Orientation of Fibers

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Model No. # 01

Lecture No. # 12

Modeling of Internal Yarn Geometry

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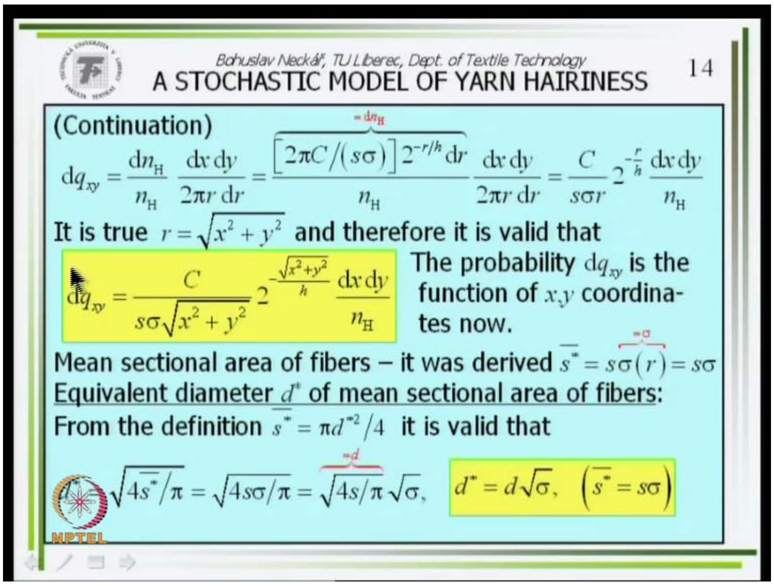

In this lecture, we, we must continue, is our model of, stochastic model of hairiness in, and of the last lecture, and we obtained a formula dq xy is equal to this expression. The signs of dq xy is the probability, that your random chosen fiber from, from a, a sphere of, from a, sorry, from the sphere of hairiness, 1 moment, our earlier picture, which we, now this one.

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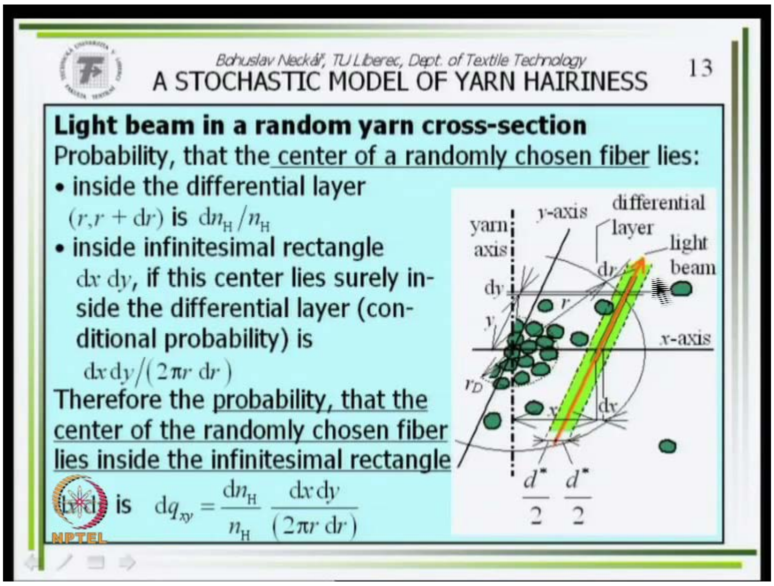

Random chosen fiber, I do not know, may be this one, may be this one, nobody knows, yeah, random chosen fiber is lying inside of our element of rectangle dx dy. Well, this is, this probability dq xy, the area, the section of areas, the section of areas, the real sections of areas of a fibers in hairiness sphere, have before and random shape, we need to idealize such sections.

So, we, we will idealize such sections as idealize a ring. We will assume, that each fiber section have the same sectional area equal to S star bar as a mean sectional area and because star bar is this, it here, it is s times sigma, which we derived earlier. We imagine, that is, mean area have to idealize, only idealize shape as a ring.

Then, such a ring have diameter d star, may be this diameter will be a little higher than this, idealize diameter, then the real diameter or the further, and it is valid, that the star bar is pi d square by 4 d star from this, this star is this, here, so that this here, so that this here, but this is d. So, the d star, it is a fiber diameter d times square root of our parameter sigma. It is a little higher than, than radius diameter d of fiber and then from S star bar, we can write S times sigma.

Now, let us go a little back to our this picture, which we know from last lecture. Let us imagine some light beam, some orange light beam, which is lying on the cross-section of our yarn into hairiness sphere, this orange light beam. How is the probability, we were solved the equation, how is the probability, that this light beam will pass through the yarn, these are some problem is hidden of fiber. How is such probability we idealized?

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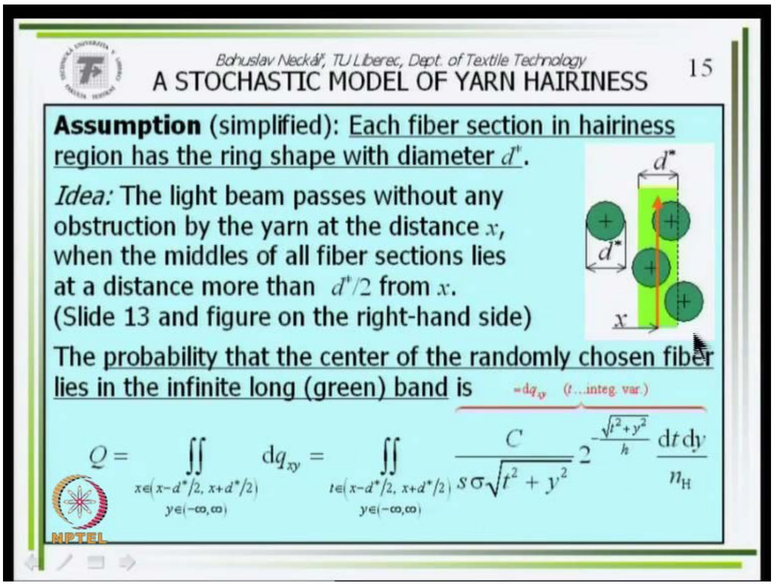

Here is some some strip, light green strip, which is also here as a light green shown. We idealize the cross-section of fibers in hairiness sphere as rings having diameter d star, clear.

