New Spinning Technologies
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Lecture - 11
Rotor Yarn: Structure, Properties and Applicatio

So, now we are going to discuss the Structure, Properties and Applications of Rotor Spun Yarns. Let us first discuss why structure is so important for any yarn? It is because the yarn property is function of fibre properties and its structure.

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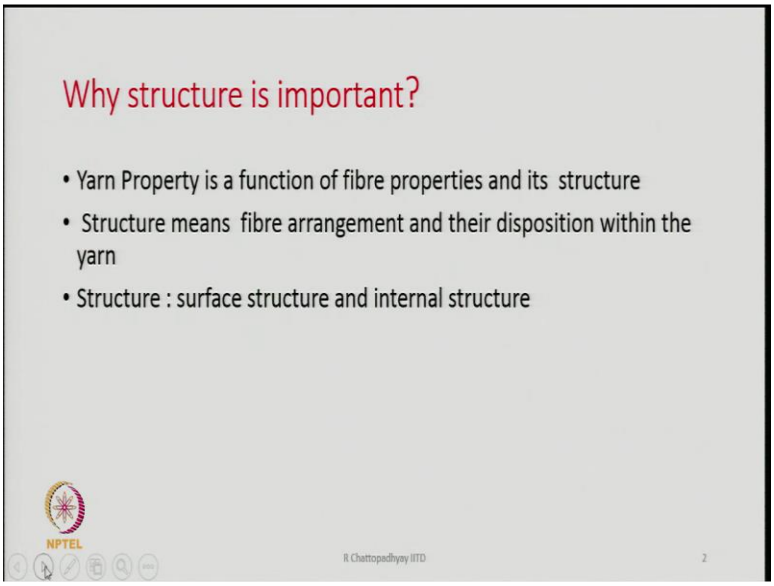

For any spun yarn for that matter, the property of the yarn is dictated by the intrinsic property of the fibres that we are using in making the yarns and then what comes is the structure part of the yarn. Structure basically means the arrangement of the elements that is the fibres, their dispositions within the yarn; that is how the fibres are located within the yarn that is all about the structure.

So, you will find that different yarns have different structures, that is the arrangement of fibres within the yarn, the shape of the fibres within the yarn, they differ from each other depending upon the technology that has been used to produce the yarns. So, whenever we go from one technology to the another technology to produce the yarns, even though the fibre may still remain same, but the structure will change.

That basically means the fibres and their locations, the way they are twisted, the configuration of them, they differ and as a result the properties will change. Now, when it comes to structure, there were two aspects of it; one is the surface structure which is actually visible to us, if we look at a yarn under a microscope. Whatever we see on the surface that is the surface structure of the yarn that gives the texture part of the fabric as well.

The other part which is not visible is the internal structure of the yarn; so, we can say structure has two components, surface structure and internal structure.

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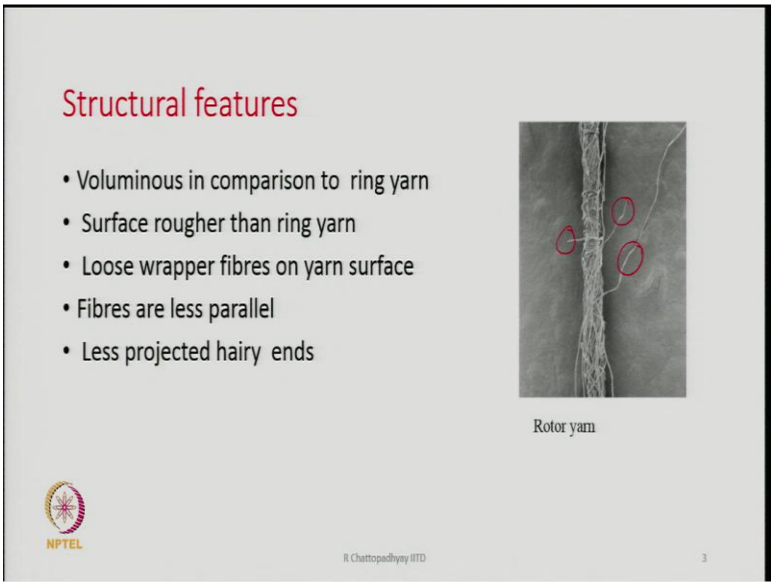

The general structural features of a rotor yarn, we are going to discuss now. See, we can see there is a an image of a rotor yarn that is what is shown, What we see from this image? Generally, the rotor spun yarns are more voluminous in comparison to ring yarn, this is generally true.

The surface is rough, we can see; look at the fibres on the surface, the fibres are haphazardly, you know lying there and they are not really well aligned. Their inclination angle of the surface fibres is not really constants, they are varying from place to place and because of all these, the surface of the rotor yarns are very rough.

Whereas, the surface of ring yarns are much smoother because the fibres are well aligned there. Next thing is, loose wrapper fibres can be seen on the yarn surface, we will find a lot of fibres which are loosely wrapped they are really not twisted, they are simply wrapping around the main body of the yarn. We call them wrapper fibres, this will be also visible and in general, fibres are less parallel.

What we see on the surface and what lies within in both the cases, the fibres are not really very very parallel with respect to the axis of the yarn neither with respect to the axis of the fibre themselves. Relative to each other, they are not very parallel and with respect to the axis of the yarn, also they are not parallel. See, this is another typical you know feature.

The other part is the hairy ends; see this is a, what you see here is a hair, this is also a hair, this is also a hair, these are hairy ends. These ends on an average are much less in the case of rotor spun yarn in comparison to ring yarns.

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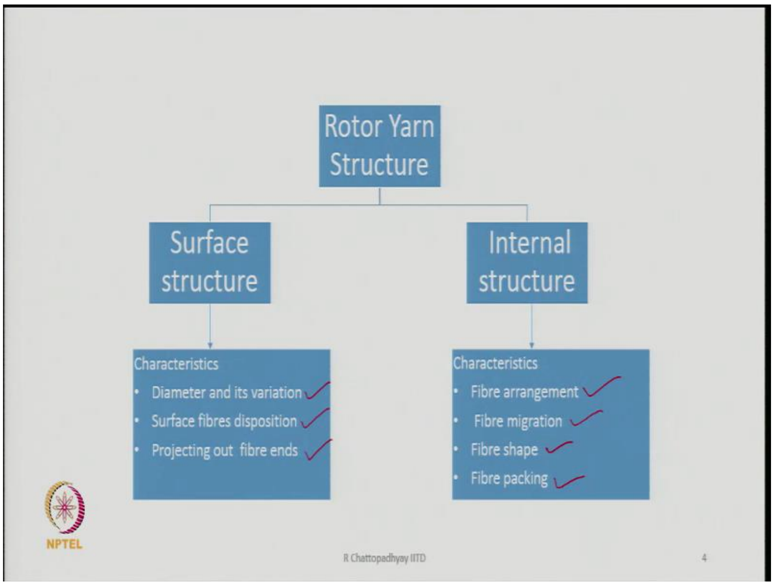

So, these are the typical some features; now, we will go little details of the structure. So, rotor yarn structure has two components as we have already discussed, one is the surface part of it, the other one is the internal structure of it. In the surface part of it, what is visible to us is diameter and its variation the surface fibre dispositions, the projecting out fibre ends, these three things is what is can be seen when we look at a yarn under a microscope.

The internal structures are related to the arrangement of fibres, the migration, characteristics of the fibres. The fibres keeps on migrating from one radial position to another radial position within the yarn, we call it migration. The shape of the fibres, the shape of the fibres which are lying on the surface, their shape will be visible. But what is lying within the yarn, their shape is not visible to us.

They are within the, they remain within the yarn, we need a special technique to look at those fibres which are within the yarn structure and not visible when we take a photograph of it. The other thing which will be important is the packing of fibres within the yarn cross sections how the fibres are packed. Packing can affect many properties and therefore, fibre packing is something which is important when we discuss about the structure of any yarn.

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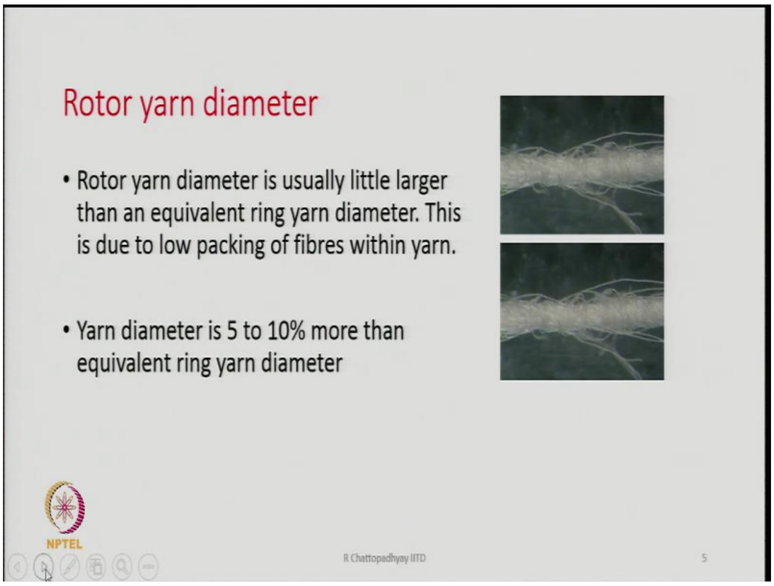

Now, when we discuss the diameter, here we see two rotor yarn images, both are rotor yarns and we can see the way the fibres are there on the surface. Many fibres appears to be quite loose. Now, the diameter when we look at it, generally the rotor yarn diameter is usually little larger than an equivalent ring yarn diameter and why is it so? This is because of low packing of fibres within the yarn.

The packing of fibres within the yarn is relatively less in comparison to ring spun yarn. Why we are doing less? We are going to discuss it. The diameter of the yarn is generally 5 to 10% greater than an equivalent ring yarn diameter. That, if the use the same fibre and make the same yarn count, then generally it has been found that the rotor yarn diameters are 5 to 10% more.

