Orientation of Fibers

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Lecture No. # 08

Orientation of Fibers

In today's lecture, we want to finish with the theoretical concept of radial migration according to professor Treloar. And then, I want to introduce an alternative model – model of equidistant migration to you.

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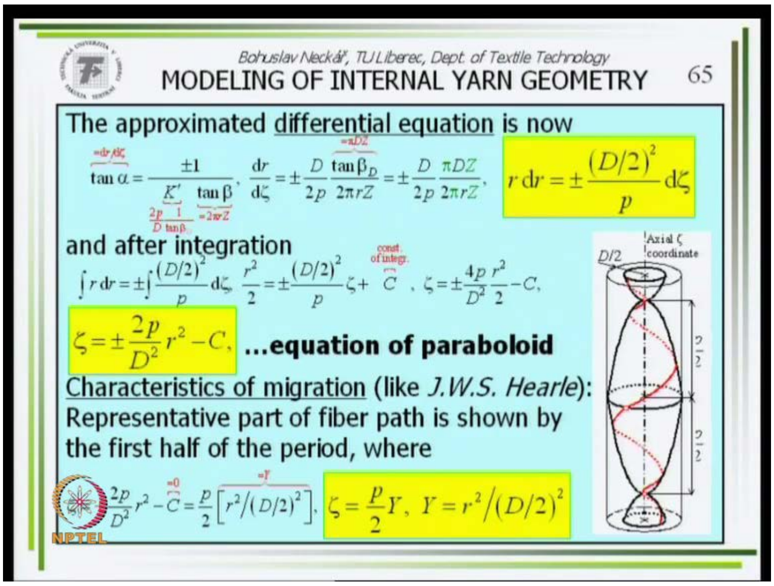

Last time, we obtained the equation zeta is plus minus 2 p by D square times r square minus C. So, it is an equation of paraboloid on which is lying Treloar's idealized fiber. So, based on this equation, we can make a small rearranging, so that first, say that we start from point r 0 zeta 0; then, the C must be equal 0; and, this ratio 2 p by D square; explain in this for r square by D by 2 square; and, this is divided by 2. Now, it is divided and this divided denominator; it means multiply. So, that it is well.

Hearle used this r square by D by 2 square as a quantity capital Y; r square by D by 2 square – what is it? r by D by 2 – what is it? It is a relative position of fiber point between 0 and yarn surface on the yarn axis. This quantity is zero (Refer Slide Time: 02:42) on the yarn surface; this quantity is 1; is not it? But, this is in square. So, Y is square of this ratio. So, defined Hearle is Y. Then, our equation is possible to write in the form zeta is P by 2 times capital Y, because this is capital Y; why is this? Then, this equation is a linear equation between zeta and quantity capital Y.

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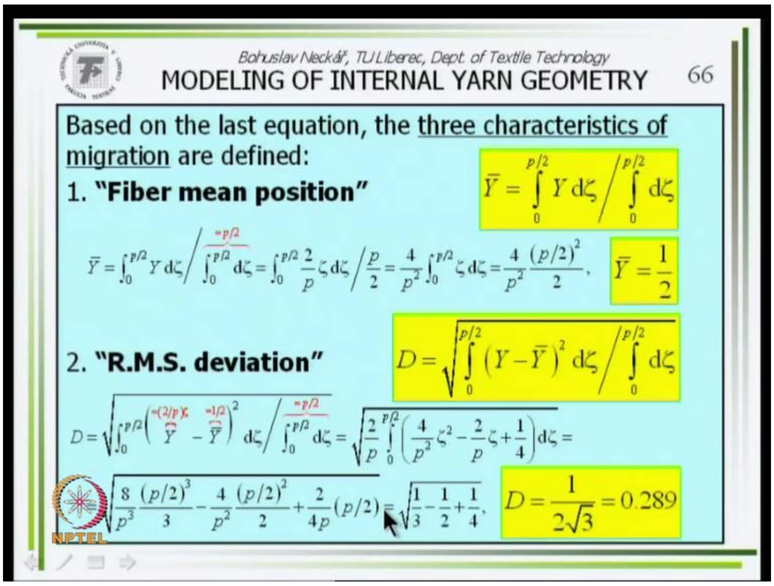

And, Hearle used the traditional statistical quantities; for example, he saw the interesting, can be so-called fiber mean position. What is its mean value of this quantity capital Y? It is called under the term fiber mean position. When we use the equations derived for Treloar's ideal model, we can use it to obtain that fiber mean position; here is 1 by 2 on the place of Y; zeta is this one; is not it. And, the responsible result we can obtain on the lengths from 0 to pi by 2 one half of period, because it is periodically same. Fiber mean position for Treloar's model is one half. The second quantity which recommend Hearle for calculation in the yarn is so-called R.M.S. deviation – (( )) deviation. What is it? This is the deviation of quantity Y; the definition is this here. Using this, after rearranging which is shown here, we obtain from Treloar's ideal model 1 by 2 times square root of 3, so that it is 0 .289.