I think, how is the position of section of fiber ring diameter d star for hindering or no. If fiber section have its central point in the, no in the distance, no far from d, d star by 2, like this here or this here. Then, light beam had have no chance to go beside the yarn, stop. When the fiber has its central point outside of this light green, light green strip, like this here or this here, then light beam can go without problems beside the yarn, yes.

So, we can formulate now the probability, that the center of the randomly chosen fiber lies in the infinite long green band. How is the probability z, that one random chosen fiber, that are fiber section, center of this is lying inside of our light green, light green strip, thickness lying on the distance x from yarn axis plus minus d star by 2 and yes, for minus infinity to plus infinity, yeah, like was in our earlier picture.

How is this probability? This probability we called Q here. How is the probability, that random choosing the fiber, a little d inside of our light green strip, this fiber can be in, have, we can have its central point here or here or here or here, in each points, in our light green strip, yeah. I said here or here or, or it means probability of this plus probability of this plus probability, yeah, you know it from theory of probability.

So, it, the probability is sum of probabilities dq xy, where x is going from sum value x minus d star by, 2, 2 x plus d star by 2, clear. Here, and y is going from minus infinity to plus infinity, is it so, yes it is.

So, we must integrate it because then, problem is this alpha, beta of integrating quantities, integrating variables, then and modulus, then we, then we rename integrating variable to t. So, we obtain, this is our equation for Q xy and we must make this double integral.

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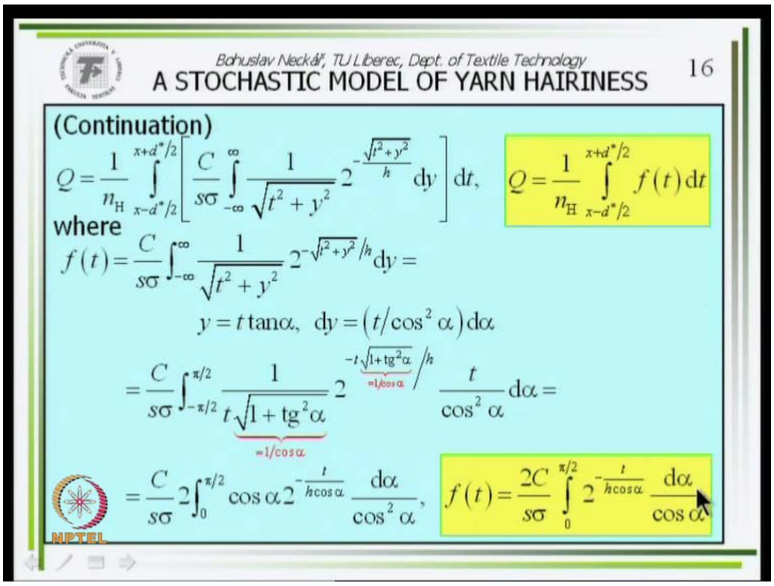

We then obtain, we, the value Q, this value Q, the signs is known, it is repetition to our equation for our last slide, we can write in this form or formally also, Q is 1 by n H times integral of this bracket times d t, that is bracket, we call f t and f t is, is this one, clear, the sign.

This integral, we can a little rearrange. Let us use some substitution y, which is here. y is t times tangents alpha, alpha is only substitution, is name of, of substitutive quantity. This alpha has a lot some special logical sense, like it is possible use, I do not know what alpha, that, which we, which we want, I used alpha, yeah. So, alpha have a lot some special interpretation, logical interpretation. It is only the variable used by integration as a substitution, yeah, method. Using this, after rearranging, which you can quietly study home, we obtain the final expression for our function f also in such form, well.

We know Q; once more, Q is the probability, that the random chosen fiber have its central point inside of our light green strip.

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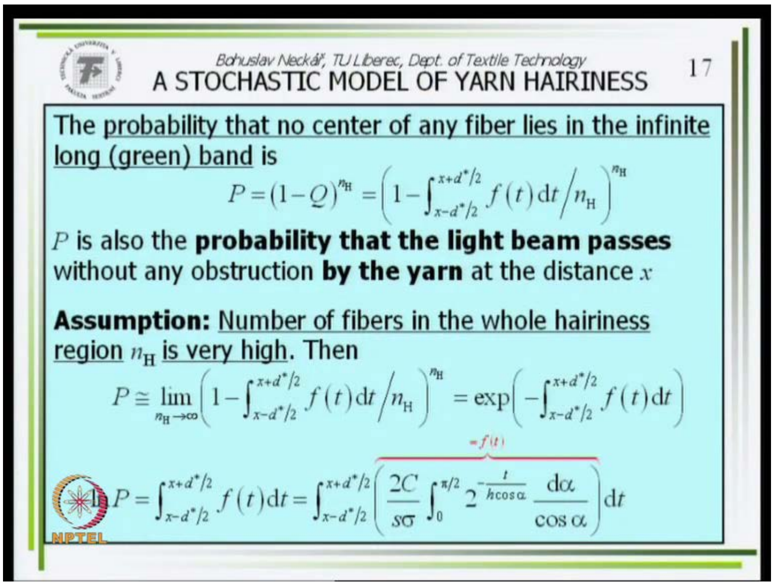

How is the probability, that random chosen fiber will not have its central point is our light green strip, 1 minus Q, well. And how is the probability, that no one fiber from, from hairiness sphere in the cross section. Let us imagine it, we are not at central point, inside of our light green strip.

This is probability, that the 1st fiber is not there and in the same moment also, the 2nd and in the same moment also, the 3rd to n H fibers. So, we must multiply each probability of each section is 1 minus Q times 1 minus Q times 1 minus Q and we must do it n H times, so that it is this probability, probability, that no center of any fibers lies in the infinite long green band, is 1 minus Q power to n H. The probability, that only light green strip is free for, free for, for a light beam is probability P, which is given by this, yeah.

What we obtain using Q, this, here? All this f, f we know, it is function f here, is this here. If you tried to rearrange it more, but all will be easy when we were assumed, that number of fibers in hairiness sphere, in hairiness sphere is relatively, very, very large, why? It often is, it often is the traditional yarns, that lot of fibers in sphere of hairiness, why? From point of your mathematic, in a basic course on this university, may be of mathematic, you, you use also 1 formula for limitation, it was 1 plus constant by x brackets power to x, if x is limited to infinity is e power to such constant; it is one of known, known formula from basic course of mathematic, mathematic analysis, the part of limits.

