Orientation of Fibers

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Model No. # 01

Lecture No.# 19

Yarn Strength as a Stochastic Process

As an introduction to this lecture, I want to ask you - do you know, why we do not use metal plates for our clothes?Of course, because they have not pores, because they are too hard and they have not pores;is it not? Pores are very specificor the the gaps between among fiber is a very specificbehavior offibrous assembly which we usevery intensively in our clothes;nevertheless, also for lot of technical applications, for example, by filtration andso on.

Today's lecture will be oriented to the possibilityon how to model the pores and gaps among fibers.

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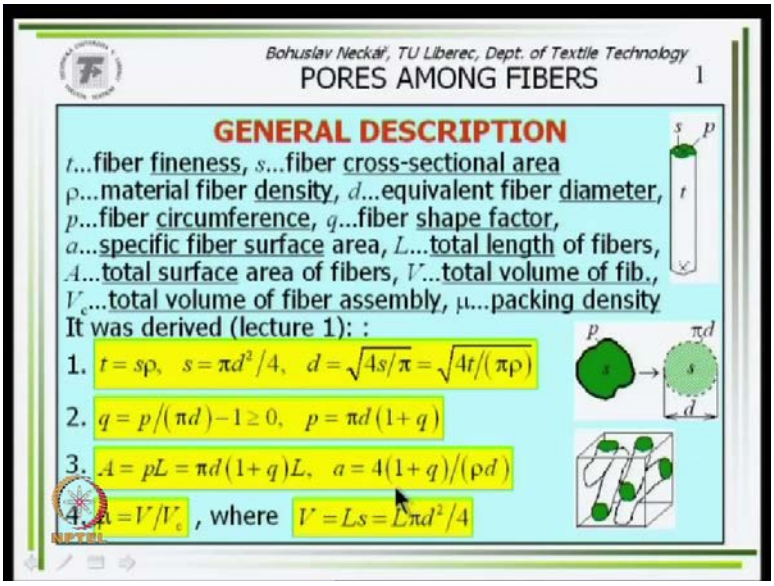

Let us start with small repetition of our earlier relations which we derived inlecture 1 about times, definitions, relations andsoon.We usesymbols t for fiber fineness, s - fiber cross-sectional area, rho -a material fiber density, d is equivalent fiber diameter, p is fiber cincu circumference, q - fiber shape factor, a is specific fiber surface area, capital L will be total lengths of fibers in our fibrous assembly,A is totalsurface area of fibers,V is total volume of fibers,V c -total volume of fiber assembly and mu is packing density.

We derived for fibers that fiber fineness t is cross section s times rhosothat all these relations are valid.q -fiber shape factor is defined as theperimeter of fiber cross section by pi d,the shortest perimeter which is possible for the same areaminus 1so thatfiber perimeter is given by this expression (Refer Slide Time: 03:07).

Total surface of fibers isfiber perimeter-perimeter of fiber cross section times total lengths of fibers.Using equation derived, their value of this equations and packing density was defined.Then,ratio - fiber volume by total volume where fiber volume is fiber cross section or pi d square by 4 L s times,of course, thetotal lengths.

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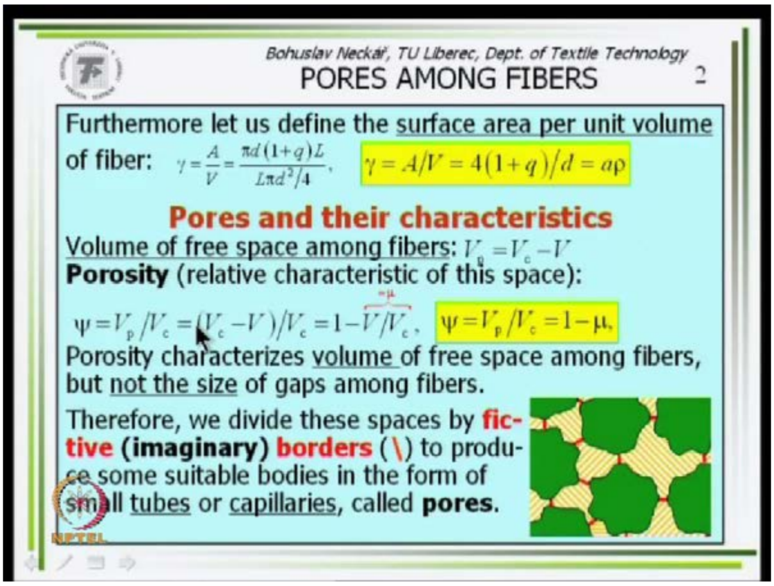

