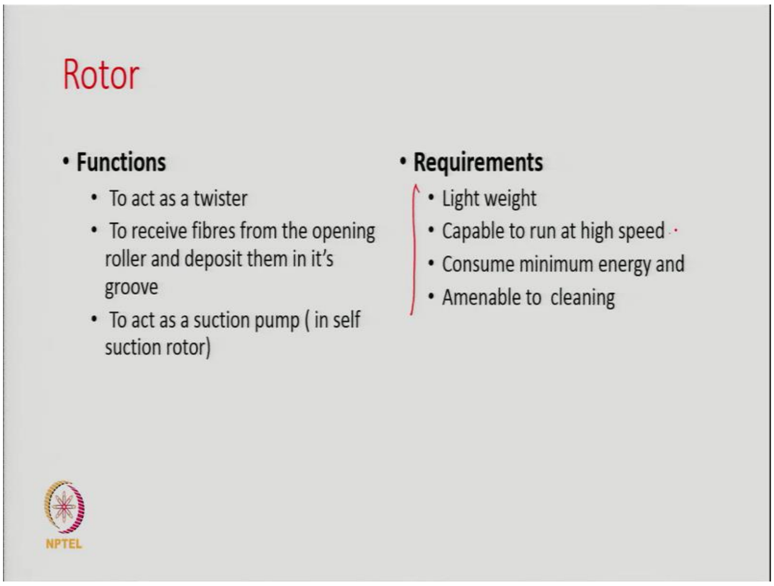

So, the rotor the main functions are to act as a twister, the second point is to receive the fibres from the opening roller and deposit them in its groove. So, it is acting as a collecting device and to act as a suction pump. Now, this is only in the case of self-suction rotor otherwise it is not does not act as a pump.

So, it is a twisting device we can say in the rotor spinning machine, its job is to receive the separated fibres which are coming from the opening roller side and then depositing them in the groove of the rotor in the form of layers after layers and is trying to consolidate also the assembled fibres these are the functions.

Now, what are the requirements in the rotor? One is that it should be light weight, it should be capable to run at a very high speed usually most of the rotors in today's machine operate at a very very high speed, it could be 80000, 90000 or 100000 or 110000 rpm. So, the rotor will be subjected to very very high forces when it runs and the it should be capable to run at that high speed and to reduce the power consumption, we have to make the rotor light.

It should consume minimum energy that is another aspect and it should be amenable to cleaning easily. We will see that when the fibres are flowing into the rotor especially the cotton fibres lot of dust particle will also flow and they will go into the rotor and where they will go then they will go and accumulate in the groove itself.

Even though we try to clean the fibres in the blow room, we also clean them on carding machines and even then lot of dust particles are still left in the card sliver and we further clean them by the opening roller assembly. There also we try to remove some of the very dust particle and some trash particles which are still left in the sliver.

But even then some particles or very very minute trashes are still left and these are the fibre these are the you know trash particles and dust particles which will finally, land into the rotor and they will accumulate within the rotor. And if they keep on accumulating they ultimately lead to breakage to the yarn twisting process get disturbed and when it happens we have to stop the machine stop that particular rotor not the entire machine and then clean it.

You have to remove the accumulated dust therefore, the design aspect of the rotor housing should be such that we should be able to remove, we should be able to be stop the particular unit, we should be able to remove the lead quickly and then clean make the rotor open and clean it either manually or by some other automatic means.

So, it should be amenable to cleaning repeatedly depending upon the level of dust which is still left in the sliver. So, these are the important requirements light weight, capable to run at high speed, it has something to do with the drive aspect and the bearing part, it should consume minimum energy because the more the speed we want to attain more power is required. So, and the power requirement goes very high then the cost of the manufacturing will go high. So, therefore, minimum energy requirement is also very important here.

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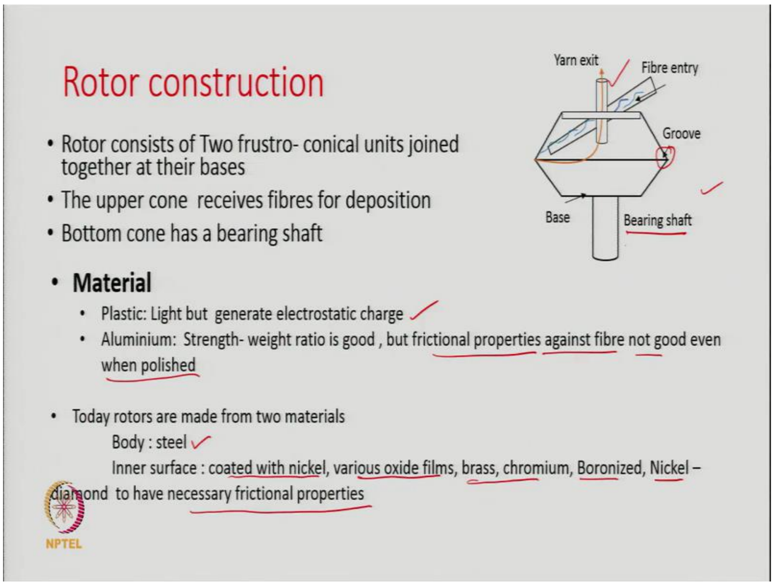

Now, rotor construction if we see in this diagram we are showing a typical simple sketch of the rotor. There is a base, there is a bearing shaft, then there is a fibre entry tube and there is another tube perpendicularly placed with respect to the rotor and through this the yarn is going to exit and here is the groove part.