What is structure of this problem? 1 minus some value by n H power to n H. If number of fibers in a hairiness sphere is very large, then this probability is roughly, limit of this expression by n H, limit it to infinity, yeah, have the structure of the limit; is this, this step clear? Then, roughly we can write, P is equal roughly limit of this and this is exponential function, it is e power to minus this integral. So, P is e power 2 minus this integral, then minus logarithm P is this integral. So, it gives back our structure of function S.

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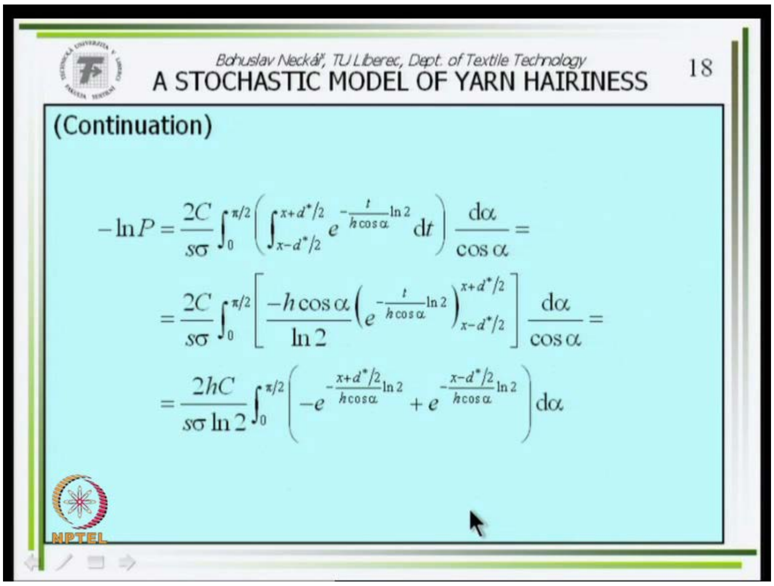

Now, and after rearranging, which is here, on this we obtain final expression here.

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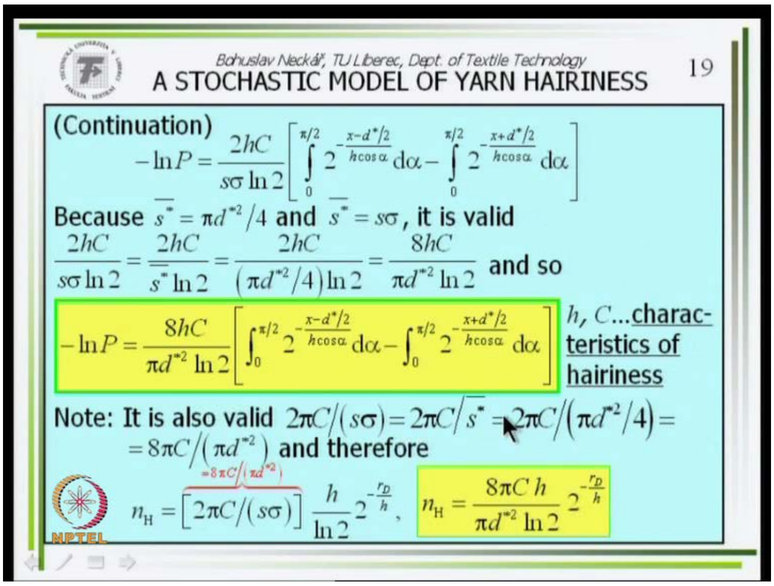

Let us continue here, minus ln P is this here, yes. We know, that s star bar is pi d star square by 4. So, this is equal to this, both are valid. Then, then it is valid, rearranging of this parameter here. According this rearrangement, trivial to this form at it, can write, that minus logarithms of probability, which is P is this is given by such equation, where 2 parameters must be known, H, half-degrees interval lengths of, half-degrees interval and C, which is the 2nd characteristic, which will related to packing density, which will be shown later. So, it is also valid, this, here in this notice shown, so that n H must be this, only rearranging of area equations.

Well, we have all what is necessary for our model, we had it too and we start to compare this results, this experimental experiences by is that picture of the yarn or, or, in, in microscope. Then, then, image analysis technique, which you know, which is here too, I hope and sorry, this model was not too precise, the question was why. So, nice model, is not it, our models are every time nice, why.

We have, we had experiences, subjective experiences with lot of pictures of yarn and we knew, that in the small area, near to yarn surface are different, small, how to say, loops, may be loops, short ends fibers and so on. And this type of fibers create something like a mousse on the yarn surface. There are fibers of one type, another fibers was long, long flying, free flying fibers, which bring complications into following technoloy and so on, and so on. So, that, may be this is the problem, do not exist only one type of fibers in the sphere of hairiness; it exists 2 types of fibers, which create both, both together, both types together. The final effect of hairiness, yeah, one type create at most something like, subjectively saying mousse on the, on the surface of the yarn, and 2nd type of, flying of a single fibers, well.

Let us imagine, that both, that we have on the surface of, in hairiness sphere, 2 types of fibers, yeah, 2 two type of hairiness; let us imagine as a red fibers and blue fibers. When you want, yeah, all together are created the effect of hairiness one type of fibers, as well as, the 2nd type of fibers follow, follows our model, but with quite other parameters. Both follows our model, both type follows our model, but this quite different parameters.

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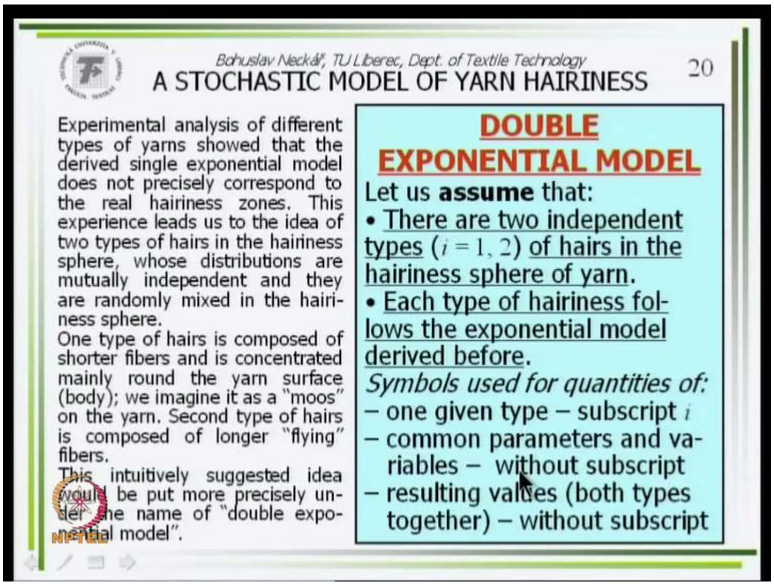

Then, we can, very easy to, to define double exponential model. We called our earlier model as an exponential model because you can, you, was it, was same, that the, that the number of producing fibers have the exponential decreasing tendency, yeah. In earlier model, therefore, now we speak about a double exponential model.