So, this is typicals the values could be little more in some cases also, these are basically typical values. So, usually the rotor yarns are little fuller; therefore, in comparison to the ring yarn.

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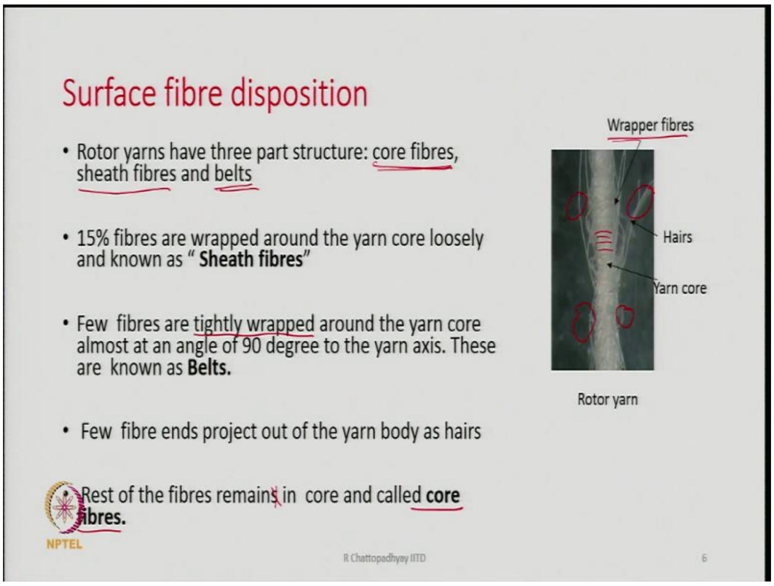

Now, if we go to a surface fibre dispositions, then rotor yarns have three part structures generally. That is, they have some fibres which are known as core fibres, some fibres which are known as sheath fibres, and some fibres which are known as belts. So, the fibres which exist in the yarn, they can be classified into three groups, core fibres, sheath fibres and belts.

15% of the fibres are wrapped around the yarn core loosely and that is known as sheath fibres. So, the wrapper fibres, what we see there, part of them are basically sheath fibres they are loosely wrapping around the main core of the yarn, the core part of the yarn. Core part of the yarn will look little dense and we will find as it is seen here, there are lot of loosely wrapped fibre around it these are known as sheath fibres.

Then, so, there are some fibres which are tightly wrapped around the yarn core and they are usually placed at an angle of 90° with respect to the yarn axis. You can see some fibres which are here like this, they are at placed at 90° with respect to the yarn axis and we can see them, that they are tightly wrapping the core as if it is a belt; so, they are known as belt fibres. So, they are also wrapping, the only difference is that they are tightly wrapping the core where as the sheath fibres are loosely wrapping the core.

So, these are the two types of fibres that is visible on the surface, other than the hairs that we also see. Now, we can sometimes see some loops also, like there is a loop, here is a loop; we can say that there are certain fibres which are forming loops. Their percentage is much less and they basically contribute towards the hairiness part of the yarn.

The projecting ends are known as hairs that is true for the case of ring spinning also. So, we are having as I shown the diagram, you know we have I have shown it with these circles, these are basically hairs of the anything that is projecting out the yarn core, projecting out of the yarn core. They will be known as hairs, even a projecting out loop also could be considered as hairs.

Out of now, if we leave these fibres, the rest of the fibres are in the core part of the yarn and they are known as core fibres. Rest of the fibres remains in the core and therefore, they are known as core fibre; so, that is how the fibres can be classified core fibres. So, majority of the fibres are forming basically core, then you have sheath fibres which is typically around 15% and there are some fibres which we call belts which could be hardly 1 to 2%.

So, this is how the fibres can be classified within the yarn; now, point is how these fibres are forming?

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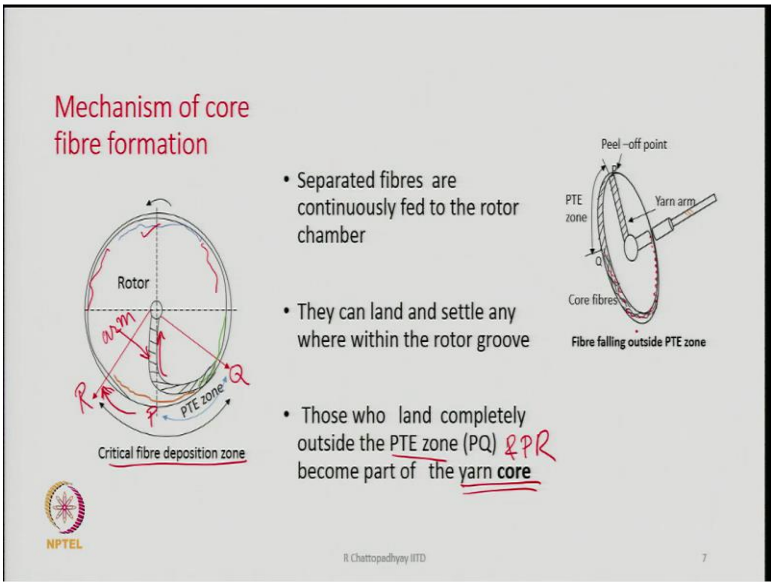

So, mechanism of formation is something which we need to know, because we will see that what role this fibre plays in deciding the properties of the yarn. And therefore, if we want to regulate or control the property of a yarn, then we have to regulate or control the formation of these fibres. And for that we need to understand what is the mechanism of formations of sheath fibres especially and belt fibres.

Now, we all know that fibres after they get separated, we feed a sliver, open it out or separate them with the help of opening rollers and then these separated fibres are made to enter the rotor spinning chamber. Now, when they enter the rotor spinning chamber, the entry point is fixed in space, but the rotor chamber keeps on rotating at a very high speed; so, the fibre can land anywhere within the rotor.

The total periphery of the rotor is around '$2\pi r$', where 'r' is the radius of the rotor; so, the fibre can land anywhere within the rotor groove. Those who land completely outside the PTE zone as shown it here; So, PTE zone is shown in here, PQ if we write it, then this is the point 'P' and this is the point 'Q'. See this is what we are showing it here in the left hand side is a circle is presenting the rotor, the groove part of it and this is what we have seen earlier this is the yarn arm which keeps on rotating as a rotor rotates.

And then here is the yarn which is taken out in this directions and part of the band of fibres within the rotor groove is twisted and that is called partially twisted. And we call it PTE, Peripheral Twist Extent or sometimes in some books you may find, it is written as twist transition zone. So, from ‘P’ to ‘Q’ is the twist transition zone because beyond the point ‘Q’ the fibres are practically parallelly laid within the groove.

So, the twist reaches up to the point ‘Q’ and the ‘Q’ actually is let us say point on the rotor groove. So, part of the fibre band which is lying within the rotor groove is twisted and we call this zone as PTE zone, Peripheral Twist Extent zone. So anything that when the fibres are falling anywhere outside this PTE zone like this blue fibre, then or if a another fibre could be somewhere here, another fibre could be here, all these fibres are outside the PTE zone.

So, if they happen to land in an area beyond this PTE zone and also the zone dictated by this one that is the critical fibre deposition zone. That is if I say PQ which is the PTE zone then on this other side also there is little you can extend it on the left hand side also. And if I give a name to this particular point let us say I give a name ‘R’, then from ‘Q’ to ‘R’ is a an area within the rotor groove which is known as critical fibre deposition zone.

That is if the fibre lie within the zone, then there is some possibility that the fibre will be part of the sheath fibres. However, if they lie beyond this PTE zone and also the zone PR they become part of the yarn core then they become part of the yarn core. See, if the fibre happens to lie anywhere beyond the RQ zone, then they will be part of core of the yarn.

And we will see now that what happens if the fibre land in the PQ zone or in the PR zone. We call this critical fibre deposition zone, because if they land here what happens to these fibres we are going to discuss this point now. In this diagram these are the fibres which are outside the critical fibre deposition zone; so, all these fibres is going to be part of the yarn core.

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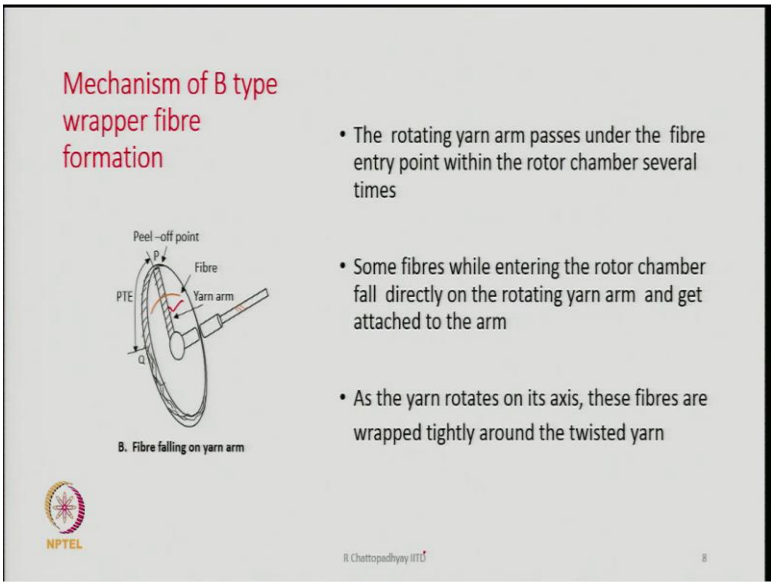

Now, what happens that when the fibres are entering the rotor chamber, then within the rotor the yarn arm is also rotating at a very high speed; so, rotor is rotating the yarn arm is also rotating. See, it may so happen that some fibres while entering the rotor chamber fall directly on the yarn arm. So, this is the fibre which is shown here and they may directly land on to it, it may happen for some fibres.