So, construction wise it is quite simple, rotor consists of two frustro-conical units joined together at their bases. The upper cone receives fibres for deposition. So, you see the fibres shown here by the blue lines. So, fibre entry point and they pass through the tube and they arrive in the rotor. Bottom cone has a bearing shaft as shown it here, this is the bottom cone and there is a fixed shaft.

The material which is used is usually if you say plastic it is lightweight, but it can generate electrostatic charges. So, therefore, plastic rotors are not made. Aluminium strength weight ratio is very good, but frictional properties against the fibre not good even when polished. We all know that aluminium is very light material amongst the metals, but the problem is that when the fibres are going to land on the inner wall of the rotor then the fibre has to slide down we will see that.

So, while it is sliding down towards the groove the friction between the fibre and the rotor wall becomes important, a smooth sliding is something which is necessary in order to ensure that the deposited fibres are not or do not get crumbled. So, therefore, rotors are today made from two materials, the body is steel and the inner surface is coated with nickel, various oxide films, brass, chromium, boronized, nickel, diamond these are basically needed to impart the right frictional properties and the other thing which is important is that the fibres are very very abrasive.

So, the inner wall the frictional characteristics of the inner wall will get change with time, because continuous abrasion between the fibres and the inner wall which is happening and hence we have to protect the rotor also. So, there has to be a kind of finish which not only give us the right frictional properties, but at the same time it will ensure that the wall do not get damaged quickly, everybody expects that it should have a certain life.

So, depending upon the know the cost of a rotor there is certain expectation about the life of the rotor also and when we discuss about the life the frictional property changes with of the inner wall is become also become very important. So, you have to ensure that the frictional properties remains what is required and what is required is a smooth sliding action of the fibres when they are going towards the groove.

They land on the inner wall which is inclined and they are gradually they will be sliding down towards the groove. So, while in this process this would not get crumbled.

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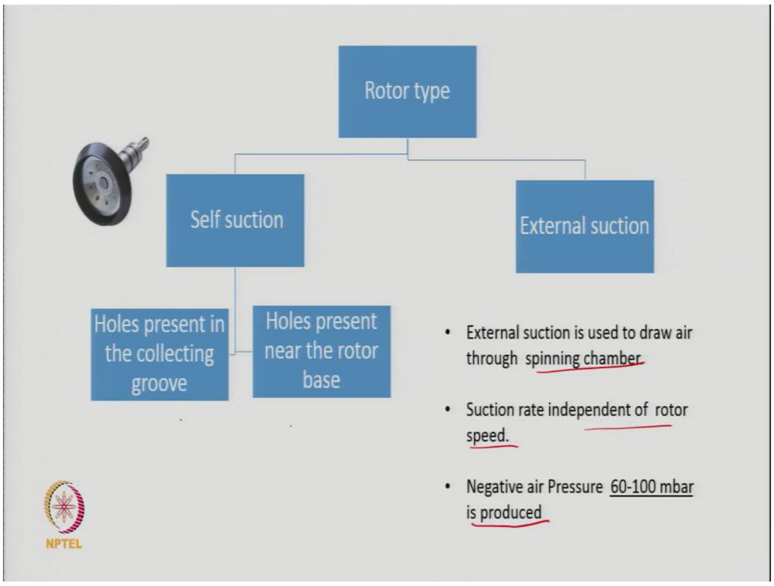

Now, type of rotors basically there are two types self-suction and external suction these are the two types of rotors which have been developed. Now, in the self-suction type there are two varieties; holes present in the collecting groove, you can see in this rotor we are showing you the holes here or holes present near the rotor base could be two types.

Here we see the holes are placed near the rotor base here, not in the groove, these are known as self-suction rotor that is the rotor itself will act as a suction pump and we do not need any external suction. The other one is external suction rotor has no holes, but the rotor chamber is connected to an external suction unit.

So, that we suck air through the rotor, why do you need to suck air through the rotor, because we need to transport fibres from the opening roller surface to the rotor and how they will be transmitted? It is through the medium of moving air which is transporting the fibre. So, we have to generate an air current through the feed tube and to generate a air current we have to suck air.