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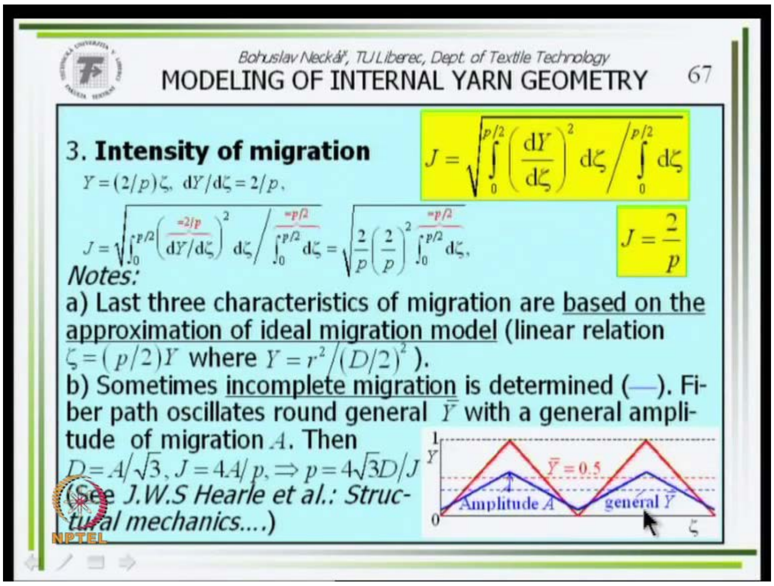

And, the third characteristic of Hearle – it is the intensity of migration. It is d Y by d zeta square times d zeta; integral of them by d zeta; and, square root then from this one. Because this is linear, it is slightly something like linear; linear is the relation between zeta and the Hearle's quantity Y; it is linear. So, fiber path in this diagram is this red – linear from 0 to yarn periphery and then back and so on here. And, this angle – this is the sense of the intensity of migration or better say, tangents of this angle. So, there are three quantities, which are very often used in the works, which study the internal structure of different yarns.

Lot of others do not think about these quantities; only take it as final equations from wealth of Hearle; and apply it on some experimental research work, which they are doing. It is in (( )) also generalized; now, only the Treloar's model also exists something, some terms in literature like the incomplete migration, which is rather fiber is not going from 0 to yarn periphery; then, these terms of (( )) is only… and so on and so on; more big than you can obtain. These relations – all these you can in more details to read; for example, in the very known book of Hearle and (( )) structural mechanical fibers – yarns and fabrics. This book is very known; professor Ishteyakor (( )); can you show with…

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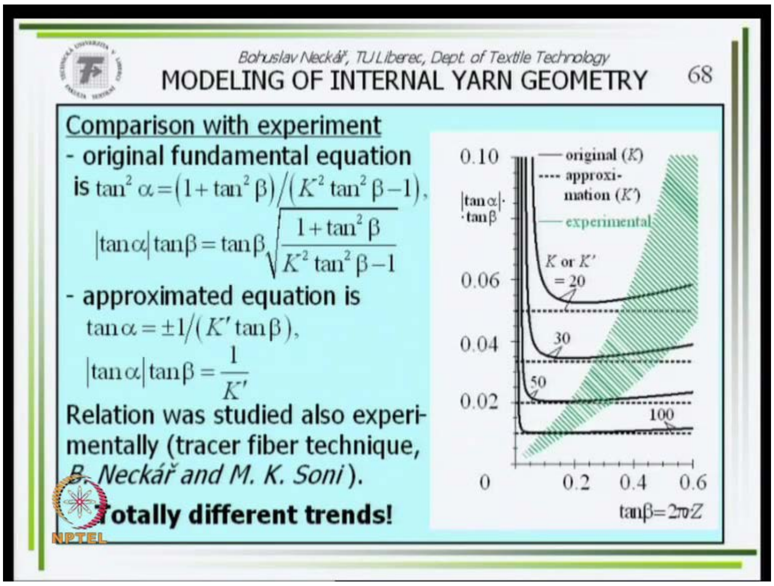

Let us compare the result of Treloar – is an experimental experiences. This is the fundamental equation; from this fundamental equation, square root of this one and multiply by tangents beta. And, we obtain such equations. Its relation between some function of beta on the right-hand side and tangent alfa times tangent beta on left-hand side. When we calculate this, we obtain the curves, the thick black lines; this is substantially tangents alpha times tangents beta; here is tangents beta – 2 pi r Z. We obtain the thick lines when we when use an approximated equation. So, we obtain this equation, so that the absolute theory of tangent alpha tangent beta is constant. Such constant is the dotted line here to this here. The dotted line – this is an approximation of original function of Treloar's model.

If K is high, you can see here that in most part, it is roughly very good. How is now our experimental experience? We measured three dimensional curves of fibers inside of the yarn. How? Principally only. We used so-called Morton tracer fiber technique. When you use the good immerse liquid to yarn or to each textile object, then all fibers stay be transparent like from glass. When you produce yarn having small value of black fibers – fibers which was before processed (( )) to blithe black; then, in immerse liquid, you see transparent yarn and the path, the projection of black fiber. You see it; other fibers do not disturb in immersion liquid. And, when you have two projections of same fiber – perpendicular projection – one time from this light; one time from this light to this yarn (Refer Slide Time: 11:42).

When you have two, then from the known relations from descriptive geometry, you can reconstruct three-dimensional curve of fiber; is not it? Principally, it is clear. So, we reconstruct lot of paths – three-dimensional paths of fibers in the yarn; then, in each radius or class interval of radii, we obtain the corresponding angles, the mean angle alpha, mean angle beta, mean angle gamma and so on here. And, through this way, using calculator, using computer, we were able to evaluate this relation experimentally too. The experimental curve based on different yarns – it was relatively large set of yarns; this work was produced, is mentioned by Doctor Mohan Kumar Soni. These curves have the trends as shown in the green area – like this or this or this area (Refer Slide Time: 13:03). So, set of curves each for another yarn. So, the strength of such curve is quite other than the trends, which we obtained from Treloar's ideal migration model.