And if it so happens, the yarn arm is already twisted; so, therefore, anything if a fibre is landing on it due to whatever reason because the air within the rotor is also a kind of vortex. And therefore, some fibres may finally find to land on the yarn arm, the yarn arm is rotating with respect to the yarn axis also and also rotating with respect to the rotor axis.

Now, if a fibre lands on it, the fibre end will be cut by the yarn arm. And if it is cut, then the fibre will be wrapped around it, because the yarn itself is rotating on its own axis. The ones these fibres are shown it here in the orange diagram the orange color fibre which is which has landed on the yarn arm, this will be going to be picked up by some hairs or some loops which are there in the yarn arm.

And once it is cut, it will immediately be wrapped around the yarn core the twisted part of the yarn it will cannot penetrate and go inside because yarn has already formed. So, it has to then stay on the surface and it will stay on the surface in the form of sheath fibres that is what is going to happen for those fibres which are going to land on the yarn arm.

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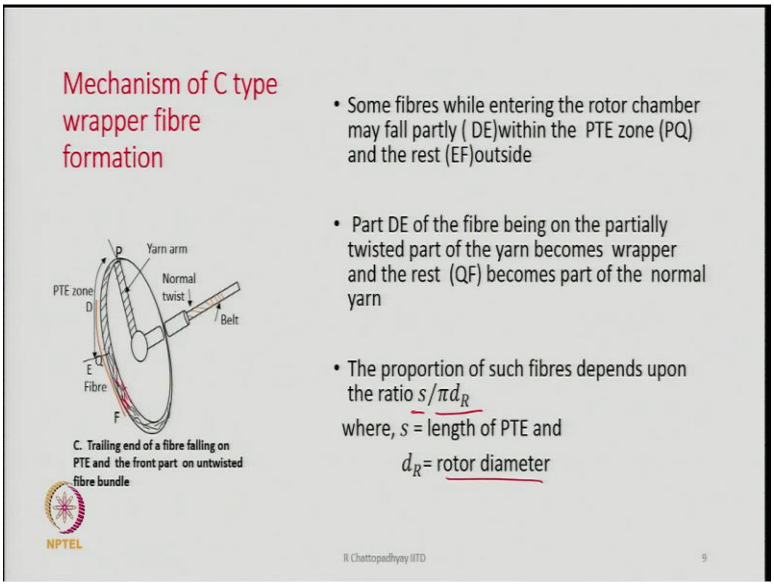

Now, we are discussing about some fibres which are landing in such a way that part of it is in the PTE zone, and part of it is lying, part of it is lying where untwisted fibre band is lying in the rotor groove, like we are showing it here by the orange color fibre. So, if your orange color fibre see from 'P' to 'Q' is our PTE zone the fibre is represented by DEF.

So, the DE part of the fibre is within the PTE zone PQ, and EF part of the fibre is outside the PTE zone. And it is basically has become a part of that these fibres which are lying parallely in an untwisted state within the rotor groove. Now, what is going to be the fate of this fibre? Part of it is in the rotor groove where fibre are untwisted. So, this part is going to form the core part of the yarn, rest of the fibre that is the DE part will be partially wrapped on the yarn core and it will form a sheath fibres.

That means, the same fibre what we will see part of it is forming the core and the rest of it is forming the sheath. So, you will have many fibres like this where some part of it is forming the core and some part of it is a forming the sheath fibres or wrapper fibres. And the proportion of such fibres will depend upon the ratio '$s/\pi d_R$'; where, 's' is the length of the PTE zone.

So, this PTE zone from here to there which is PQ, PQ is basically in terms of length which is 's'. So, this proportion of these fibres will depend on the ratio of '$s/\pi d_R$'; where

‘s’ is the length of PTE and ‘d_R’ is the rotor diameter; that is rotor circumference is ‘πd_R’ and ‘s’ is the length of PTE.

For the given fibre this is going to depend upon this ‘$s/\pi d_R$’. So, this is; so, there could be many fibres like DEF whose part of it may be few millimeters will be within the PTE zone and the rest will be a part of un twisted bundle of fibres. So, this many fibres will be able to see which will belong to this category.

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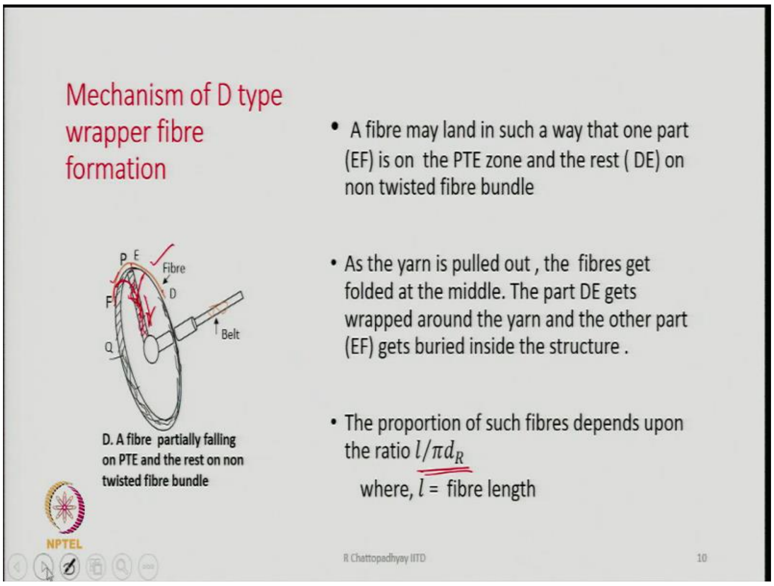

And then comes another type of fibres where you see here in this diagram that is DEF this fibre has landed in such a way that part of it again is in front of ‘P’. Therefore, it will form the wrapper fibre; so, sheath fibres; let us see in this case, the EF part of the fibre is going to form sheath fibre. Because EF part is all landing on the peripheral twist extent zone or fibres are already twisted to some extent.

Now, this fibre this part of the fibre we will be see little bit of twist and it will basically kind of wrapping will be there. The other part DE part will be how it will look like; now, as the fibres since the yarn is being withdrawn. So, what will happen? The fibres will get filled that is this fibre will change its position from here to there; it will be like this.

Further it will be like this and so what will happen as the yarn is being withdrawn in these directions this fibre DEF will be pulled along with the yarn and it will be folded.

So, it will have two parts now, one part is basically partially staying in the PTE zone, the other part is actually on the already formed yarn that is on the yarn arm.

And therefore, what is going to be the you know you know the configuration of this fibre now? This fibre will be folded and then wrapped that is going to happen to these fibres. And proportion of such fibres will depend upon the ratio of '$l/\pi d_R$'; where, 'l' is the fibre length and 'd_R' we have already said. So, in case the fibres you know lie or land the way it has been shown here, then this is going to be the fate of the fibre.

So, it is going to be some kind of wrappers is going to be formed and this is the way in which fibres are forming.

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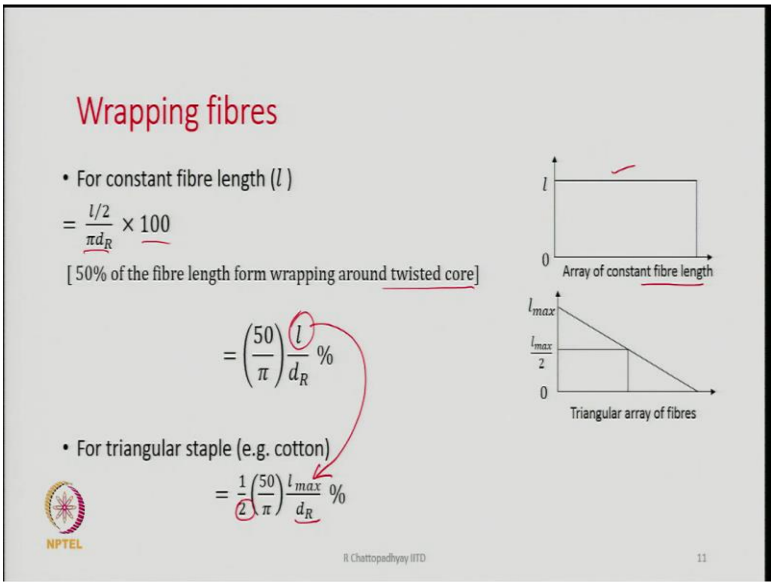

Wrapper fibres, we call them sheath fibres also and some of them will be tightly wrapped and we call them belts. So, we will find many fibres like, this there could be some fibres which are partially forming part of it is forming the sheath fibre and part of it is actually its within the yarn core. So, it is buried inside the core one part the other part is lying on the surface.

So, one end or one part is part of the core and other part is part of the sheath, this kind of fibres also will be visible. The wrapping fibres or the sheath fibres there has been shown that the for constant fibre length or constant fibre length array is shown it here. The proportion of such fibre is going to be,

$$= \frac{l/2}{\pi d_R} \times 100$$

'*l/2*' because 50% of the fibre length from wrapping around the twisted core that is why this value is coming '*l/2*'.

Or as for triangular staple length which is close to cotton, this value is going to be,

$$= \frac{1}{2}\left(\frac{50}{\pi}\right)\frac{l_{\max}}{d_R}\%$$

So, when the fibre length is constant this is '*l*', when the fibre length is not constant and following a triangular array then we can '*l*' will replace it by '$l_{max}/2$' that will give you the proportion of wrapper fibres that we can roughly you know expect in the yarn.