We use symbol, one type of fibers have general symbol I, the quantity is for one type of fibers, we will have same subscript I. Common parameters there are, they were be without, without subscript and without thing, values of without subscript, well.

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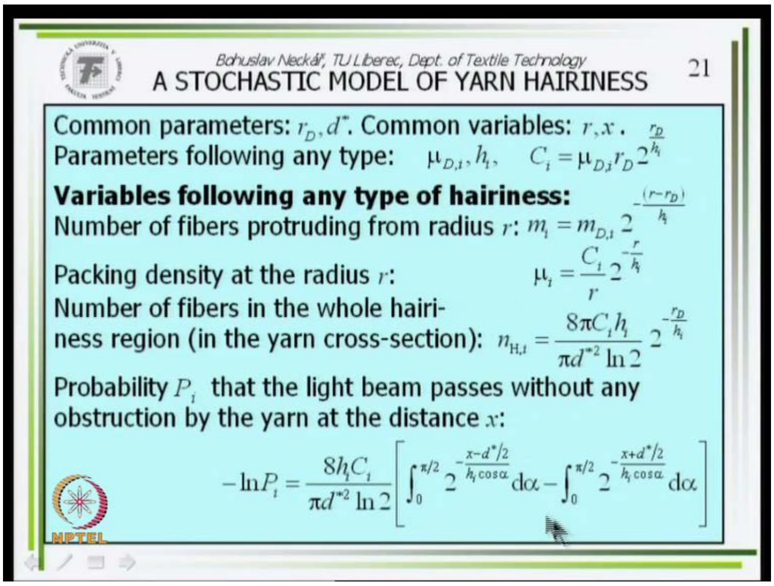

Common parameters r D, one yarn, same radius r D, yeah; common parameter is also d star because the, we said the distribution of directions of fibers is, is independent to position of the fiber, so that also d star.

Common Variables were also the variables r and x, radius of differential r and distance on which is going the, the light light beam. Parameters following any type are mu D. Packing density, starting value of packing density on the yarn body, it is packing density for 1st type of fibers and for 2nd type of fibers, clear, mu and h i, h i is half-degrees interval, which is either for 1st type of fibers and for 2nd type of fibers.

And that is why, the parameter C, we derived this equation here, you can see here, how is the structure here. Parameter C, C i related to h i and packing density, yeah, starting value of packing density and the quantity each. So, number of fibers protruding for radius to type 8 type, 1st or 2nd, yeah, is, this is our known equation only on the place of m, is now m I; on the place of m d is m d i because this related to 1st or 2nd, generally 8 type of fibers, yeah.

Similarly, packing density at radius r, our old equation with subscripts on the quantity, which are related to our type of fibers, number of fibers in the whole hairiness region is this here. Same idea, only a subscript i and our probability, which is probability of be free our green strip for light from fibers of light in 1st or 2nd type, yeah, is this here.

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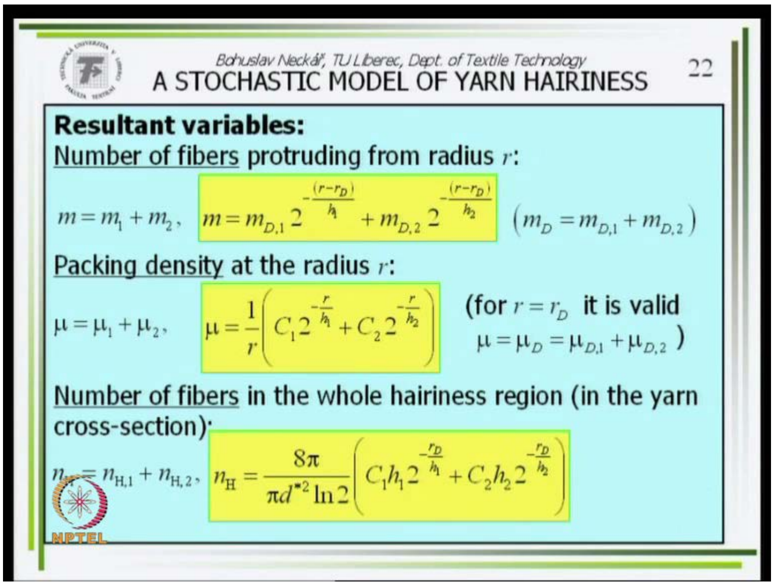

Now, how is the resultant variables for both types together? Number of fibers protruding radius r, it must be number of fibers from 1st type plus number of fibers from 2nd type. So, m 1 plus m 2, we obtain this here, yeah, especially total number of protruding fibers, the, the cylinder of compact body yarn m d, it is m d 1 plus m d 2; from starting position are going out red as well as blue fibers when you want here, well.

How is packing density? It is the same packing density, is the packing density from the 1st fibers plus packing density from the 2nd fibers; it is evident, it is trivial. So, mu is mu 1 plus mu 2, using this we obtain this here. Special case on r equal r D, starting radius for hairiness sphere mu is mu d and it is sum of mu d 1 and mu D 2 evident.

Number of fibers in the whole hairiness region, it is the same, it must be sum of both, same logic, then it is this here using our equations.