Let us introducemore;onenew quantitysurface area per unit volumearea, surface area of fibers in our fibrous assembly.We saidit is this -pi d times 1 plusq times L and a volume of fibers is pi d square by 4 cross section times L.From this, gamma which is A by V is given by such expression (Refer Slide Time: 04:14to 04:26) andin comparison to a, what wasa?ais specific fiber surface area which is here.You can see that the surface per unit volume is specific area, specific fiber surface area times rho.

Well, pores - relatively easy is to obtain a quantity which we call porosity.What is porosity?A model fiber has some gaps, some space of air;volume of this space is V p;yes,V p which istotal volume minus volume of fibers because what is not the fiber volume is the volume ofair. I think air who who isgiving inside for example(())usually had beside fibrous are air is free air sothatthe porosity is the ratio volume of poreof air among fibers times total volume is thisone,then thisone (Refer Slide Time: 05:43)because this packing density porosity is 1 minus mu. When the packing density is 40 percentage, then porosity 60percentage.Butmore precisely, if porosity 0.6, then packing density0.4andsoon.

It is easy and easy to obtain.Nevertheless,let us imagine twosituations.Onebox, big box from compact polyester and on the center isonebig hole.Can you imagine such box?Packing density inside this box can be, I do not know, may be 0.5.Let us imagine second box full of compressed polyester fibers.Packing density is also 0.5.Nevertheless, between thesetwoboxes, high difference with behavior, the behavior of thesetwo boxes is quite odd.Why?Because in the first case, the air is inonebig hole; in the second case, the air is in a very longpath of very small tubes besideby fibers.Therefore, we need alsoto calculatesome dimension of this air space onof such airspace air space,if itis big or very thin,so that we must create something which we will call pores.

Starthing idea is following.Let us imagine that you have some red pencil.Can you imagine that you have some red pencil?Yes, you can.Makebetween fibers, some red lines as it is shown here inthe scheme of schematic scheme of some section of fibrous assembly.Make this your red pen.Such lines, how you want - very subjectively; very subjectively, how you want?

This imagination is for this moment.Later, I take your red pencil backhere.Thensay, but now in the moment because understand it; please imagine itso.Using your red pencil, you divide thethe region of air to some tubes having very differentshape.Such tubes,such tubes, now,socreated, we can call pores.yeahThereal,thethetheyour red lines, we will call as a fictive or imaginary borders because they are not in reality;it is only your fiction; it is only usedthrough your pencil.

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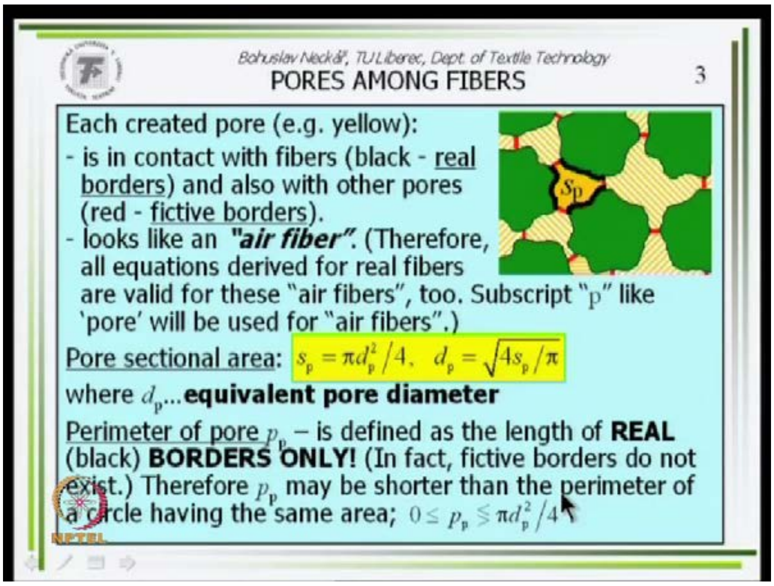

So, each created pore is in contact with these fibers,black borders, real borders, and also we have the poresin our scheme.Using your red pencil, there are in fictive borders andthis tube, this air tubeso createdlooks like an air fiber.yeahTherefore, practically, all equations which we derived for fiber are valid also for our air fiber, air tube.