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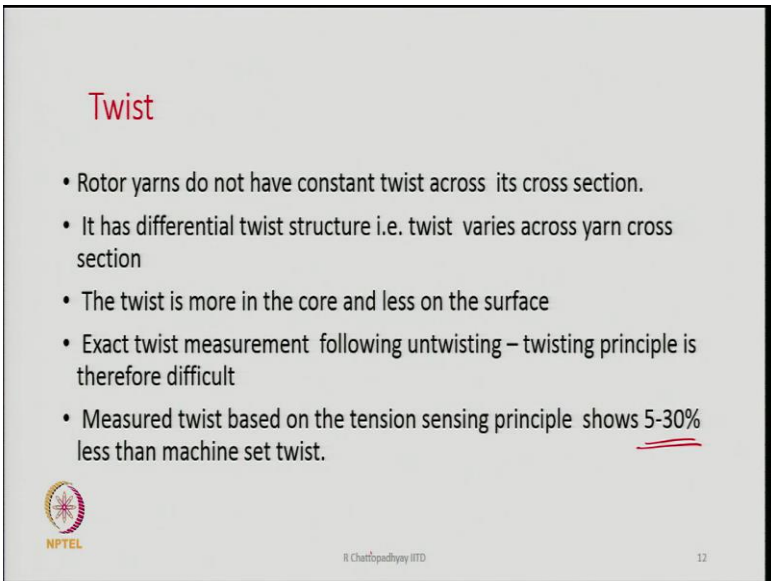

Now, the next topic of discussion is twist; see rotor yarns do not have a constant twist across these across its cross section this is something quite different from ring yarns. Rotor yarns do not have the constant twist; it has a differential twist structure that is twist varies across the yarn cross section. So, twist is not same throughout the cross section of the yarn, the twist is more in the core and less on the surface.

So, core part of the yarn this is more twist for a surface part of the yarn; so, sheath fibres they actually slip while they are getting wrapped there is a chance of slippage. And therefore, there is a loss of twist in the sheath fibres. As a result the twist distribution is not uniform from core to the surface of the yarn. Exact twist measurement; therefore, becomes difficult following untwisting-twisting principle.

Because, by the time see the surface fibres are inclined at a certain angle which is less than the core fibres. And if it is so, if we try to untwist the yarn in order to estimate or measure the value of twist in the yarn; and what will happen by the time we will untwist the surface fibres and make them parallel; the core fibres are still having some twist.

So, what we will find that in such condition if we try to stretch, the yarn the yarn is not going to break this is not going to happen in the case of ring yarn. In the case of ring yarn if we remove twist by untwisting and if we when you make the fibres, surface fibre parallel with respect to the yarn axis. Then if I stretch the yarn, the yarn will break and it will break because of slippage of fibres.

Because there is no twist left in the yarn and the simply little bit of stretch the yarn will break, because fibres are going to slip, this is not going to happen in the case of rotor yarn. By that time you have made the surface fibre parallel by untwisting on a twist tester, the core fibres are still having twist and hence if I stretch it the fibre the yarn is not going to break easily, there is no slippage.

Now, what we should do? People may try to further untwist it; so, like keep on untwisting in order to make the core fibres parallel. So, that they loss all twist and becomes parallel to each other what we will find that the surface fibres are now getting twisted in the opposite directions. So, by the time we make the core fibres parallel, we will find the surface fibres are twisted now in the other directions.

And so, surface fibres will be tightly wrapped now and they will hold the core fibres together, even though core fibres are parallel if we try to stretch the yarn is not going to break easily. Therefore, twist determination in the case of rotor yarn is something which is difficult and we cannot measure the twist accurately this will not be the case in the case of ring spun yarn.

So, measure twist based on the tension sensing principle shows 5 to 30% less than the machine set twist. So, whatever twist is set on the machines if we try to measure the twist based on tension sensing principle, we will find that the twist value is less by 5 to 30% in the yarn and come. This is with respect to whatever twist we set on the machine is the mechanical twist or machine twist that we set.

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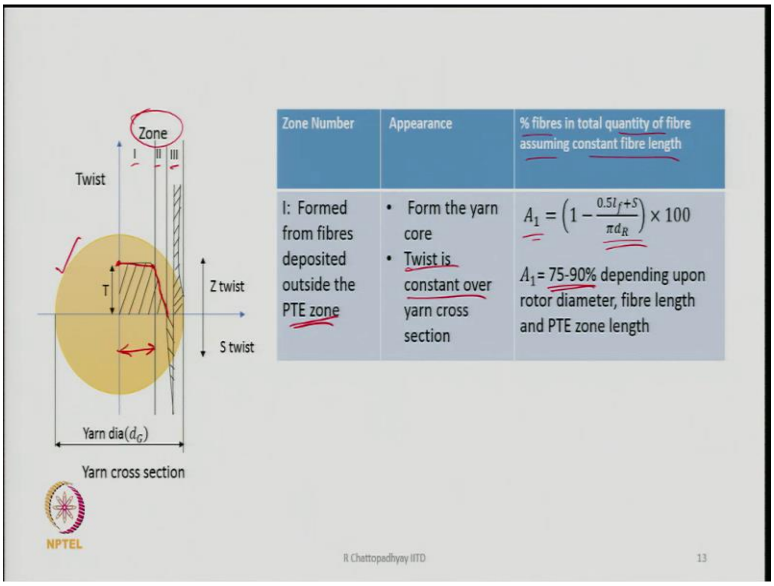

This is what is the, now then this diagram while trying to show the yarn cross section how the twist is going to vary across the cross section of the yarn. So, this is the yarn cross section and the cross section has been divided into three zones; zone 1, zone 2 and zone 3 and the twist variation is shown. So, what we see here at the core this is the level of twist, this twist goes like this and in the zone 2 the twist is declining.

So, in zone 1 that is the core part of the yarn the twist is practically constant. So, in zone 1 formed fibre deposited outside the PTE zone and here the twist is practically constant over the yarn cross section. And the percentage of fibres in total quantity of fibre assuming constant fibre length is going to be around 75 to 90%.

This is 'A_1' is how much is,

$$A_1 = \left(1 - \frac{0.5l_f + s}{\pi d_R}\right) \times 100$$

Approximated equation to find out the percentage of fibres which will belong to 'A_1' category that is the core fibres category. Now, why this has come we will come to know gradually why it is '$0.5l_f + s$'? So, the core part from here to there that is zone 1 the twist is practically constant.

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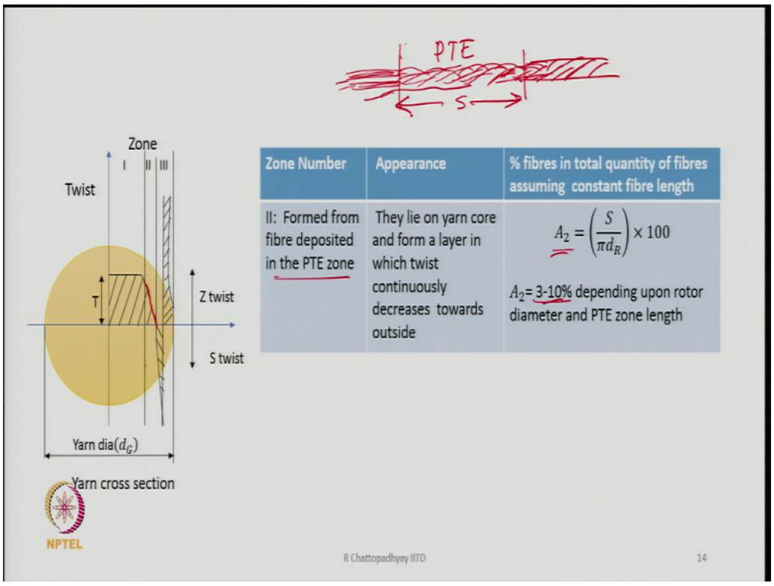

Then comes zone 2 the twist is actually declining; so, this is this declining point is zone 2. So, from fibres deposited in the PTE zone; so, these are basically because of the fibre deposited in the PTE zone where the fibres are partially twisted. And therefore, when a fibre lands on this area it will also be receiving not the full twist, but little bit of twist. And this twist will gradually be less and less, depending upon how much part of the fibre is lying on what part of the PTE zone.

On the PTE zone itself, the twist is 0 to the maximum level of twist that we want we get in the yarn. Because, twist is not constant in the PTE zone, if the PTE zone see it will be like this these are the; these are the several straight fibres parallel fibre then then here the fibres are little bit of twisted. The twist is initially less and then your parallel perform here to there; let us say is the my PTE zone and then onwards this twist is full as the nominal yarn twist.

So, here when the fibre is lying here like this part of it is receiving some twist and part of it is receiving much less twist. So, here this zone this will receive more twist, this part will receive less twist; so, like that on an average it has been found that the fibres which are in this area they are basically almost part of it is forming sheath.

Twist level is declining in those fibres which are in zone 2 and their number is basically 3 to 10% and this gives you an estimation of the 'A_2' type of fibres which are in zone 2, '$(S/\pi d_R)\times 100$'; where, 'S' is the length of the PTE zone; so, this is my 'S'.

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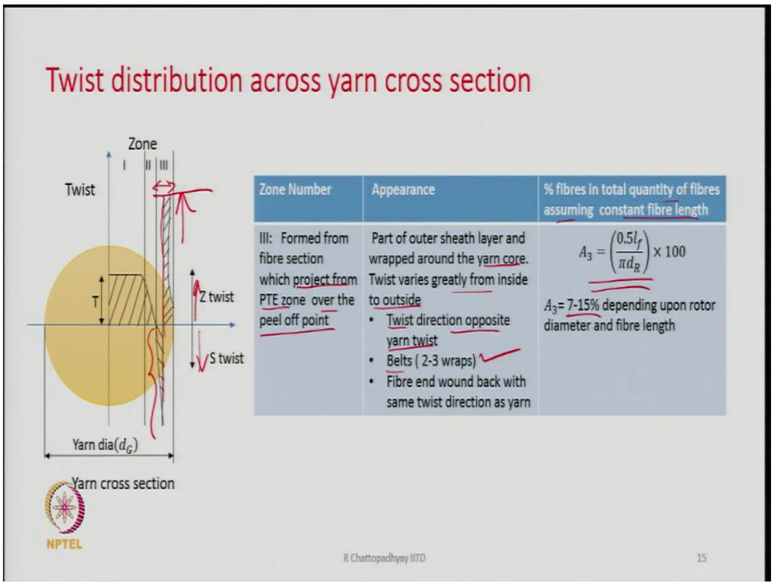

And then comes twist distribution again, but now zone 3 this is the zone we are discussing now. What we see here? These are formed by the fibres which project from PTE zone over the peel-off point. A part of outer sheath layer and wrapped around the yarn core; twist varies greatly from inside to the outside. See here in this zone the twist which was going down suddenly changes goes very high. So, in the periphery or the yarn surface will find some fibres which are giving this kind of twist.