We have totally different trends; what we need to say, Treloar's model is not valid; sorry, but it is so. In the time of Treloar's creation of this theoretical model, it was not enough experimental possibilities to experimentally verify this model. If is (( )) second time that Treloar's model was very good; from other side for other scientists, which can use a lot of ideas, lot of imaginations, which started professor Treloar his work stay be from this point of view useful to these days.

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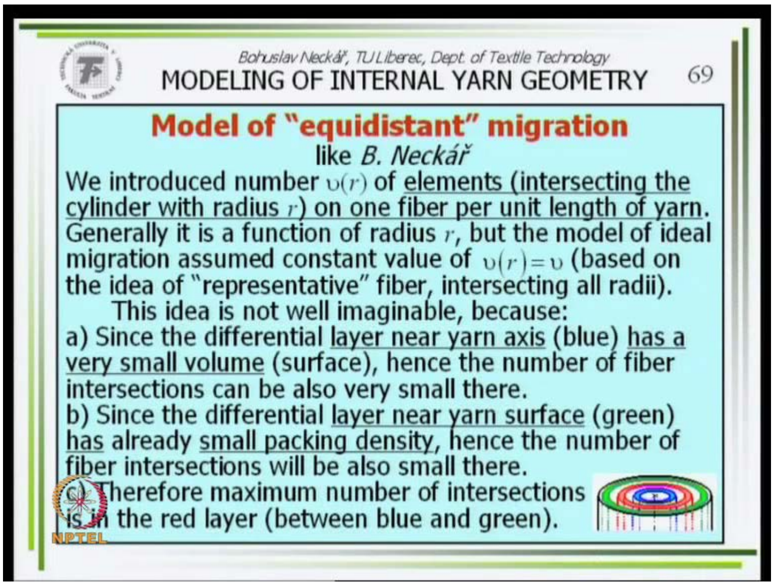

Because this model was not good, was not corresponded to this yarn, we said we need to start another model – model which we called model of equidistant migration. In

Treloar's model, we introduce number nu of elements intersecting the cylinder with radius r on one fiber per unit length of yarn. Generally, it is a function of radius r, but the model of ideal migration assumed constant value of nu based on the idea of representative fiber, intersecting all radii. This idea is not well imaginable, because since the differential layer near yarn axis, for example, this blue layer has a very small volume, rather very small surface. Hence, the number of fiber intersections can be also very small there. (( )) B – since the differential layer near yarn surface – the green one here – has already small packing density. Hence, the number of fiber intersections will be also small there. And, the yarn periphery packing density is every time smaller in reality, so that the fibers cannot chance to be here so often than in the middle radii; is not it? Therefore, maximum number of intersections is in the red layer between blue and green. Is it imaginable?

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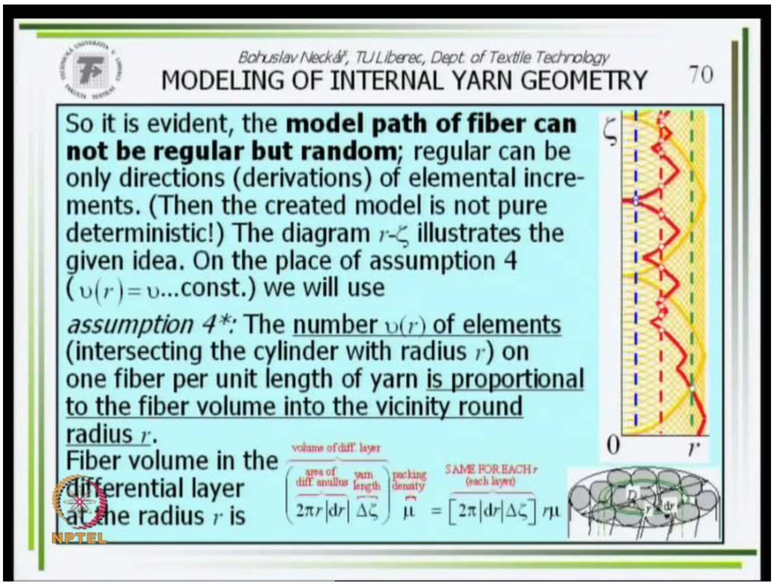

So, it is evident that the model path of fiber can be regular, but random; count to go every time from axis to periphery; then, back to axis; then, back to periphery and so on. Regular can be only directions – means derivatives of elemental increments, so that then, the created model is not pure deterministic as earlier. The diagram here r zeta illustrates the given idea. On the place of assumption 4 nu… Nevertheless for our model, we use on the place of earlier assumption 4; what was earlier assumption 4? Earlier assumption 4 say that nu is a constant (Refer Slide Time: 17:51) number. What is nu? Sense of nu – number of intersections in given radii in yarn lengths and per one fiber; we say no; it is not constant; it will be constant. This number of elements is proportional to the fiber volume into the vicinity round radius r. When in the vicinity round radius r is lot of fiber material, then probably lot of intersections will be there when you know that only a few intersections will be through our radius r; is not it? This is our modification of assumption and other versions.