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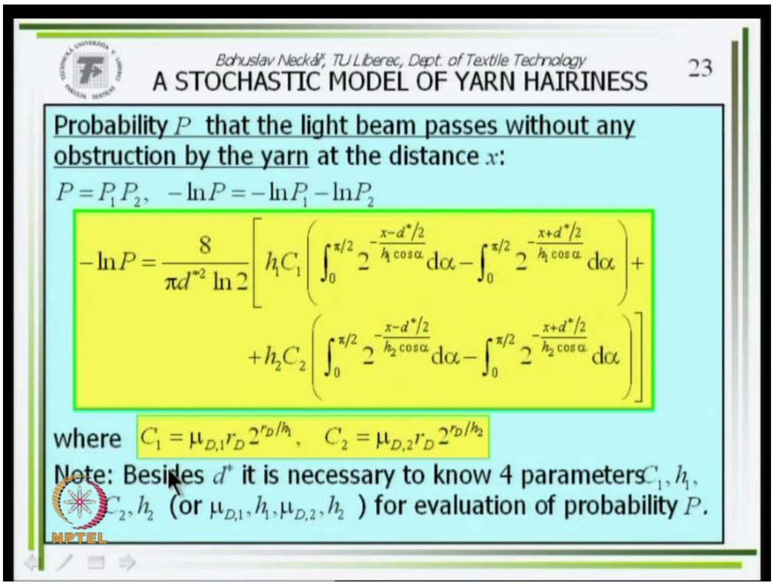

(( )) is a, the question about probability, how is the probability, that the light beam passes without any obstruction by the yarn at the same distance x without problems. It is a probability, that no one red fiber, is in the start in our light green strip and in the same moment also, no one blue fiber must restart there, yeah, both together, both, both situations must be together.

How case it is from theory of probability? It must probably this and this also, both together. It is, we must multiply the probabilities, so that the, the final probability P is P 1 times P 2. Now, it is evident minus logarithm is this here, we are using our equations, we obtain this expression, where C 1 and C 2 are this here. So, we, for this solving of this probability, we need for parameters C 1 h 1, C 2 h 2 and or mu D 1 h 1, mu D 2 h 2 because C is is given on this and this well.

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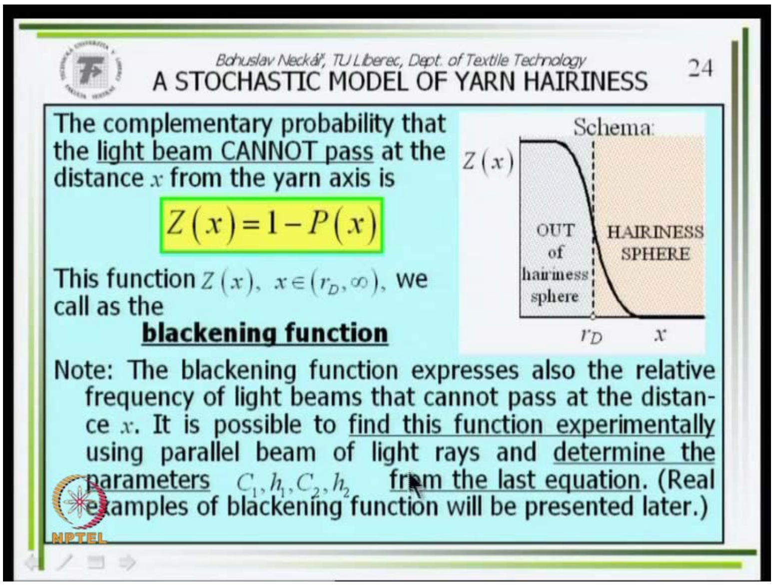

And the complimentary probability, that the light beam cannot pass at the distance x from the yarn axis, it must be 1 minus P; P is function of x. Therefore, in this moment, I write P as a function of x, yeah. Such function cannot pass, we call as a blackening function, this is a blackening function. And how is this, this function? How, how shape have this curve of such functions? Schematically, it is shown on the picture.

The blackening, the black in the central part of the yarn, this is yarn radius from 0 to to, to, to, to, to, to, to infinity, (( )). This is the blackening function in the center, we see only black, black, black, black points. Then, it is this blackening function is equal 1 and then more and more is increasing of x, more and more light beams are, are passing beside yarn, then the blackening function is smaller and smaller and smaller and limited paralytic in this x, limited to infinity. It limited to 0 on some radius r D, starting the hairiness sphere. So, for axis up to only this, we create a model for this part, this is only extrapolation. It is not too important for us because it is the body of the yarn and there another there are valid another regulations, well.

This blackening function, I must also sure comment, I want to comment some integral characteristics because now the blackening function is a function, have function, but sometimes we need to have some scalar quantity, which characterize intensity, how to say it, intuitively of hairiness.

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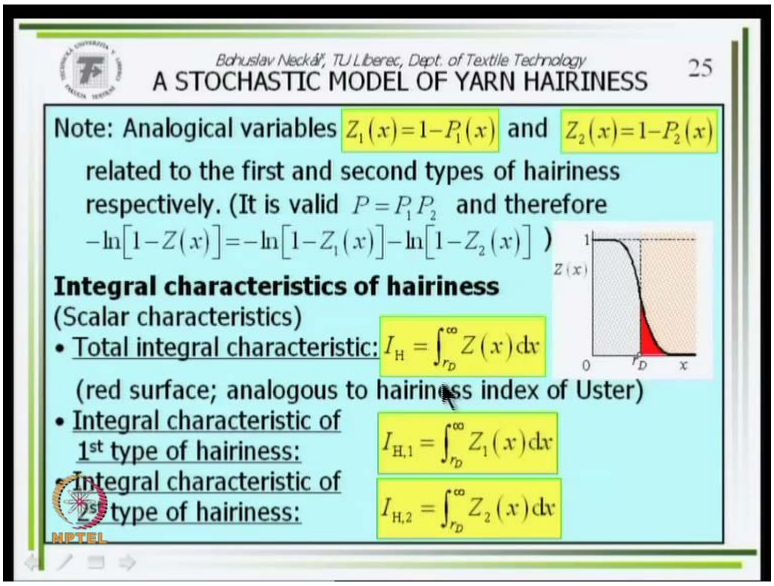

We can say, that it can be for example, area on the area blackening function. So, this is integral of our blackening function, yeah.

Then it is scalar value and it, it can be some characteristic of scalar, characteristic of hairiness, we can also separately characterize. Similarly, how is the effect of the 1st and the 2nd type of fibers?