Some of the fibres also we can see them twisted in suppose we want we are putting '*Z*' twist, we will find some fibres with having little bit of '*S*' twist and some are also having '*Z*' twist or the same fibre part of it is '*S*' part of it is '*Z*' in terms of directions. And fibres in total quantity of assuming constant fibre length in this category is going to be '$(0.5l_f/\pi d_R)\times100$'. And this is typically 7 to 15% depending upon the rotor diameter and fibre length.

Belts will be a part of this category fibres; so, twist direction opposite to the yarn twist like from here to there twist direction has changed from see this side is '*Z*' and this side is '*S*', this is '*Z*', this is '*S*'. So, part of it will see that this is having '*S*' twist followed by some fibres having or same fibre part of it forming '*Z*' forming '*S*' this kind of also can be same. So, the surface fibres what we see has a different types of twist, core fibre mostly twist is constant.

Then there is a transition zone where twist is declining towards the surface, because we have said there are many surface fibres or sheath fibres will lose twist because they are slipping when they are trying to be twisted. Their ends are free, the ends can rotate and therefore, the twist leakage is possible for many fibres. Because the twist leakage some of these fibres may not be having the full twist that the machine is going to impart on them that is these are the fibres which are in zone 2.

Then comes a zone 3 where there are many of these are basically forming belts they are tightly wrapped. So, therefore, the twist level you see is going very high up to this much, because they are forming almost perpendicularly placed with respect to the yarn axis this is going to happen for some fibres. So, they may show part of it '*S*' twist part of it '*Z*' twist also, because there is lot of turbulence within the you know within the rotor and so many fibres we are injecting per unit time.

So, some of these fibres will be directly landing on the yarn arm and they may get twisted very tightly. So, these are the so, the you can say roughly that the twist across the cross section of the rotor yarn is not uniform that is twist in the core part is quite uniform. And the core looks like a ring yarn; whereas, the sheath part the twist is generally on an average less than the core part.

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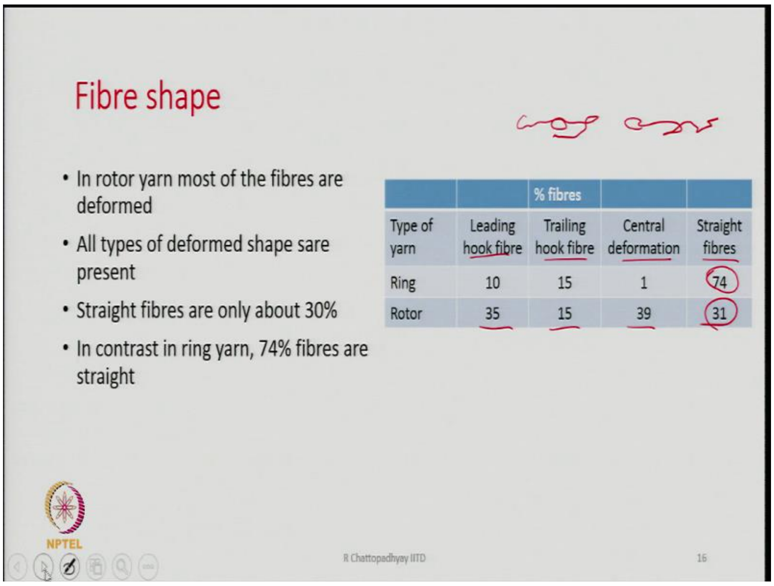

Now, comes fibre shape, a table is shown here which gives an idea about the shape of fibre that is leading hook fibre, trailing hook fibre, central deformations and straight fibres. These are the four different categories and a comparison has been made between ring and rotor and what we see here in rotor yarn most of the fibres are deformed.

Deformed basically means you will find the fibres having a shape like this or some fibres all kinds of varieties of shape will be visible. If we go by the tracer fibre technique by which we can really visualize a fibre within the yarn, then you will find like this there are varieties of shapes. Though they are twisted they are not really you know flat, they are following a helical path at the same time, but they are folded, they are buckled, their ends may be hooked this is what is going to happen.

All types of deformed shapes are present straight fibres are only about 30% in rotor yarn. The rest of the fibres are not straight. So, if 70% the fibres are not straight; then obviously, this is going to affect the many properties of the yarn. In contrast the ring yarn will find 74% and even maybe more percent are perfectly straight and parallel.

Thus we can say we that ring yarns will be always stronger than rotor yarn, because most of the fibres are straight and parallel. And therefore, they participate fully in in sharing the load, when we try to stretch a yarn. Whereas, fibres in the case of rotor spun yarns are all basically crumbled many of them deformed and they behave like short fibres.

Though their length is more if we straighten them out, but because their effective length goes down they behave like short fibres and therefore, the strength is less that is one of the reason.

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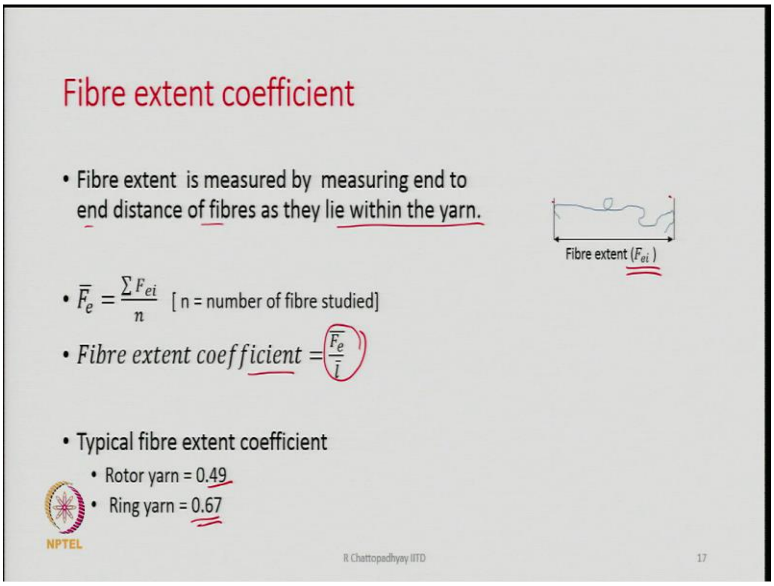

Now, comes another important aspect is fibre extent coefficient. Fibre extent is measured by measuring end to end distance of fibre as they lie within the yarn, like this fibre is shown on the right hand side; so, end to end distance is from here to there this distance is the fibre extent. So, we can find out what is the average fibre extent? If we look at 100 fibres each fibre will have one value.

So, average value is,

$$\bar{F}_e = \frac{\Sigma F_{ei}}{n}$$

And then you can find out fibre extent coefficient which is the ratio of these two,

$$= \frac{\bar{F}_e}{l}$$

That will this ratio will give us some idea to what percentage of the fibre length is actually utilized or in in in the yarn.

So, typical fibre extent coefficient for rotor yarn is only 0.49, for ring yarn it is 0.67. So, on an average we can say therefore, in the rotor yarn most of the fibre length is utilized; whereas, rotor yarn it is not because fibres are crumbled, fibres are deformed there have been hook.

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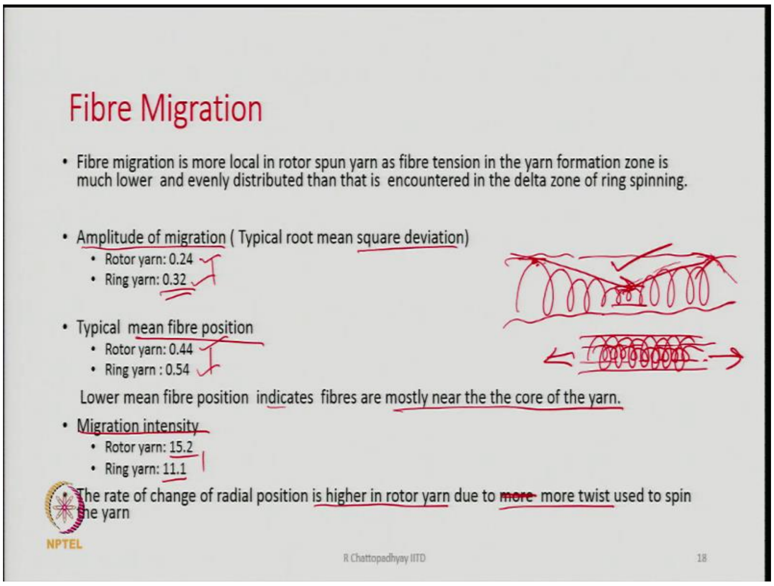

Then migration is another important phenomena, see in all spun yarn; unless the fibre migrate, there will not be any strength in the yarn. Twisting is the mechanism or a process by which we induce migration in the fibres and what this migration means? Fibre migration means that the fibres are moving from one radius to another radius of the yarn.

Fibres are continuously made to move from surface to the core part of the yarn and core to surface part of the yarn in the case of ring yarn and this movement of the fibre within the yarn body is actually helping to hold the fibres together. If it is not, then there will not be any interlocking between the fibres existing in different concentric zones of the yarn.

So, here therefore, migration is very very important that is a fibre will move like this, this is what is known as migration; so, it is going from this is the yarn let us say the yarn. So, they are going from the surface of the yarn to the core part of the yarn and then again going to the surface and this is they are repeating, this is what is called migration.