Then, the assumption used by Treloar. Highest fiber volume in the differential layer at the radius r – so, 2 pi r d r (( )) because it must be positive for calculation of volume and so on; 2 pi r d r is a total area per one differential annulus – our known differential annulus times yarn lengths delta zeta. It is volume of our differential annulus, so that this is volume of our differential annulus times packing density; it is volume of fibers in our differential annulus; is not it? After small rearranging, this volume of fibers in our differential annulus – we can write it is only graphical rearranging; r is changed – this r evidently. And, nu can be changed too. We need to think about the constant value of nu. So, they are changed. All other numbers in this expression are stable, are constant. So, this expression in brackets (Refer Slide Time: 20:37) – it is some (( )) differentially small constant; same for each differential layer; is not it?

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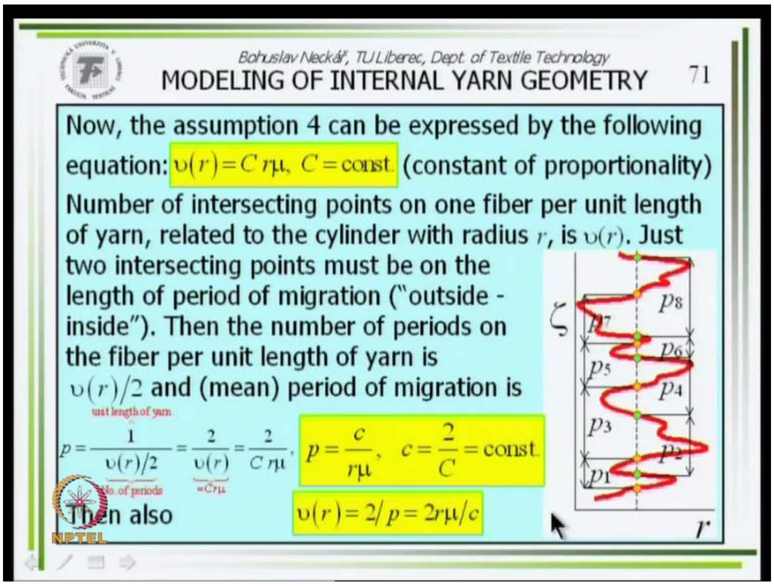

And, this value say volume of fibers in differential layer on the radius r. So, we can say this is constant – variably r and nu. So, we can say that our nu must be proportional to the quantity r times mu, because we said the higher is volume of fibers in vicinity round the radius r. So, higher is the number of intersections of [FT] So, this equation must be right in our model, where C is some constant of proportionality. Number of intersecting points on one fiber per unit length of yarn, related to the cylinder with radius r and it is nu r. Just two intersecting points must on the length of period of migration outside-inside, from center of the yarn to periphery and back. Then, the number of periods on the fiber per unit length of yarn is one half of nu. I think it must be evident here; number of intersections per one fiber and two intersections – the lengths corresponding to two intersections represent the period lengths. So, this equation is valid, (Refer Slide Time: 22:49) so that the period is 1 by nu r by 2, because nu by 2 is number of periods per lengths unit. So, we can derive the period of migration. Now, after rearranging, we obtain this… And, using this small c as a constant, which is 2 by constant – capital C. We obtained the peri of p is C by r mu. Then also, nu r is 2 by p. So, it is 2 r mu by c.

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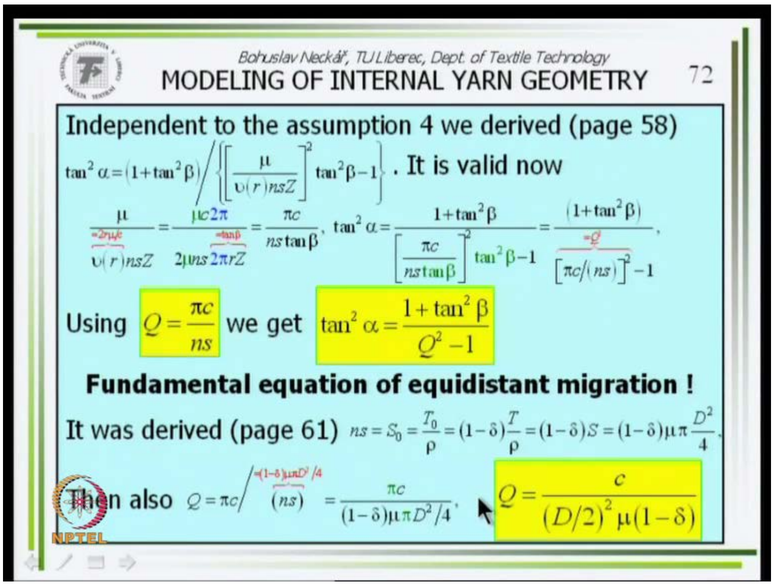

And, how is now the fundamental equation for our equidistant migration? Before using assumption 4, we derived such equation. So, it is valid also now. On the place of nu, we use we use this expression (Refer Slide Time: 24:28). So, this is here; we obtain this. We multiply and divide by 2 pi; and, it must be equal to this. It is only rearranging of this equation based on nu, which have a new definition, so that we obtain this here for tangent square alpha. This is constant; inside of brackets, it is a constant. This constant – I want to call capital Q. So, we can write the tangents alpha square is 1 plus tangents square beta by Q square minus 1, where Q is given by this (Refer Slide Time: 25:23).

Have this structure; constant Q has this structure. This equation is a fundamental equation of our equidistant migration.