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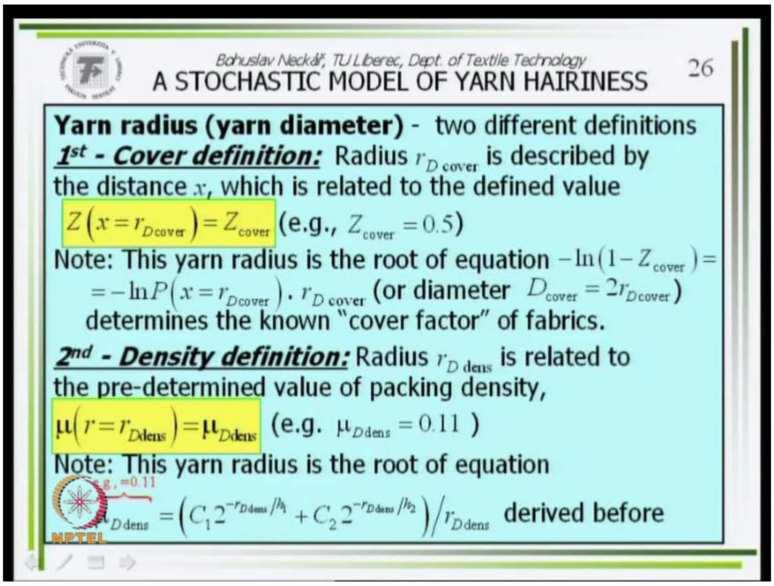

We can also, based on this, of our equations define diameters, yarn diameters. In my department we use 2 different, 2 different definitions.

Here is the 1st cover definition. We can say, that the, we, we call as a yarn radius, one-half of yarn diameter, such radius on which the, the blackening function value is one-half, it means one-half of points is black because fibers in microscope and 2nd half of point is white because light, yeah. This definition corresponds to the idea of covering and dominant is the black points, then we feel it as a yarn based on our eyes and we can say, this is yarn, for example, woolen fabric in a (( )) of course, yeah. So, it is shown how to work. We usually use this constant 0.5 (( )).

The 2nd definition is the definition based on the packing density, Professor Ishtiaq often use this definition and we use this definition also. Based on my meaning, the cover definition is sometimes better for application, by construction of woolen fabrics.

The density definition is better for study of the mechanic, internal mechanic of the yarn, whereas the density definition, the density definition is, that the radius on which the packing density have given, given value, this is, this is our, this is our radius. There are different possibilities, but usually this quantity is given between 0.1 and 0.15, it means stand to 15 percentage, earlier I used 0.14, means 13 percentage as a criterion for diameter. Now, may be a little smaller value, 0.11, not too important for practical point of view.

And using cover equations, we can define, in which moment, in which radius, especially this, this value is.

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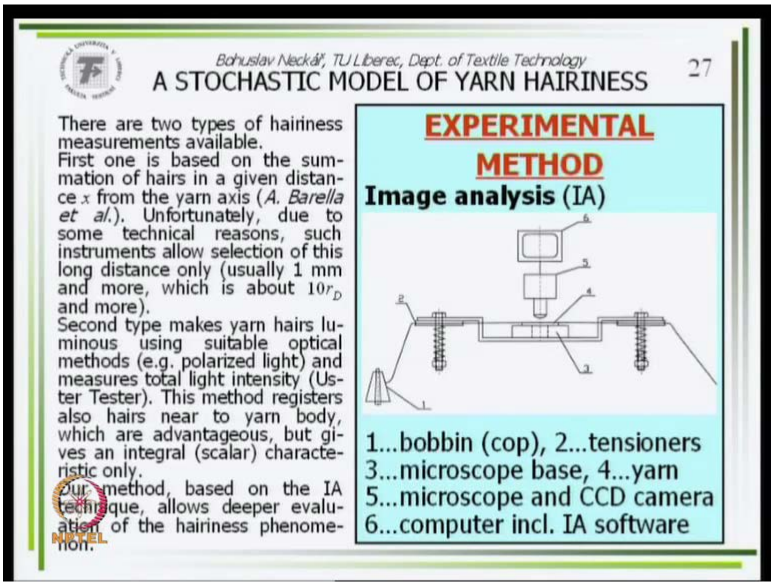

Well, this is concept, theoretical concept of hairiness of course, I do not know a whole literature, which is in the world, nobody knows it. Nevertheless, I do not meet one, one publication, it is an alternative theoretic model, Probabilistic model of hairiness, as the empirical models you have lot.

Therefore, this is for me the best because I do not know the 2nd version. Now, I assume quickly to the experimental method, experimental, our experimental method is very easy in principle. Yarn is going through microscope in, on the microscope. We have some camera, CCD camera and the picture is, we obtained on the screen.

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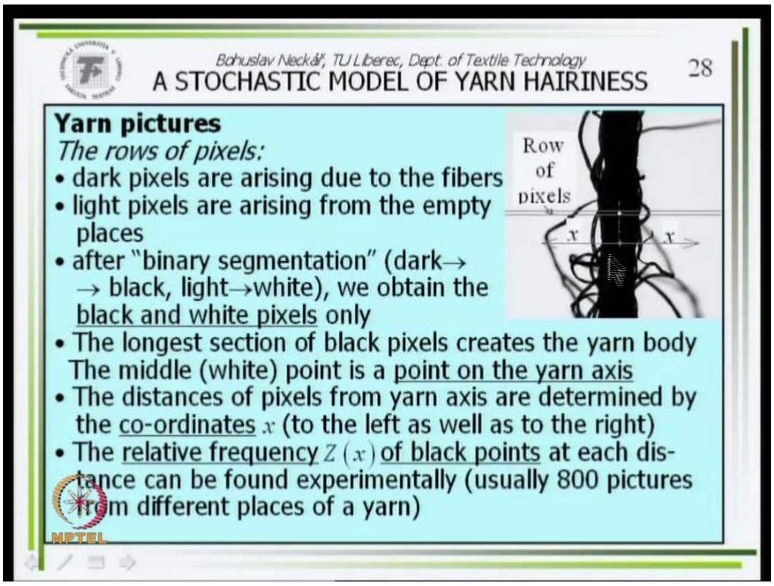

We apply on the, like this here yeah, and in this row of pixels we can say, we define the center of this black part as a Yarn axis and, and to both sides we can say in which distance is black or white pixel, yeah.

When we repeated lot times from lot of pictures of the yarn, we were, we can construct experimentally, out of blackening function, I think, it is yeah, it is great. For example, in small distances, practically 100 percent each of, of points is black, may be, in such distance, sometimes black, sometimes white, may be near to 0.5 in, I do not know, in this distance 100 times white and one time black, and therefore, here, very small value of blackening function.

So, such blackening function is possible using, of course, it needs some manipulation, it can, some binary segmentation and so on and so on of our picture, yeah. But it is only the know how, know how of our experimental method.