This migration is important, because without this there will be no strength in the yarn, the fibres will simply slip. If I only have fibres like this suppose same there that is they are following a spiral path, but there is no change in the radial position of the fibre and there is another fibre which is also following a spiral path like this, this is following there also there is no radial position.

So, if there is a one helical path or larger diameter another helical path of smaller diameter, there is no interaction between them. And if the fibres do not interact by moving from one radius to another radius in that case if I pull this fibres will slip easily; and there will be no strength in the yarn. What we need is something like this and this is what is in simple term this is what is migration.

And we studied migrations of ring spun yarn rotor spun yarns and many other yarns because it is the migration there actually holds the fibres together and we call it an interlock structure of yarn for spun yarn; for filament yarn, we do not need migrations. Fibres will migrate there also if we put twist, but we do not need migration in order to hold the fibres together; so, that strength can be imparted anyway.

So, migration this particular movement of fibres within the yarn is characterized by amplitude of migrations, by mean fibre positions, and by migration intensity. There is a three different parameters I am not going to discuss in details what are these parameters, but these are the three parameters by which we characterize this migratory path that the fibres follow.

Mean fibre position if you look at first rotar yarn 0.44, ring yarn 0.54, low mean fibre position indicates fibres are mostly near the core part of the yarn in the case of rotor yarn. Most of the fibres or most of the length of the fibre is placed near the yarn core that is why it is mean fibre position is less. The amplitude of migration, how much they are migrating from this path to this path? So, here it is going from here to here then going back like this.

So, this is the rate of the migratory path moving rate of movement of the migratory path towards the yarn core is called the from there we can calculate what is migration intensity the rate. The other part is amplitude of migration which is measured by root mean square deviation, if it is migratory what is the amplitude of this wavy path that the fibres are following.

Now, this is what it shown it is here rotor yarn 0.24, ring and 0.32 that is the amplitude of migrations is less in the case of rotor yarn in comparison to ring yarn. What does it mean, that basically means that migration is more local in the case of rotor spun yarns. That is they are not cutting across the cross section part of the yarn is little bit less in the case of rotor yarn that what basically means that migration is more localized; it is not happening across the full cross section of the yarn.

Whereas, for ring yarn it is still better this value is more and the intensity as I said the rate of change of the migratory path as it moves from surface to core, core to surface that intensity is more for rotor yarn, less for ring yarn. That basically means that the rate of change of radial position is higher in the case of rotor yarn due to more twist used to spin the yarns that is the reason.

Generally, we use more twist to spin rotor yarn because we expect some fibres to lose twist. See point is as the fibres are twisted, the fibres are pressed against the rotor wall due to centrifugal force. There is no other mechanical you know device to hold the fibres together. Like in the case of ring spinning when the fibres are twisted in the delta zone the trailing end of the fibres is they are under the nip they are gripped firmly by the pair of front rollers that grip is very very firm.

So, if we twist the other end the front end of the fibres the trailing end of the fibres cannot rotate and lose twist. This is something which is not there in the case of rotor spinning, because the fibres are simply pressed by centrifugal force there is no pair of rollers to hold the fibre end. So, therefore, when the front end of the fibres get twisted as the torque flows, the trailing end may rotate a bit on its axis and therefore, can lose some twist.

So, twist loss is possible in the case of rotor yarn and to compensate that we use generally a higher level of ‘TM’ twist multiplier in ring in rotor yarn in comparison to ring yarns. So, this excess twist multiplier that you use can also lead to a very high migration intensity; that is the reason why migration intensity could be higher; so, these are all typical values. So, the exact values for a given type of fibre or kind of you know speed at which the yarns has been spurn the values may little bit differ from each other.

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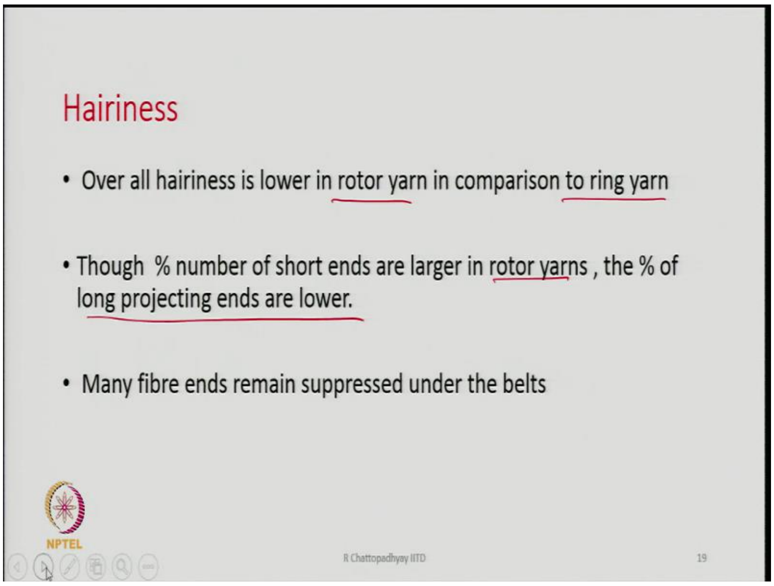

The next one is hairiness overall, hairiness is lower in rotor yarn in comparison to ring yarn and first of all the hairiness is little less. Though percentage number of short ends are larger in rotor yarn, the percentage of long projecting ends are lower. So, long projecting hairs are much less in the case of rotor spun yarn many fibre ends remain suppressed under the belts, the belts are tightly wrapping.

So, therefore, some fibre ends actually remain suppressed and they cannot project out and therefore, also we can say the hairiness becomes less in comparison to ring yarn.

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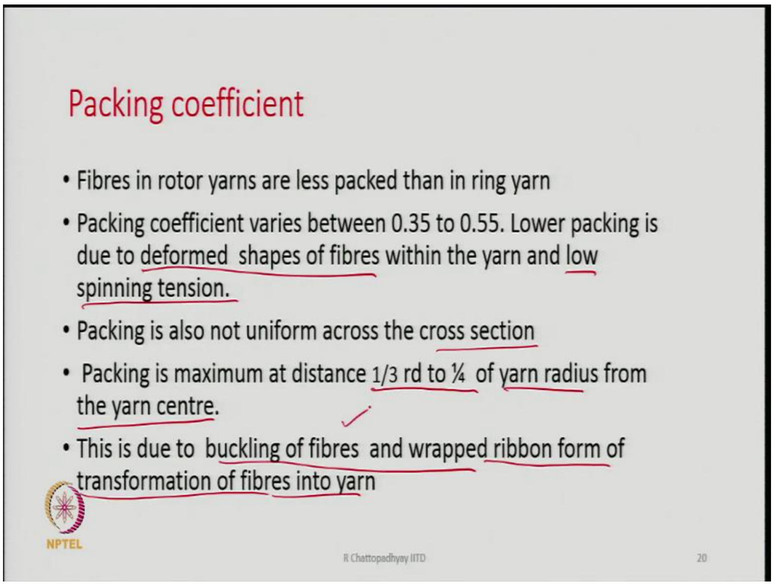

Then comes packing coefficient, fibres in rotor yarns are less packed than ring yarn, that reflection also we get in the mean fibre positions. That packing is coefficient varies between 0.35 to 0.55, on the ring yarn it will be close to 0.5 and can go up to 0.65, 0.6 depending upon the level of twist. Lower packing is due to deformed shape of fibres within the yarn and low spinning tension.

Tension under which the yarn is spun that this tension at the yarn formation point is less in comparison to a tension that the fibres experiences in the delta zone of ring spinning. Packing is also not uniform across the cross section of the yarn; so, the packing is maximum at a distance of $1/3^{rd}$ to $1/4^{th}$ of the yarn radius from the yarn center.

So, packing is not constant, packing is also not constant for ring yarn as well across the cross section of the yarn. So, fibres are packed more near the center and packed less on the surface that is true for ring yarn also and this is also true for rotor yarn as well. Surface fibres are little less packed; core fibres are tightly packed that is how the packing coefficient varies from surface to core.

And this low packing is because of the buckling of fibres and possibly wrap ribbon form of transformation of fibres into yarn. So, twisting you know twisting phenomena or twisting process has been described by 'Hearle' that it could be wrap ribbon type of twisting depending upon the spinning tension under which the bundle of fibres a ribbon of fibres is actually twisted.

In the case of ring spinning a ribbon a flat ribbon is twisted or in the case of rotor yarn it is not really a flat ribbon it may be a it is a triangular shape it takes within the rotor groove the bundle of fibres and then that is twisted. So, there is a chance that the buckling phenomena could be there could be there because many fibres are actually buckled and deformed.

The other thing is the wrap ribbon form of twisting also may be possible when the fibres bundle of fibres are transformed from a bundle to a yarn a twisted yarn; now, to discuss about property.

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So, structure part is now we have completed we will move to property. As I said it is the property of the fibre and the structure, these two actually decide the property of the final yarn. And similarly the yarn property and the fabric structure will decide the property of the fabric.

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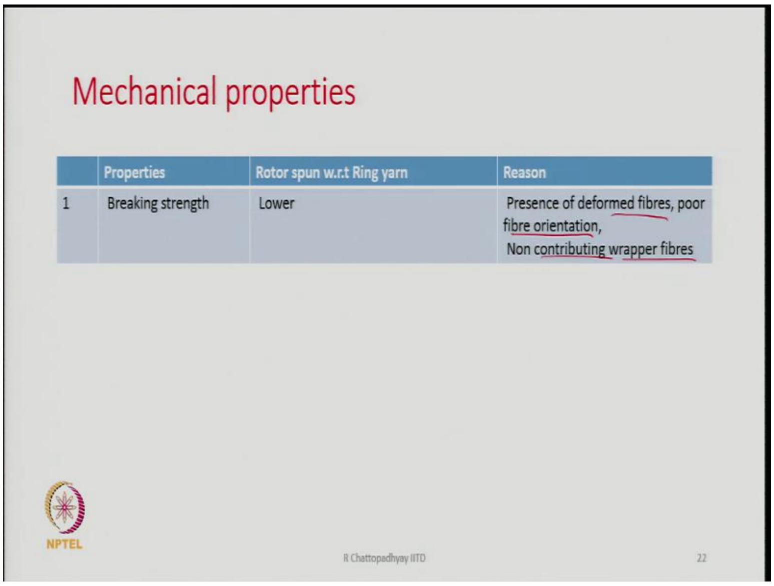

So, property first of all strength, breaking strength is always lower with respect to ring yarn we are always comparing with respect to ring. Because, ring is the yardstick we want to judge the quality of other yarns spun on other technologies with respect to always ring yarn.