On the page 61, it was derived n times as this (Refer Slide Time: 25:48) and this too. The derivation is there. We can use this relation; then also, Q, which is pi c by n s. Using this on the place of n s, we obtain this here. So, Q is C by D by 2 square times mu times 1 minus C. It is some constant, which is related to our earlier constant of proportionality; then, one half of yarn diameter packing density and 1 minus delta.

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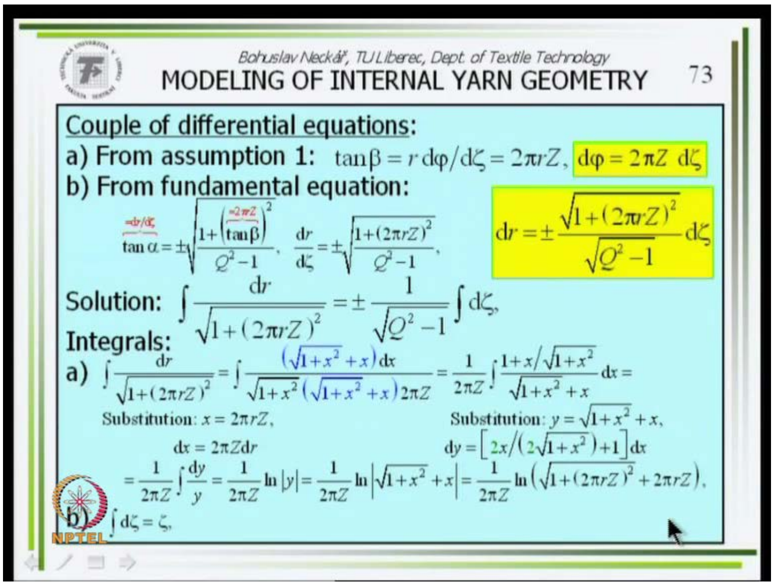

Our couple of differential equations for equidistant migration is following. First, is Treloar is same for helicon model, same for Treloar's model (( )). Second is interesting. Now, from fundamental equation, square root of this is here; tangents alpha is d r by d zeta; tangents beta is 2 pi r Z. So, the d r by d zeta is plus minus square root of this quantity. This is differential equation between increment of radius and increment of increment of zeta. This equation is possible to solve analytically; it is not (( )) integral. So, after integration, we obtain this equation plus minus r is r two parts from inside to outside from outside to inside every time. Now, I think we need not to comment it step by step; we must do this integral; r is constant, but r is integrating variable here. It is possible how you are… See here include the substitution, which is here. So, you can quietly… How to study, how to integrate? Its resulting integral value is here. The second is trivial. So, integral for this zeta; zeta is evident.

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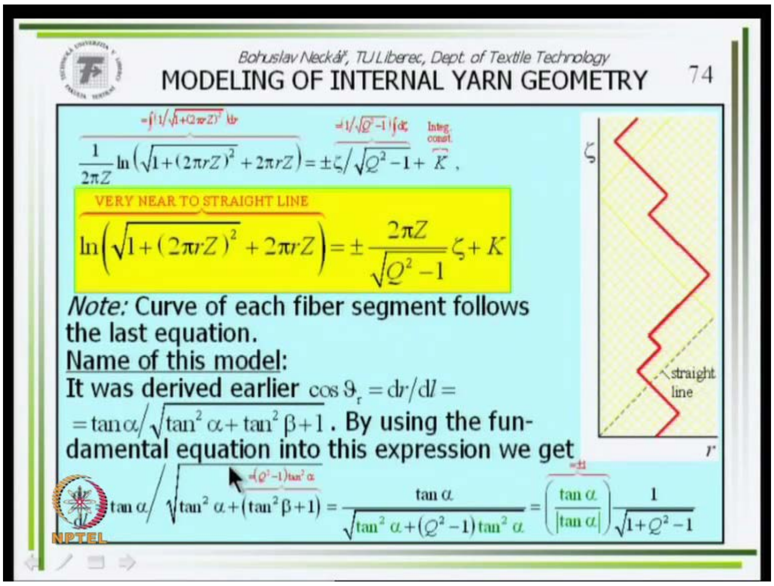

And, using this, we obtain this here, where some K in the moment is integrating constant. So, the trick to the relation between r and zeta is given by such equation in equidistant migration model. Graphically, it is shown on our picture; the yellow colour is too light. This is a set of directions, which are valid, so that our fiber must follow the trends, which are in this yellow net; it is relation between r and zeta. You can see it is not linear; there are some curves. It was really calculated by program; it is not linear lines; it is some curves. But, practically, you can see that these curves are very near to the straight line. We will then make some (( )) Why I call this model as an equidistant model? We know that cosine theta r is d r by d l and is given by this expression. By using the fundamental equation in this expression, we get d r by d l, is this one; evidently, this is the same (Refer Slide Time: 30:14) – tangents square beta plus one is also in our fundamental equation; where is this here? (Refer Slide Time: 30:22) It is here. So, it is Q square minus 1 times tangents square alpha, where I use it here. So, I obtain this here; tangents square alpha is going before square root. So, that says here. And, what is this? Tangents alpha by absolute value plus or minus; or, plus 1 or minus 1; plus minus.