So, we are sucking air through the rotor and there is a escape route also has to be there and this there has to be air entry there to air escape route both and the entire thing is connected to this rotor housing in a way is connected to a external suction pump which is drawing air and this suction pump through ducts are connected to all the rotors of the machine.

And it is this fluid flow or the air flow through the rotor is also very very important because if the turbulence gets created within the rotor the fibres which are getting deposited there will be disfigured or you can say they will be crumbled too much they will be entangled, they will get caught by the you know by the yarn which you are forming. So, all sort of disturbance will be created and they basically in a way the yarn quality will suffer and that could be frequent end breakages.

So, the right velocity of the air and the nature of air which is there within the rotor in terms of the movement of the air within the rotor they are all very very important. To ensure that the rotor spinning machine works very very you know very very smoothly and with it without creating much problem.

The external suction unit what we have as it is written here is used to draw air through the spinning chamber, suction rate is independent of the rotor speed that is the great advantage. So, in the in these two cases the suction rate would depends upon the speed, when the speed is higher suction rate is higher, when the speed is low suction rate also falls down so, but in case of independent suction unit it is this problem will not be there.

Negative air pressure of 60 to 100 mbar is what is produced that is what of you know negative pressure we require within the rotor chamber, that will then cause the air to suck to get sucked from the atmosphere or from the environment.

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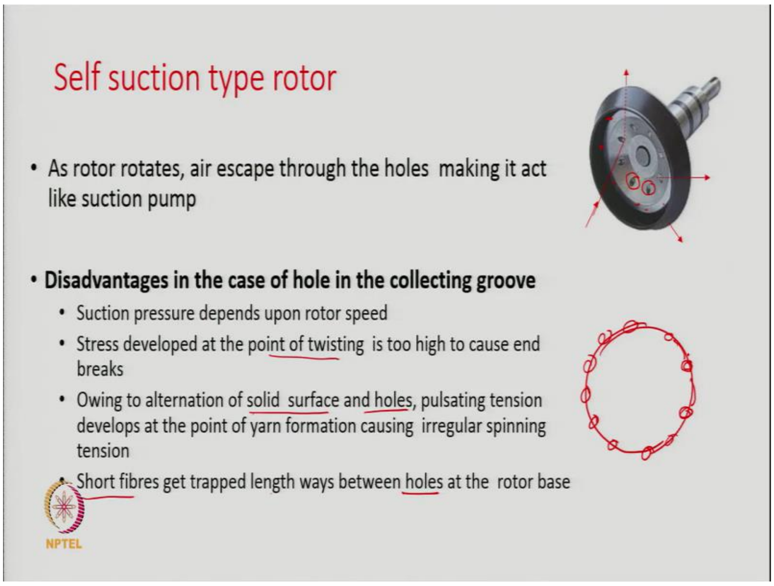

Now, self-suction type of rotor if we look at it the air enters and then these are through the hole itself the air will escape. Disadvantage in the case of hole in the collecting groove, if I place the hole here the holes are placed on the base, but if the holes are there suppose they are here in the groove, this is groove, this here is groove here, these are the grooves then what are the problems suction pressure depends upon the rotor speed that will be true irrespective of where hole is placed.

Now, the stress developed at the point of twisting is too high to cause end breaks. If the holes are there, in the groove itself because grove is the place where the fibres are deposited. So, at that place if the air is also trying to push the fibres and trying to escape through the holes, then lot of stress will develop on the fibres because the air is passing through the fibres at the twisting points.

The twisting point is moving along the periphery of the rotor or along the periphery of the groove where the groove is. So, the when the point moves or point is close to a hole or aperture lot of stress will develop additional stress will develop which may cause end breakage.

And owing to the alternation of solid surface and hole, pulsating tension develops at the point of yarn formation causing irregular spinning tension thereby leading to breakage because the periphery is let us say this is the periphery of the rotor or the groove. Now, I have holes like this here, another here, another here, another here like that we have holes at regular interval.

So, we have a solid surface then there is a hole, another solid surface then there is a hole and this will create a pulsating tension, tension peaks will be created repeatedly which can cause irregular spinning. The other problem is short fibres get trapped length ways between the holes, short fibres because the holes are quite close to each other in comparison to the length.

Even the short fibres can get between the holes and they can also get accumulated in the hole can choke the holes the dust will go and you know settle there. So, having holes whether on the base or in the groove will have lot of implications and therefore, today you will not find a rotor where the holes are there inside. So, the self-suction rotor therefore, could not succeed we all have external suction rotors.