Breaking strength is lower, why? Presence of deformed fibres poor fibre orientation, non-contributing wrapper fibres; some fibres are loose, some fibres are tightly packed in the core. So, when we stretch the yarn the core fibres will take the load these wrapper fibres are not going to share the load.

So, automatically the strength will go down besides the fibres are deformed also and the migration is also less all these are the reason.

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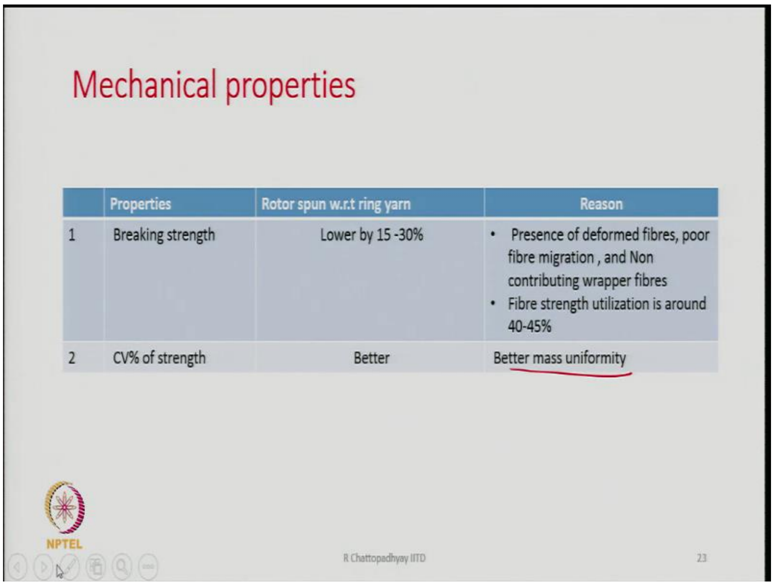

CV of strength is better however, because the yarns is more uniform, why it is uniform? Because of more number of doublings, back doublings if you remember that word that happens within the rotor and directly we are feeding sliver So, there is no chance of generation of drafting wave by the rollers which we get in the case of you know roving frame and ring spinning machine itself. This is something which is missing and hence the uniformity is better.

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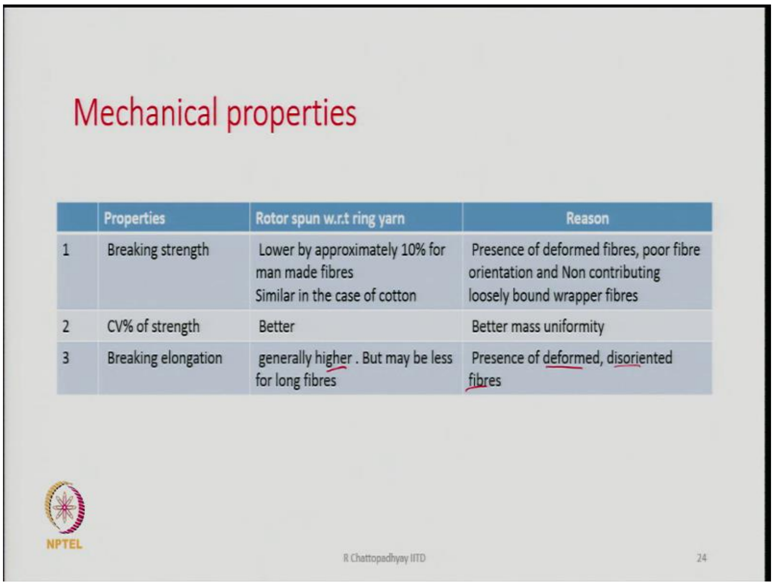

Breaking elongation generally higher, why? Because of deformed and disoriented fibres; so, when we stress these fibres try to unbend first.

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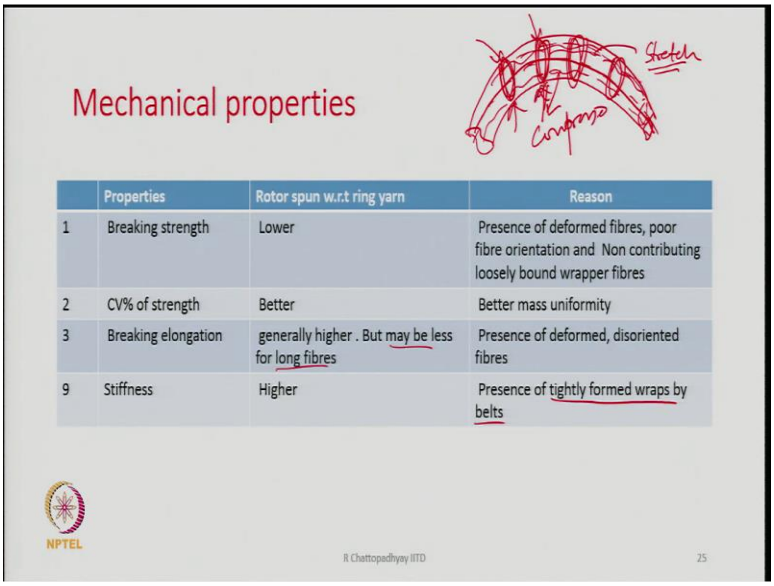

And hence the breaking elongation of these yarns are generally more, but may be less for long fibres also. This also has been seen and the fibres are too long then breaking elongation of the rotor spun yarn may be little less than the equivalent ring spun yarn. Stiffer the bending rate is more, why? Because of tightly formed wraps by the belts. The belts actually is tightly holding the fibres the core fibres and therefore, when you try to bend it the core fibres cannot really you know move.

See, whenever there is a bending of a bundle of fibres what happens that the some fibres are trying to move with respect with the other fibre. If the cross section of suppose I want to bend a yarn; suppose, this is my yarn and we all know the beam bending neutral axis. Let us say these are the fibres and what happens, that these fibres on the surface of the cross-sections and this is the cross-section of the yarn they will try to stretch.

Whereas, the fibres which are below this neutral axis here, this fibre are going to get compress. So, they are going to stretch longitudinally, they are getting compressed longitudinally also that is and as a result there is going to be a lot of shear between the two group of fibres. And if the shear possibility is allowed; that is if the we allow the fibres to slip over each other while their whole structure as a whole is going to bend, then the bending rigidity will be low.

But if we make tight bands over here and tight bands mean lot of force which is acting radially, in that case what will happen? The fibres relative movement between the two group of fibres will be restricted and we not need more force now; so, bending rigidity is going to be high. Therefore, presence of tight belts is the reason why the rotor spun yarns are stiffer in bending.

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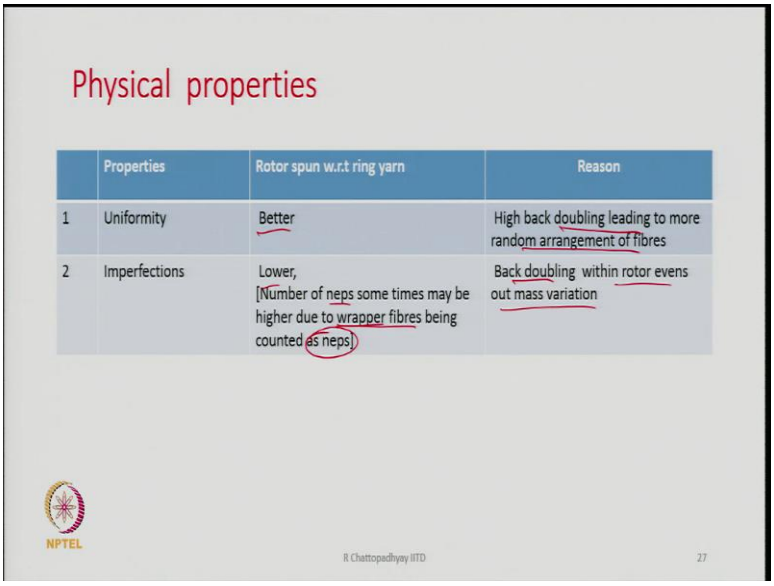

Uniformity, already discussed that is physically there are better uniformity because of high back doubling and random arrangement of fibres. Imperfection is generally lower because of back doubling within the rotor evens out the mass variation. Therefore, thick, thin places are also much less, but sometimes you have to remember that the wrapper fibres sometimes get counted as neps.

Wrapper fibres the loose wrappers can slide and they accumulate and form neps the other thing is the belts increase the mass locally and they can be counted as neps also. So, sometimes the neps number may go high even though if we look at the yarn we may not be able to find too many neps.