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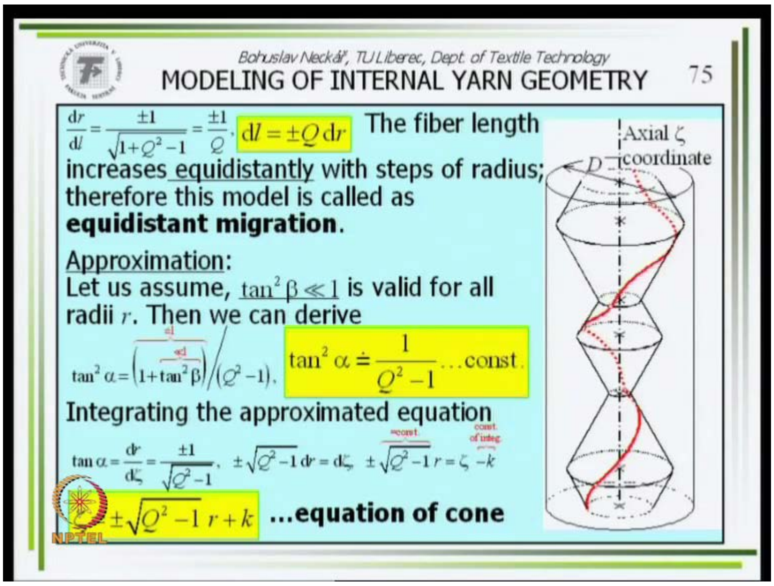

So, we obtain dr by dL is plus minus 1 by this; but, this is constant. So, it is plus minus if q is this one; (Refer Slide Time: 31:07) it is a constant. In some approximation, we can say it we can obtain it in given expression. So, here the fiber length increases – fiber lengths dl – this is important; fiber length increases equidistantly with steps of radius; increasing of radius. Increasing of lengths is proportional fiber length is proportional to increasing of radius. Therefore, increases equidistantly the step of radius; therefore, this model is called as equidistant migration. So, is not that equation? Why the term equidistant? Also, in this model, it is possible to construct some approximation.

You saw that our curve was very similar to the straight lines; so, let us assume as earlier as by Treloar's model. That tangents square beta is much more smaller than 1; then, tangents square alpha is… This is very small value, so that 1 plus something very small is roughly 1; this is one (33:10). So, that is 1 by Q square minus 1. So, it is constant. And, tangents square is constant square alpha, so that tangents alpha is constant too; plus minus. So, that dr is constant times d zeta; or, d zeta is constant times is how you want; and then, we obtain that zeta is some constant square root of Q square minus 1 times r; it is linear function. So, linear function plus k (( )) So, starting point is in the point 0, 0; then is k is 0, 2; it is integrating constant; which of equation it is linear relation between radius and axial coordinate zeta; what it have cones. So, it is an equation, which characterize cone. In this model, the idealized fiber is lying on a cone surface.

This picture (Refer Slide Time: 34:38) can help to how to imagine our fiber. At first, fiber is not going every time from center to periphery from periphery to center; it is going maybe from center to some radius; then, back. The point is not on the periphery; it is on a radius; then, back to small radii; then, back to higher radii and so on and so o, so that the track here of the fiber (Refer Slide Time: 35:10) can be like this red curve in the diagram r zeta here. You can imagine it as a… The fiber is going, is on the surface of some cone; then, back its curve; and go to smaller radii or to another cone; then, break it and go back to the surface of the third cone and so on and so on like this here. So, is the picture of fiber tractor e, which is random from point of view points in which break; and, change the direction from inside to outside or from outside to inside.

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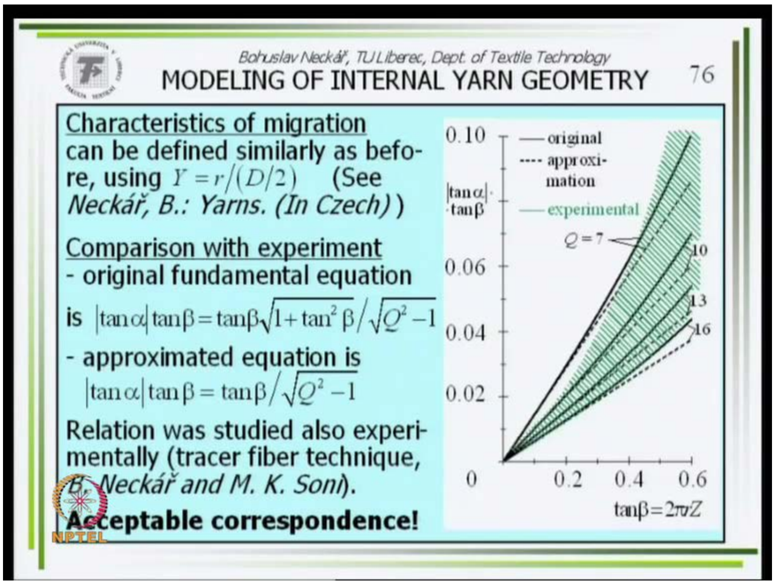

And, we obtain such result. Now, the comparison is experiment. We change only one assumption – assumption called number 4. On the place of idea of constant nu, which represents it; each fiber must go from periphery to center and from center to periphery. We assume that there are quantities for intersections of radius, is proportional to the vicinity of fibrous material around this radius. We measured it experimentally how I explained when I discussed the results by Treloar. And, the same diagram here is tangents beta; it means 2 pi r Z. And, here is absolute value of alpha times tangents beta. our curves in equidistant model; other thick curve is here; the thick curves here. And, the approximation, which we used are the dotted lines here. And, the same trend of experimental curves – it is this and the experimental curve was so; or, so on and so on. It is not ideal, but I think it is much more better correspondent, the theoretic model of the experimental experiences. And, only one idea is changed from assumption 4 to newer assumption 4 star (( )).