These equations which are valid for air tubes, the quantities related to our air tube,we will have subscript p like pore because this this air fiber,this air tube we call pore.For example, here is onepore;black is real borders, red isfictive borders, area,cross sectional area of this pore is S p which is pi d p square by 4 where d p is this.Here d p is equivalent pore diameter.You know this equation from fibers.It was equivalent fiber diameter.Now, it is equivalent pore diameter.

Onedifference between our air fibers and threefibers existin the theorem of parameter of pore.You know, opposite to fibers the parameter of pore to the parameter of pore, wecalculate the real borders onlyso that the lengths of parameter of pore, ourair fiber is isthis length this black lengths plus this black length plus this black length (Refer Slide Time: 12:06). Butnow, this red parts therefore, the parameter lengths of the parameter lengths in pore is shorter than the parameter fromhow it this term defined in traditional geometry because the red parts are not our lengths related to to parameter, because it do not exists;it is only your subjective red pencil yes.

Therefore, thelengths of parameter can be higher, but also smaller than the pi d square by 4,d p square by 4 in a yarn in a fiber.It is notpossible is it not?We discussed it.All other equations are valid.

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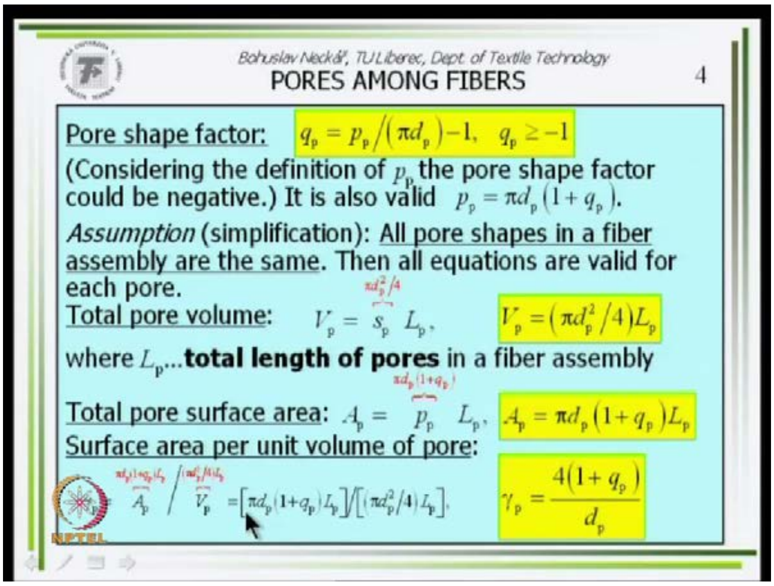

qp per shape factor - same equation is for fibers onlysubscript p.Nevertheless q p shape factor of poreneednot be higher than 0;can be also smaller than 0 because parameter is without red fictive borders andit must be higher equal minus 1.Volume, total pore volume is s p times l p. So, that is where l p is total length of pores, some of all some all some of all paths which you through which you can go when you will beso smaller than microlevel.

Totalpore surface area that is parameter times length is the total pore surface area, surface area per unit volume of pore is gamma p isA p by V p.Are we not using equation derived on the place of A p and there, obviously, V p which is here in a red to showafter rearranging, we obtain gamma p and such for…