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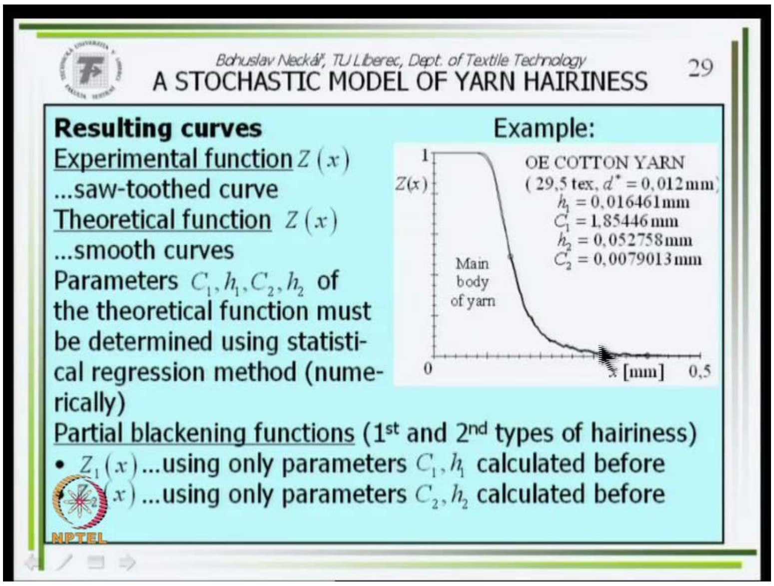

And then, we obtain experimental, experimental curve, this slightly. So, to it curves and experimental curve, experimentally elevated curve of blackening function, and using such parameters, we obtain theoretical curve. You can see, that is, for (( )), choose parameters, our theoretical model for the our experimental result very, very good.

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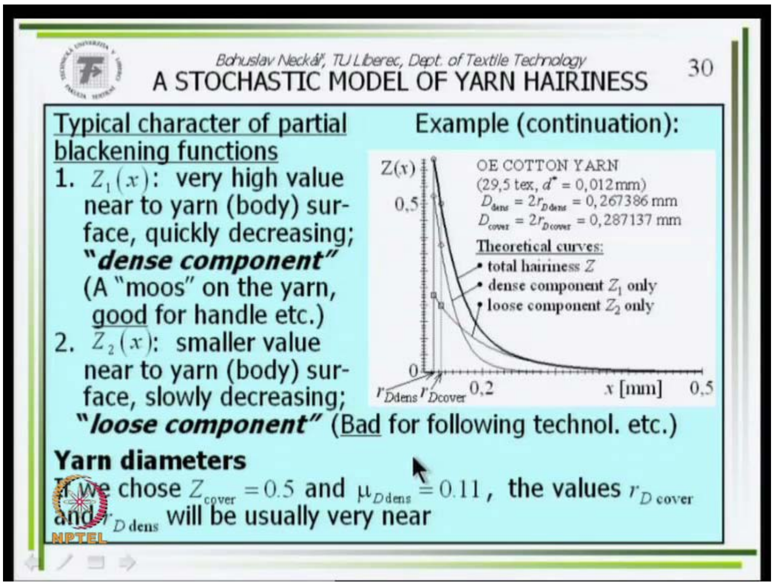

We can divide our result into parts because have to, to we speak about 2 types of fibers and in most, volume of our yarns is very high differences between these 2 types of fibers. It is shown from also here, their starting packing density of 1 type, we call this as a, as a dense component.

It started on the yarn surface in a very, relatively very high value of packing density, from starting cylinder of yarn body lot of fibers are going out. So, number of protruding fibers in a cylinder of yarn body, in the 1st group, this dense component fiber is very high, but they are short. So, number of protruding fiber through this type of fibers is quickly decreasing, is reduced to 0.

In this example, it is this curve, yeah, started in high value, but quickly decreased to 0, x (( )). The 2nd type of fibers, we call it as a loose component, started on the starting cylinder of yarn body, with small value of packing density, it mean, means now too much fibers is going out from the 2nd type, but number of this decreased slowly, so that when some fiber is starting from cylinder, then usually it is very long, finish on the very long lengths, it is a called loose component.

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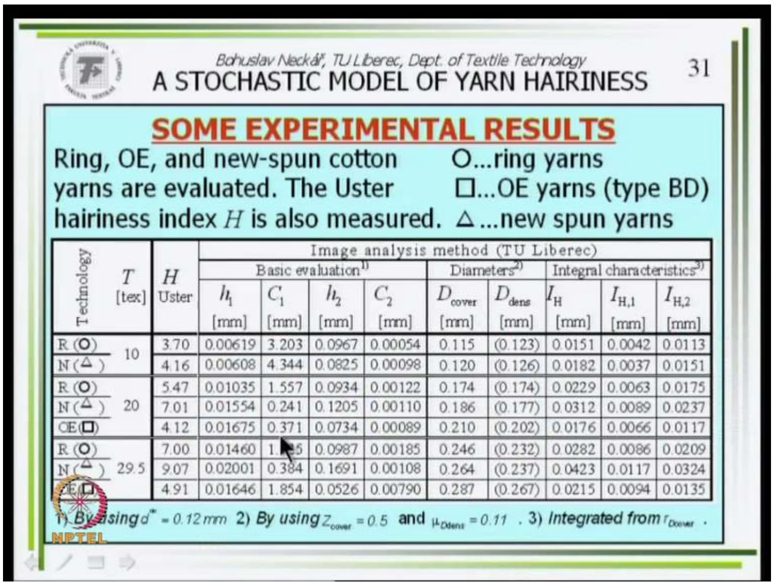
Bohuslav Neckář, TU Liberec, Dept. of Textile Technology

A STOCHASTIC MODEL OF YARN HAIRINESS 31

SOME EXPERIMENTAL RESULTS

Ring, OE, and new-spun cotton yarns are evaluated. The Uster hairiness index H is also measured.