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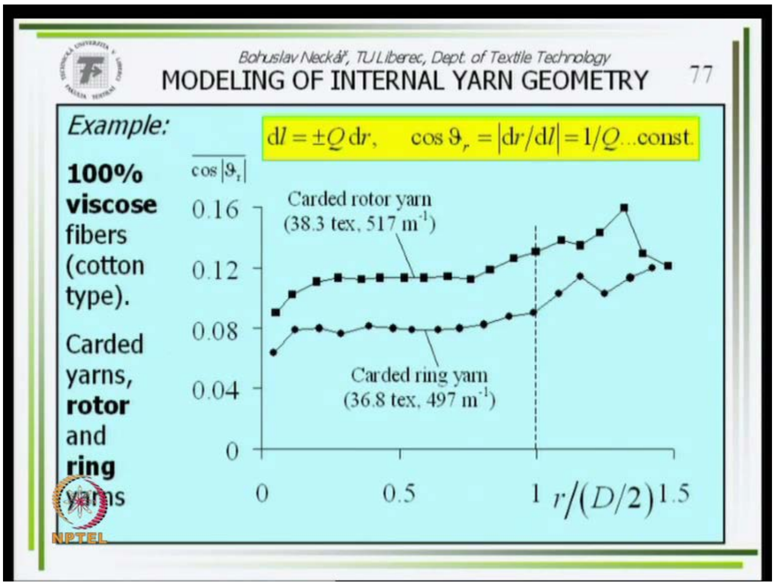

An experimental graphs from… You can see this is a mean value of cosine absolute value of angle theta r on different radii inside of yarn from 0 to yarn surface. Here is radius of theta – have this k of radius from yarn center from 0 to…; one is because here is r by D by 2. Cosine of theta experimentally measured is this here like this. Two examples are here – carded rotor yarn and carded ring yarn; both form viscose fibers. We analyzed viscose yarns, because viscose fibers were the best for experimental work based on the transparency of such fibers in immerse liquid using Morton's tracer fiber technique. You can see that roughly the values can follow our ideal model. This way it is constant – equidistant migration. Here now, but this is for (( )) outside of yarn radius.

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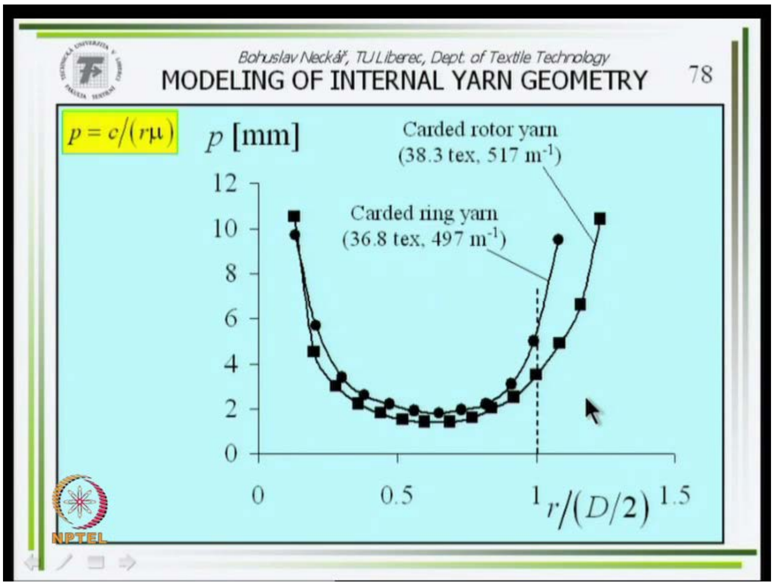

Periodic migration – pure experimental results; also, ring yarn and rotor yarn; length of mean periodic migration and also r by D by 2. You can see that periodic migration is not constant based on radius. As we assume, it is higher value indulged in the round axis, because small surface of cylinder in small radius. Therefore, no too often the fibers have the chance to go inside, then outside. Therefore, number of intersections is small. Therefore, the mean length of period is relatively high. The same is on the yarn. The surface – it is increasing, because packing density, the border between yarn body and higher yarn is small. Therefore, fiber is here only sometimes. Therefore, the (( )) is higher; and, minimum periods – maximum of frequency of intersection is in this central part as we assume.

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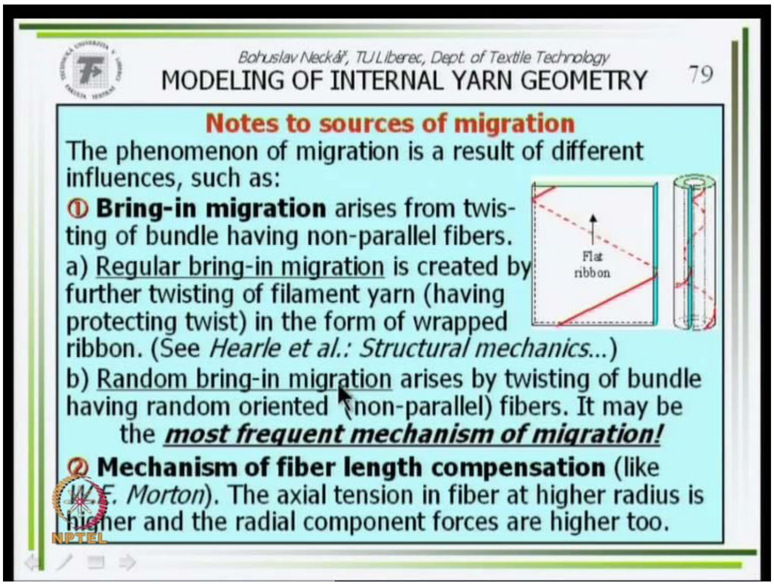