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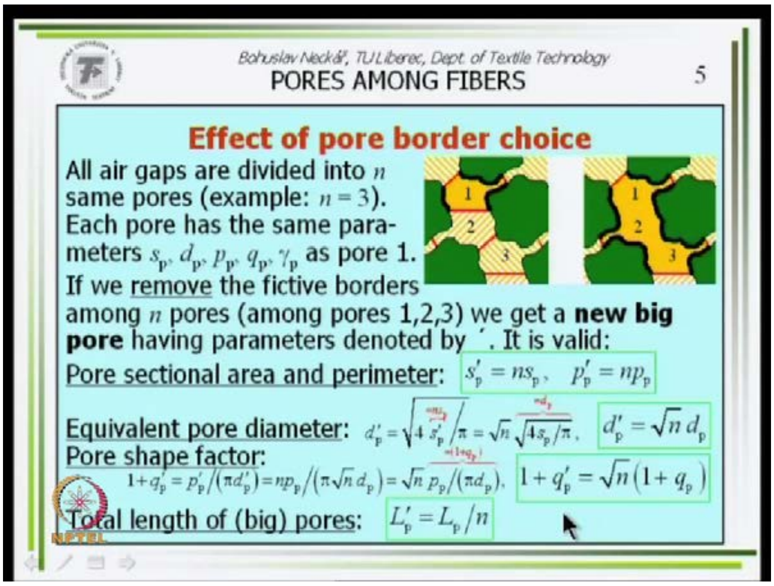

This part we can jump.You can write it when you want andit is not too necessary.

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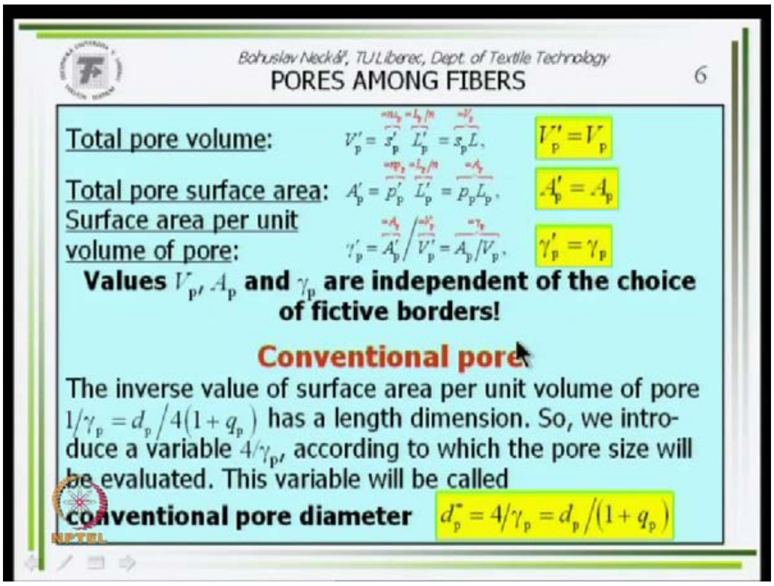

So, that we jump jumpin to samethis formulation of conventional pore.

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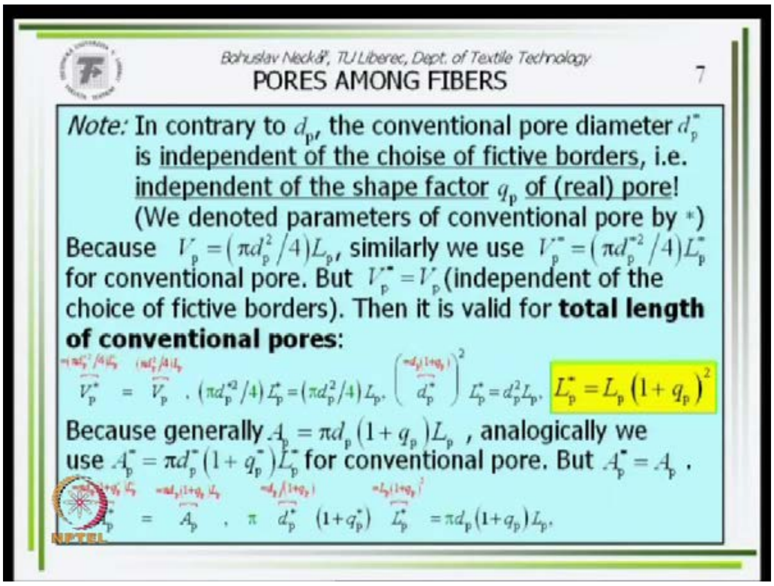

I willdefine conventional pore more easier for you.