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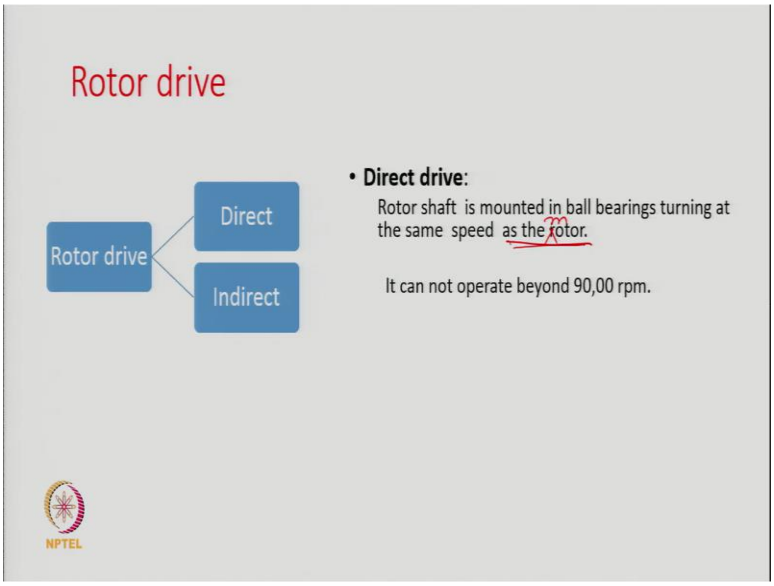

Rotor drive if we see drive could be two types direct drive or indirect drive, in the case of direct drive rotor shaft is mounted in ball bearing turning at the same speed as the rotor itself. They will run at the same speed as the motor because the rotor shaft is connected to the motor directly and these cannot operate beyond a 90000 rpm.

So, this kind of drive is there, but the limitation is we cannot go beyond the 90000 rpm, there are mechanical you know difficulties in running the rotor beyond the speed of 90000 with direct drive; that means, and second thing for each and every rotor we should have a motor. So, there are individual motor drive where if we have 120 rotors in a machine we need 120 motors.

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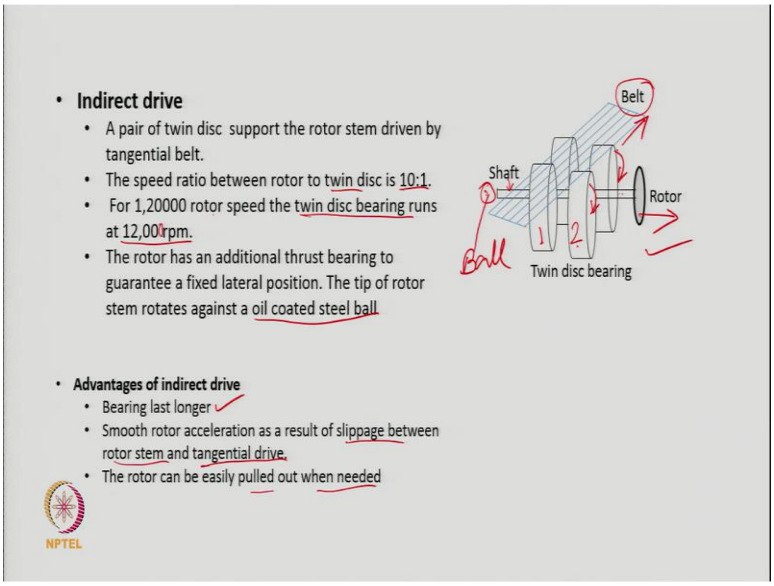

The other one is indirect drive as it is shown here a pair of twin disc support the rotor stem driven by a tangential belt. So, these two are the twin disc and here is the rotor and this is the rotor shaft, this is the rotor shaft. So, the rotor shaft is placed in between in the nip of the twin disc bearing and then the twin disc, disc 1 and disc 2, this is disc 1, this is disc 2, these two discs are actually in contact with a tangential belt and the belt is driven by a motor.

So, the belt is tangentially placed on the disc it is in contact with the disc, as the belt runs this will rotate the disc will rotate and the disc rotates the shaft rotor shaft will also rotate and thereby rotor rotates. The speed ratio between the rotor to the twin disc is 10:1, that is how the diameters are chosen, diameter of the disc and the diameter of the rotor shaft are chosen in such a way that one rotation of the discs will give you 10 rotation of the rotor shaft. So, the ratio is 10:1.

So, for 120000 rotor speed twin disc bearing runs at 12000 rpm it will run at 12000 rpm. So, the speed of the disc is much less in comparison to the speed of the rotor 10 times less. The rotor has an additional thrust bearing to guarantee a fixed lateral position. The tip of the rotor stem rotate against an oil coated steel ball.

So, there is a oil coated steel ball which is placed over here because it the at a high speed the shaft can generate thrust, the tip of the rotor stem rotates against a oil coated this has to absorb the shocks. So, oil coated steel ball is placed over here and when it is pressed is going to absorb the thrust.

So, that our aim is to ensure that the rotor rotates uniformly at a high speed without much of a vibration, because vibration will lead to tension peaks in the yarn that will cause yarn breakage. So, we have to avoid that and that is how the entire rotor drive system has been designed and which is followed by the well reputed machine manufacturers.