Some notes to the source of migration – the people, the colleagues of professor Hearle studied the migration in filament yarn. They take filament yarn having a small twist from production; you know that we often give small twist to filament yarn, because be enough compact for manipulation technological process; is not it? This filament yarn – re-twist it on a twisting machine; and then, they studied the migration and he obtained some migration. Some period – it is very periodical effect. Why it is shown here? From couple of cylinders, last couple of cylinders, the filament yarn is going out flat as a ribbon; and then, the twisting followed the mechanisms of ribbon twisting. What is it? I have a microphone (( )) be carefully, but I prove it. This is a ribbon – my tie. When I twist it so, this is the character of ribbon twisting. And, the fiber which is on this side; then, on this side; for example, yellow stripes on my tie.

Now, the yellow strip is here; but also, inside; outside as well as inside. Therefore, they obtained periodical migration, which is bring-in migration from the character of starting product, a little twisted filament yarn. In more details, it is in the book of Hearle and (( )) The second mechanism of bring-in migration is random bring-in migration. When you will see the thin sliver, very small sliver, which is going out from last couple of cylinders in ring spin machine, you can see that no all fibers are perfectly parallel. They have some distribution of directions; is not it? And, this distribution is going inside to the yarn structure. Therefore, we can see the change of radius as far as the change of local twist to fiber element, so that migration, the second influence is random orientation of fibers in the ribbon, which is coming to creation of the yarn.

This may be the most frequent mechanism of migration – (Refer Slide Time: 44:46) Morton – his name was here mentioned (( )) fiber technique was also on professor on Younis in Manchester; or, (( )) then, Treloar and Hearle.

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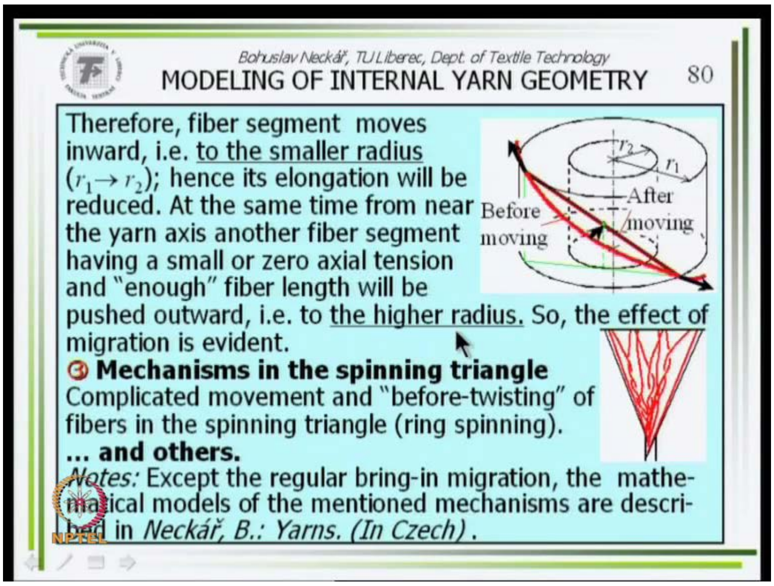

And, he mentioned that exist some mechanism, which is known as a mechanism of fiber length compensation. When we twist yarn, the peripheral fibers have some force, axial force; thus, elongated there was… Therefore, they want on this red fiber, inside exists some axial force. So, is it a fiber? Wants to go in because resulting force is this one; is not it? You imagine. If it is possible, this fiber wants to have this tractor E as this straight line. And, the fibers, which are inside of the yarn, have the lengths enough, because it is a little compressed; it can go outside. Therefore, the fibers can change mutually. This is the principle of Morton's idea.

But, based on my personal meaning, this effect is not too high. Why? It exists very significant friction between fibers and changed the fibers; need very high forces, because the frictions do not want to do it. Therefore, based on my personal meaning, I think that this mechanism is not too important. Then, let us see the third mechanism. When you have watched what is doing; and, in the spinning triangle, you will not see only the fibers, which are going immediately to this top point of triangle to d r; (Refer Slide Time:

47:22) you will see its scheme, but you will see something like here is in this triangle – some twisting of the yarn together. This mechanism then the structure, because friction and so on is partly coming to the yarn, so that the fiber changed radius, because the starting structure can be this one. Also, this is the mechanism for fiber migration and lot of others.

Although some of them is spoken in my book, but sorry for you it is in check language. Good for you is that the check language is possible to read your professor Ishteyak in those pictures. This is all for today. This theme was a little more theoretical, but I hope through these models, minimum you can better imagine how the structure of real yarn is and then you can imagine what you need to do in a process of spinning. In spinning process, I think also different modifications of spinning technologies; try to make better structure of starting, maybe a ribbon or starting product at this small sliver, because to obtain the yarn, which is now to intensive migration. This is more. It has the chance to have higher value of packing density, be more compact and so on. But, it will be question of our next lesson – packing density, compactness diameter and so on .