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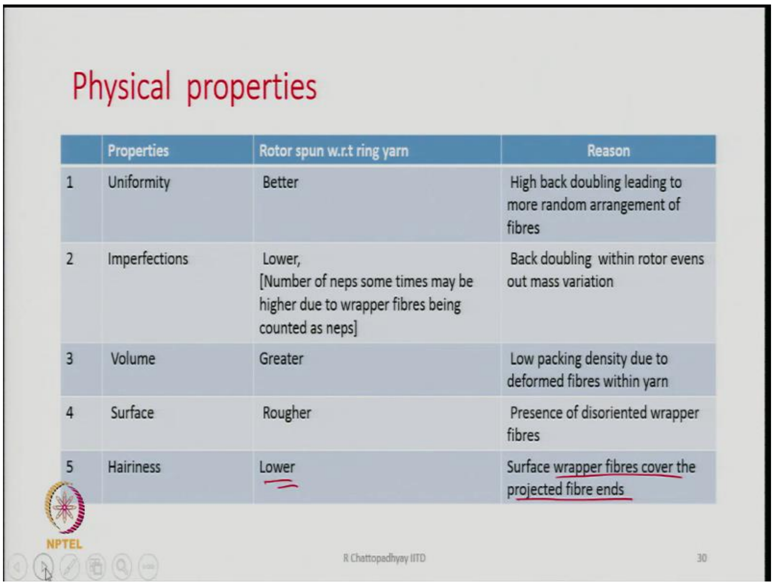

Volume is always greater because of low packing density and which is because of lot of deformed fibres which are there. Surface is generally rougher; we have seen the surface of the yarn lot of disorientation is there, belts are there and if these are the yarn is not smooth is quite rough. Hairiness is lower that also we have seen because of the wrapper fibres cover the projected fibre ends, the belts are also suppressing lot of hairs not allowing them to project out.

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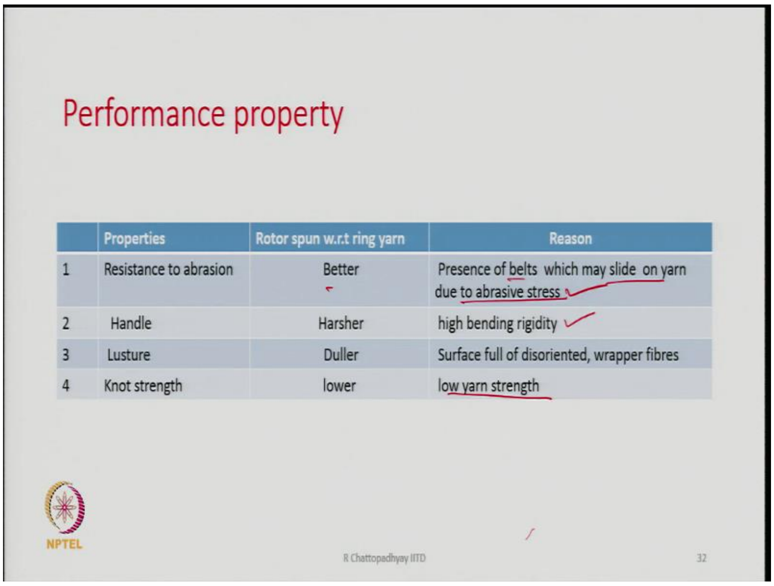

Property resistance to abrasion is better, because the belts which may slide on the yarn due to abrasive stress and wrapper fibres also can do the same thing sometime they accumulate and they keep sliding and they reduce the abrasive stress on the core part of the yarn. Handle is harsher because the bending rigidity is high; lusture is duller, because the surface fibres are highly disoriented; this is comparison to ring yarn. Knot strength is lower, because the yarn strength itself is low because of reasons already stated.

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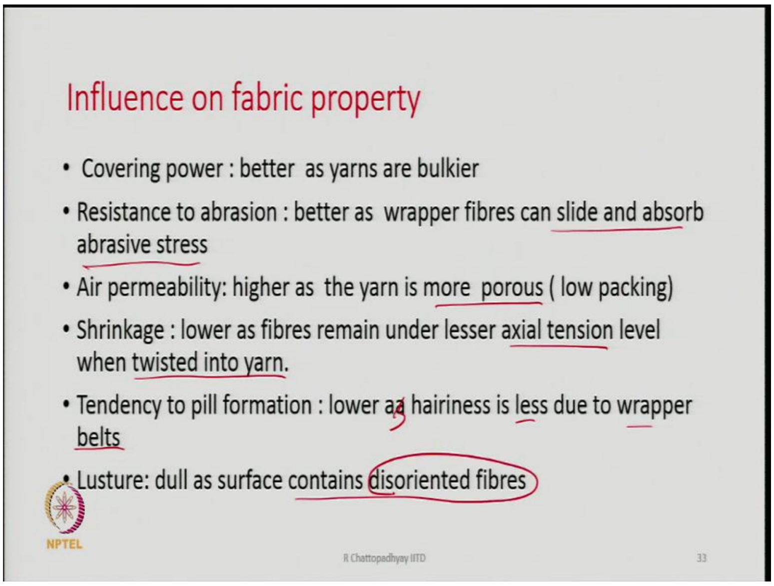

And how does it influence the yarn property, covering power will be better because the yarns are fuller and bulkier. Resistance abrasion is better, because of wrapper fibres can slide and absorb the abrasive stress in the fabric also. Air permeability higher as the yarn is more porous because of low packing. Shrinkage lower as fibres remain under lesser axial tension level when twisted into the yarn.

If we take the yarn and dip it into water, we will know that the yarn shrinks. Now, this shrinkage depends upon the spinning tension under which the yarn was spun. In ring yarn the spinning tensions are always higher; there is a big balloon, there is a traveler and the entire balloon a traveler has to rotate and there is a friction on the ring and traveler.

So, as a result the spinning tensions are very high; so, fibre in the delta zone experience more tension. In comparison to the fibres in the twisting zone or the air formation zone of the rotor spin rotor spinning process. And because they under the they undergo lesser axial tension during transformation from bundle of fibres to twisted yarn, their shrinkage is less.

Pill formation tendency is also lower as hairiness is less due to wrapper fibres and belts; so, pilling tendency is less. Lusture is dull or the fabric lusture will be dull because the fibre surface is having loss of disoriented fibres; so, the yarn is dull the fabric also will be dull.

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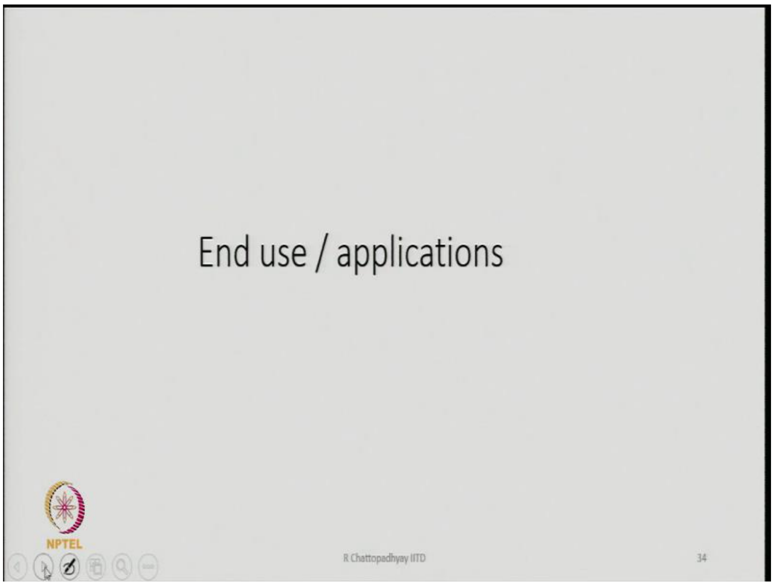

And the now we go to the end use that why are the rotor yarns are generally used.

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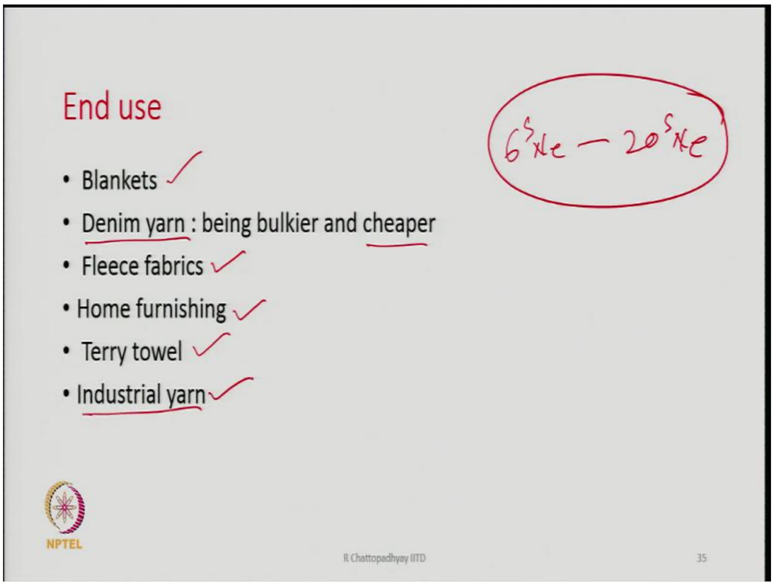

So, once we know the property the typical end uses are blankets; rotor yarns are generally, we produce coarse yarns. Generally, the count value of the yarn may vary between 6^s Ne to 20^s Ne, this is the range in which we spin the yarn. So, generally in the coarser category of yarn counts can be produced and so, any product that needs coarse counts rotor yarns can find a place there.

So, blankets is one place, denim is another where these rotor yarns are very much used. Though ring yarns also used for denim, but rotor yarns can be also be used because we can spin the yarns, yarn at a you know coarse yarns and denim needs coarse yarn because we want to produce high GSM fabrics, we need coarser yarns.

So, yarns are bulkier and the other thing is that commercially they are cheaper; therefore, they are very suitable for this. Also we can go for fleece fabrics, home furnishing products, terry towel also people have tried. It will become little harsher, if you try to form the pills, but in the ground they can be easily used.

So, they can they are finding place in the terry towel also and they can be also be used as industrial yarn. Now, with this we conclude this particular you know discussion on the structure and properties and end use of rotor yarn. So, with this the rotor yarn is now or rotor spinning is now finished in the next lecture we will discuss some other spinning system.

Thank you.