O...ring yarns
□...OE yarns (type BD)
△...new spun yarns

Technology	T [tex]	H Uster	Image analysis method (TU Liberec)								
			Basic evaluation[1)]				Diameters[2)]		Integral characteristics[3)]		
			h_1 [mm]	C_1 [mm]	h_2 [mm]	C_2 [mm]	D_{cover} [mm]	D_{dens} [mm]	I_H [mm]	$I_{H,1}$ [mm]	$I_{H,2}$ [mm]
R (O)	10	3.70	0.00619	3.203	0.0967	0.00054	0.115	(0.123)	0.0151	0.0042	0.0113
N (△)		4.16	0.00608	4.344	0.0825	0.00098	0.120	(0.126)	0.0182	0.0037	0.0151
R (O)	20	5.47	0.01035	1.557	0.0934	0.00122	0.174	(0.174)	0.0229	0.0063	0.0175
N (△)		7.01	0.01554	0.241	0.1205	0.00110	0.186	(0.177)	0.0312	0.0089	0.0237
OE (□)		4.12	0.01675	0.371	0.0734	0.00089	0.210	(0.202)	0.0176	0.0066	0.0117
R (O)	29.5	7.00	0.01460	[illegible]	0.0987	0.00185	0.246	(0.232)	0.0282	0.0086	0.0209
N (△)		9.07	0.02001	0.384	0.1691	0.00108	0.264	(0.237)	0.0423	0.0117	0.0324
OE (□)		4.91	0.01646	1.854	0.0526	0.00790	0.287	(0.267)	0.0215	0.0094	0.0135

1) By using $d^{*} = 0.12\,mm$ 2) By using $z_{cover} = 0.5$ and $\mu_{Ddens} = 0.11$. 3) Integrated from r_{Dcover} .

Some fast results, can see it, see h 1, h 2; h is half-interval of decreasing of number of protruding fibers. h 1 is 0.00, maximum 01 and something, yeah, it is 0.02. In opposite to them h 2 is much more higher, yeah. Where is h 2, a much more higher than the values h 1.

The interval of 2nd rows fibers is half-decreasing, it is much more higher, long point fibers.

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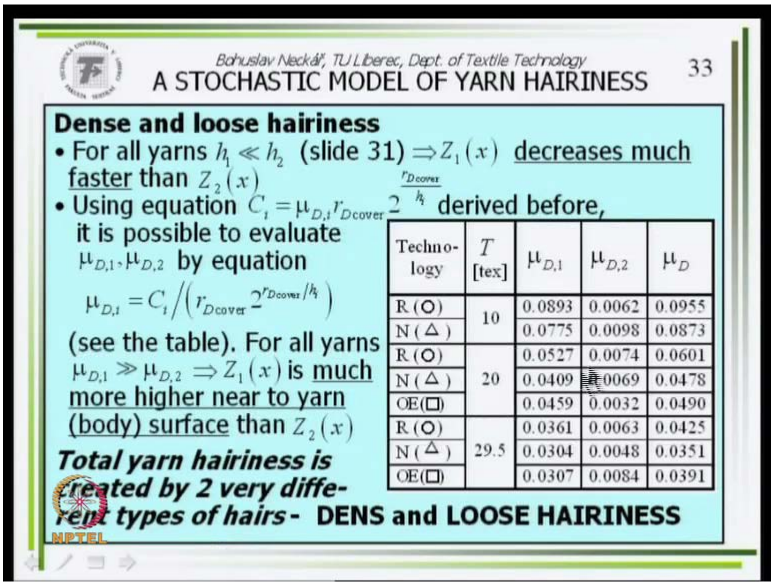

From other side, sorry, packing density is 1 and 2nd starting value d 1 is much more higher than d 2 in some set of different yarns. It means, starting number of fibers is much more higher, but quickly are going down group 1 and the 2nd group, it is in opposite.

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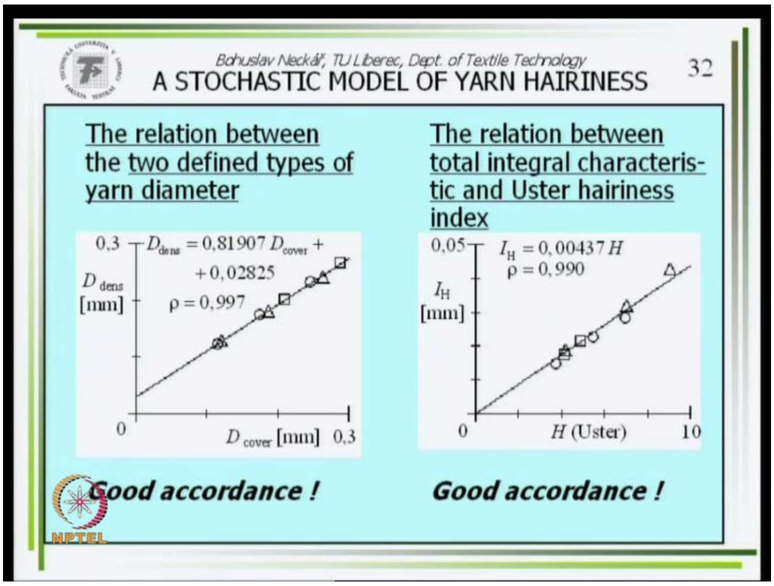

Some graphs, here are much more graphs, this is groupings of a, is working on this field in our department, very, very good. We can also evaluate some star value. This red area under our curve is integral, this is one example on abscissa of this graph, right hand side to right hand side, there are 2 diameters, D cover and d dense, evaluated from our model. You can see, that the correlation is very, very high.

It is possible to, to, we like, we, we, we mention, that it will be solved. Interesting case, this 2nd diagram, this, the, my meaning, very interesting. This is uster hairiness, you know, that uster, I shall say (( )), like an instrument produced in the Swiss town named uster, because uster is name of town in Switzerland, the company have the name, but in the whole world it is known as an uster instrument, so I, I call uster instrument, in uster instrument is possible measure is so hairiness, some value of hairiness.

This measured value by uster and this is our integral from our curve, you can see, that the the correlation is 0.99, correlation coefficient very high. So, it, our method, if the, the very proportional result, then uster method, but he obtained also a whole curve in relation to radius. How is it decreasing? The, the hairiness and we can divide whole hairiness to 2 parts, this mousse part, intuitively say, and the part for, of long flying fibers.

Therefore, our methods, we mean, that it is deeper, can deeper analyze based on our theoretical model, which I presented in our last lectures, can deeper analyze the phenomenon on hairiness of the of the yarn, well. And this is all, I am sorry, that today is couple of, or the the last 2 lectures was a little difficult for you, but no too much, only we used more known, known laws, which are valid in the theory of probability, is not it, well.

Thank you for your attention.