Advantages of indirect drive; one is the bearing last longer, smooth rotor acceleration as a result of slippage between the rotor stem and the tangential belt. So, rotor acceleration is smooth so some slippage is actually good. Rotor can be easily pulled out when needed, when we want to take out the rotor for some inspection purpose we simply pull the rotor out in this directions easily and push it back it settles between the disc.

So, pulling out the rotor for inspection purpose, for cleaning purpose or replacement purpose is very easy and put it back also is very easy. So, these are the advantages and bearing last long because the bearing speed is not that much at the most 12000 rpm because it will always 10 time less whereas, in the case of direct drive if the rotor speed is 80000 the bearings also rotate at that speed.

And hence that problem exists and generally most of the drive we have twin disc bearing and this kind of drives are indirect drives are used.

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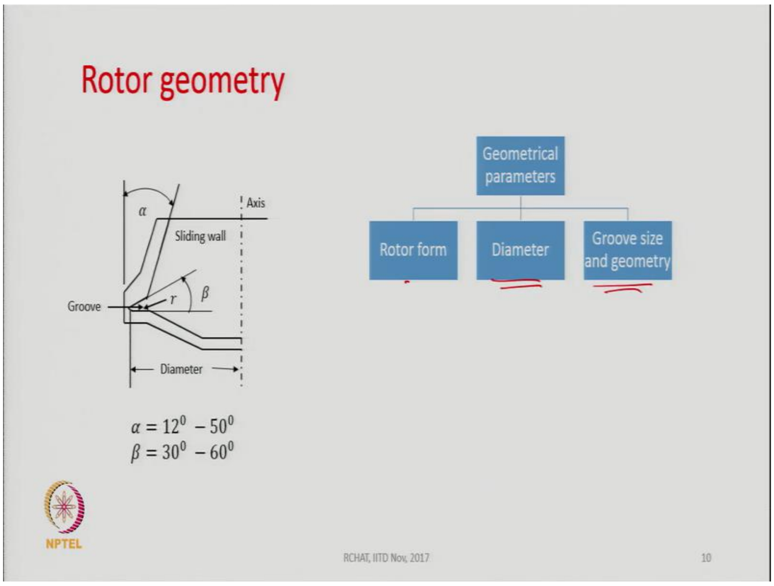

Now, rotor geometry, the rotor in a very simple term it is two cones attached at the base, but it is very important that what should be the inclination of the upper cone, what should the inclination of the bottom cone, these are important and we are going to discuss that. The geometrical parameters are form of the rotor, diameter and group size these three things are very very important.

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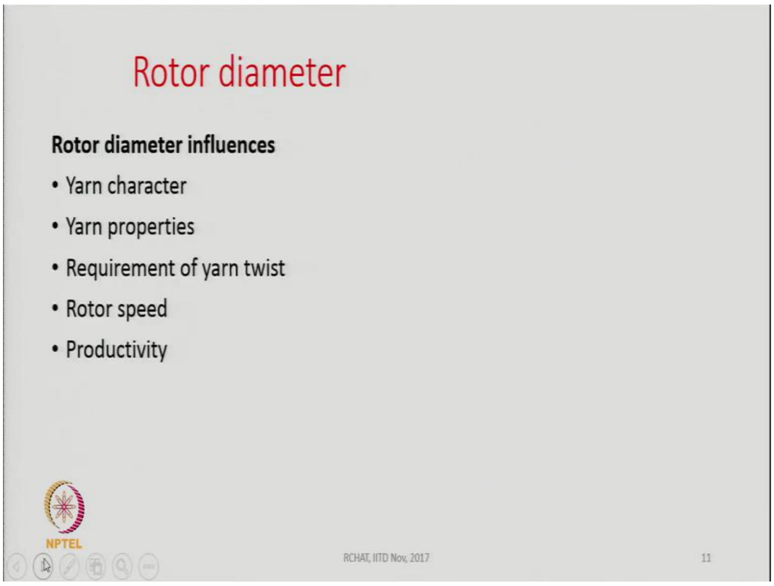

First we will discuss diameter, rotor diameter influences yarn character, it will also influence yarn properties, it can also have implication on the level of twist that we need to make sure that the spinning is going on smoothly or the spinning stability is there we are not encountering frequent breakages. It will also have effect on the rotor speed that we are going to choose and it can also have influence on the productivity.

So, rotor diameter selection for a given count of yarn and type of fibre is important because there are many things which are influenced or which are affected by the rotor diameter.

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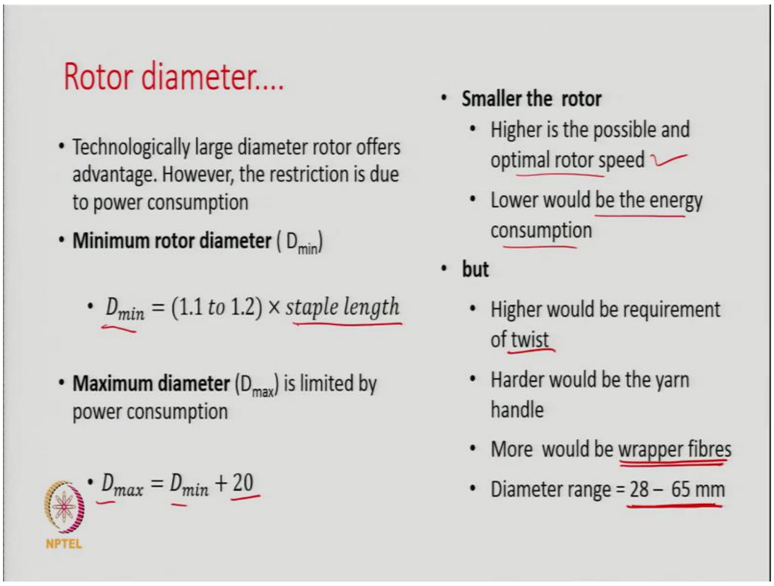

Technologically large diameter rotor offers advantages. However, the restriction is due to power consumptions, larger the diameter more is going to be the weight or the material remains same. So, though there are technological advantages we will discuss what are the advantages. Restriction is due to power consumptions.

So, minimum rotor diameter has been prescribed which says minimum diameter of the rotor will be 1.1 to 1.2 time this staple length of the fibre, diameter should not fall below this. And the maximum diameter is limited by the power consumptions. So, 'D_{max}' is 'D_{min}+20', these are some empirical formula which I have been suggested that there is a minimum diameter which is mostly decided by the staple length of the fibre or length of the fibre that we are going to process and there is a maximum diameter also, if we go beyond that power consumption is going to be unnecessarily very high.

The smaller the rotor higher is the possible and optimum rotor speed, small diameter has a advantage and lower would be the energy consumptions. Speed that can be attained will be could be higher and the energy consumption can be lowered because the mass is less, the weight is going to go down.

If we have a option between two diameters then lower diameter is always beneficial generally we will feel that because it will have less weight and hence less energy requirement will be there. Or the other way we can say it if the diameter is small I can go for little higher speed and take advantage of the productivity for a given level of twist if I can increase the speed by 10% let us say going from one diameter to little smaller diameter my productivity can increase also.

So, that way you know it can help, but higher would be the requirement of twist if we go for small diameter rotors. So, the possible gain that we expect because the speed is 10% more so, one can think that will lead to 10% more productivity, but not necessarily because we may find that by doing so, the end breaks have gone up and to compensate that then we have to go for higher level of twist and if we do so, a productivity will again go down.

So, what was expected that expectation may not be fulfilled because with smaller rotor higher twist is required in the yarn and there are to spin satisfactorily and if I can go for higher if we have to go for higher twist then harder is going to be the yarn, the yarn character is going to change.

So, that will be a there is a negative consequence of trying to go for lower rotor diameter and why it will be harder because of more wrapper fibres formations which are going to discuss later. There are many fibres in the rotor yarn which are actually wrapping the yarn perpendicular to the yarn axis, some of them will wrap and the inclination angle could be less than 90°, but there could be some fibres which will be wrapping the core part of the yarn at 90° also.

And these wrapper fibres which are wrapping the yarn code at 90° they will make the yarn hard these wrapper fibres are known as belts that will cause the rotor yarn harder. So, the diameter range practically varies between 28 to 65 mm. So, depending upon the type of fibre or blend ratio or level of dust which is there in the sliver, the fineness of the fibre, the length of the fibre, whether the fibre is cotton or it is polyester cotton or viscose, mixed cotton or PV only depending upon that the diameters are chosen and typical diameter values of the rotor lies between 28 to 65 mm.

We will learn more about the rotor selection in some other you know session.

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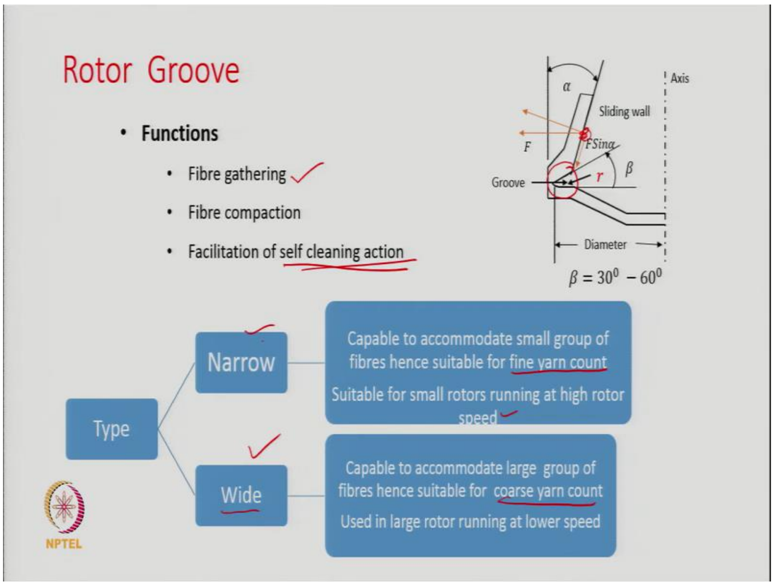

Now, we will go to the rotor groove, the groove is a very interesting area of the rotor, functions are here is the place where the fibres are going to gather the groove is shown in this diagram. So, groove is here, the fibres will flow down, the fibres will arrive here and then they will flow down simply they will slide down and will finally, reach the groove which is a very narrow you know wedge shaped space within the rotor.

The groove helps in compaction, because of the centrifugal force that is acting on the fibres and the limited space in which we are trying to accommodate the fibres in the corner and we are creating a corner and we are placing the fibres there and then you are applying a force because which is a centrifugal force and hence the fibres are getting compacted there.

And facilitation of self-cleaning action that is another function of the groove, that groove the rotation of the yarn within the groove can also help in cleaning the groove. The fibres which are accumulating within the groove they are ultimately getting twisted and when the yarn is getting twisted, we will see that when the place where the yarn formation point is there within the groove at that place the accumulated fibres are getting twisted and the twisting action rotation of the fibres within the groove will cause lot of dust particles which are settle there, those dust particles will be scraped out.

So, that is another you know purpose of the groove geometry that it facilitates self cleaning. So, how much cleaning is possible which all depend upon the geometry of the groove. Now, the groove types are two; one is narrow and the other one is wide. So, narrow means the corner is very very narrow, the dimensions are too less and wide means it is quite wide.

Narrow grooves capable to accommodate small group of fibres and suitable for fine count yarns, when you try to process fine what we try to produce fine count yarn, the number of fibres in the yarn cross section also will be less. So, we have to go for a very narrow groove so that we can compact the fibres.

If the groove is wide and fibres are less in number then compaction will be less, suitable for small rotors running at high rotor speed, when narrow grooves are there in small rotor mostly which are running at high speed. The wide grooves are capable to accommodate a large group of fibres and suitable for coarse count.

So, generally narrow groove means for finer count yarn and coarse groove means for coarse count yarn because number of fibres in the cross section is more and hence the groove size has to be bigger and they are used in large rotor running at lower speed. So, one is wide groove, the other one is narrow groove.

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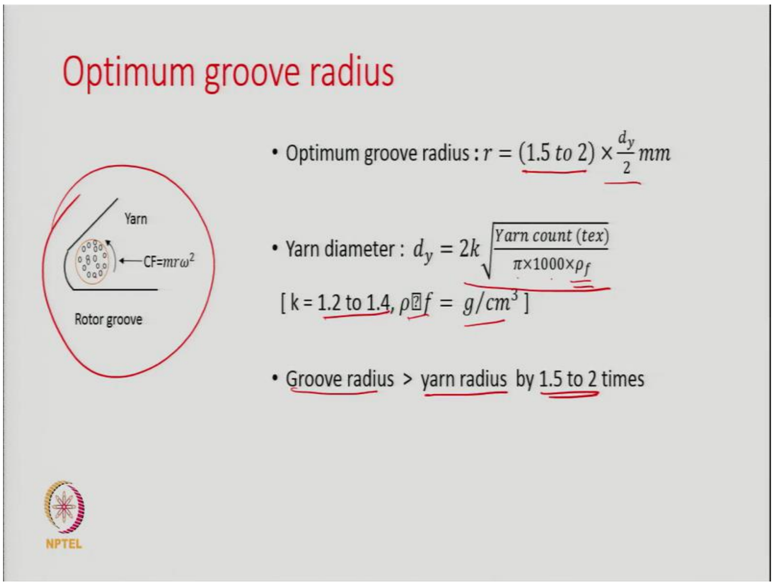

Now, groove what is the optimum radius of the grooves? If I look at the groove here as shown it here, this is the groove and these are the fibres, these are the fibres. So, optimum groove radius so, what should be the radius of this groove it has been stated to be 1.5 to 2 times the yarn radius, $d_y/2$, where 'd_y' is the diameter of the yarn.

So, groove radius would be 1.5 to 2 times the expected yarn radius and yarn radius or yarn diameter we can all calculate based on this simple formula which have been stated in many text books. The diameter of the yarn is,

$$d_y = 2k\sqrt{\frac{yarn\ count(tex)}{\pi \times 1000 \times \rho_f}}$$

'ρ_f' is the diameter of is the density of the fibre not diameter is the density of fibre.

And 'k' is a constant and the constant 'k' is could be 1.2 to 1.4 and 'ρ_f' is the fibre density the unit is g/cm^3. So, groove radius must be greater than yarn radius by 1.5 to 2 times.

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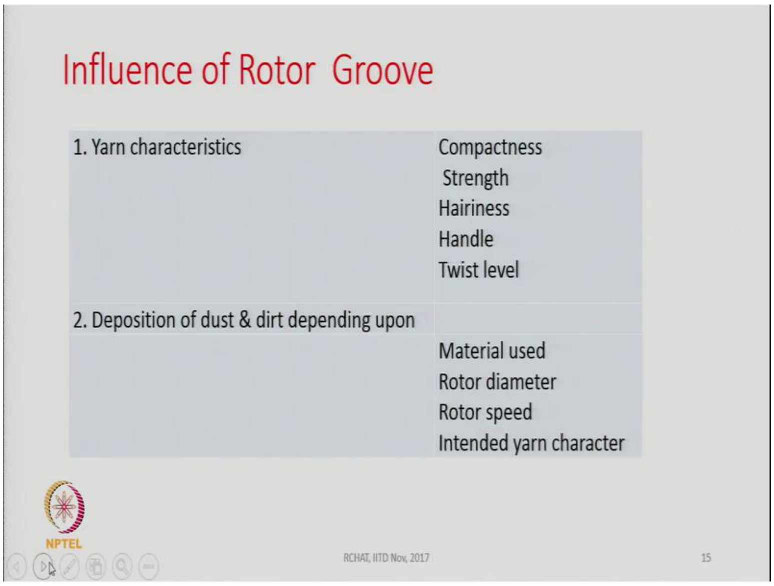

Now, what is the influence of rotor groove? The yarn characteristics; that means, compactness of the yarn where; that means, the diameter of the yarn, then it affects the strength of the yarn, the hairiness of the yarn, the handle part how soft the handle is whether it soft or harsh or hard and it can also affect the level of twist.

Second thing is deposition of dust and dirt depending upon, the material used how much dust will be settling there and how quickly they will be removed due to self-cleaning action of the rotor itself will all depends upon the groove geometry. Some grooves which is too narrow the rotating or the yarn formation point may not be able to really reach the remote corner of the groove and will not be able to scrape out the deposited dust.

In that case some dust will always remain inside the groove the it depends upon the material used, rotor diameter, rotor speed and intended yarn character, what type of yarn finally, you want to character basically means whether you want a soft yarn, whether do we need a hairy yarn or we need a hard yarn. So, character of the yarn can be changed depends upon the rotor groove.

Rotor groove can affect therefore, rotor speed, rotor diameter selection also depend may depend upon rotor groove and the material that is used and intended yarn character.

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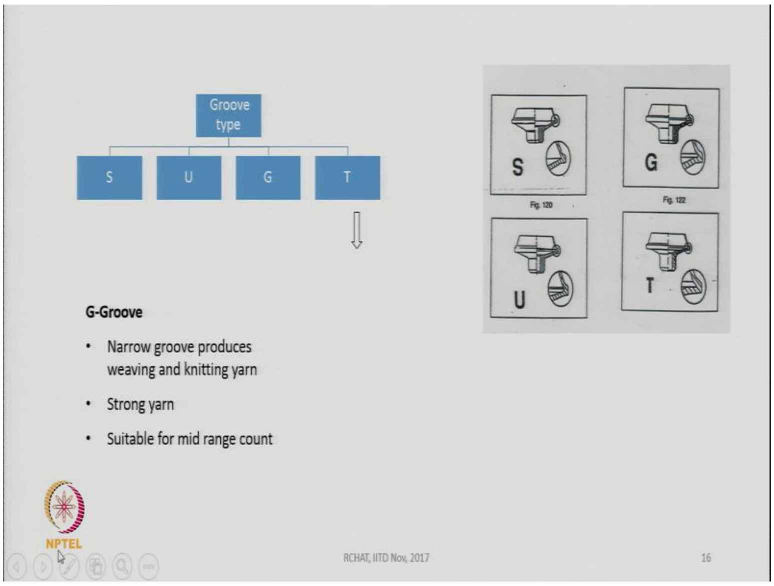

Now, grooves type has been stated in the textbooks as S type, U type, G type and T type these are the four different types of grooves which are there. G groove ultimately grooves are basically two types you can say narrow and wide and within that these varieties may exist depending upon the as I said type of fibre you want to process, how much dust is there, if we want to process only viscose yarn there is no dust in that, if we want to process only viscose and polyester together there is no dust in there.

So, whether dust exists or not, whether trash exist or not and what is the count of yarn I am going to produce. So, these are the many different aspects that affects the grooves reaction also. So, rotor and groove they go together with this let me close.

Thank you.