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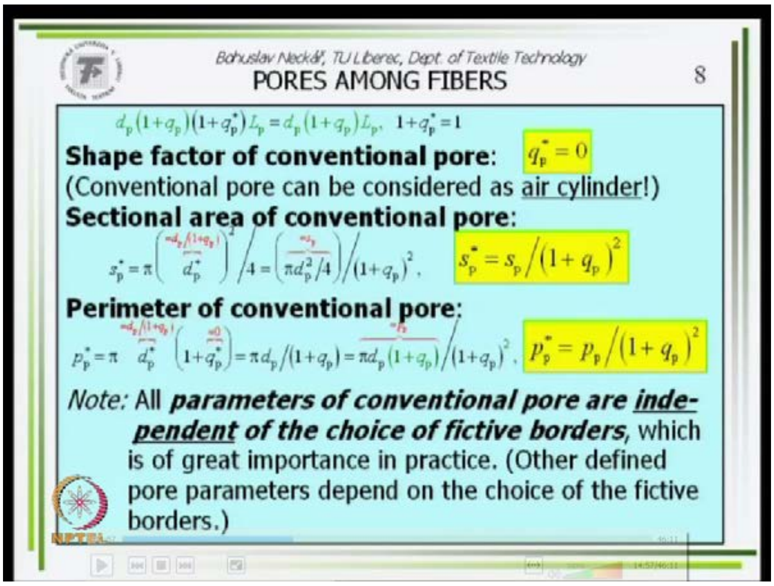

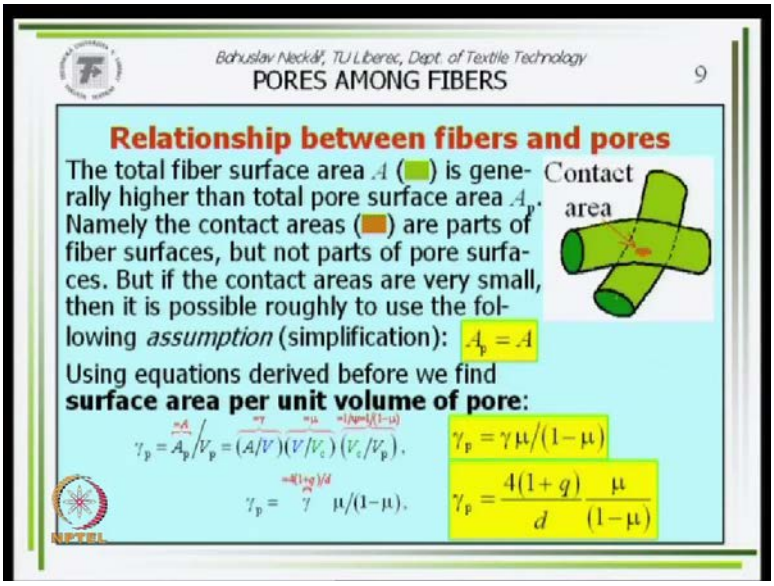

So, we derived equations which are valid for pores for our air fibers; we can say air tubes.These equations,these equationsgive togetherdifferent quantities,different quantities s p, d p,V p,A p, q p, gamma p whichare valid for pores.Nevertheless, we usually need, we do not knowthese characteristics.We know the characteristic of fibers, we know fiber diameter because we know fiber fineness, we knowfiber surface andso on andso on.

How is the relation between pores and fibers?Can we obtain something; can we say something about the pores when we know enoughquantities related to fibers?How it is?

Let us imaginethat you are very small micro and you are working inside of our fiber structurethrough the pore tubes.Because down the go,down to your face,you your hand will be on the walls around, what is it?What are the walls around you?It isa surface of fibers; is it not?But this is also surface of pores,so that we can say that the surface of fibers is same than the surface of pores.

This idea is notfully clear.Why?Let us imagine the situation which is in our picture.By contact of 2 fibers,some contact area with red which is here related to fiber surface, but it is not; this contact area is not surface, pore surface.It is not part of pore surface; is it not?So that the pore surface is a little smaller than the surface of fibers, but if this contact places are not too largeaa limited to point, no too compressed fibrous material andso on.We can say that our starting idea can be as a assumption used. So, we were used that surface of fibers, total surface of fibers is equal to total surface of pores A p is equal

A.Then gamma p wasA p by V p becauseA p is equal A, we can write this black here (Refer Slide Time: 18:46), we can multiply and divide by blue.It is blue;it is blue blueV and by green V c,sothat we obtain this expression.But this is gamma;this is mu;this is 1 by psi;so, 1 by 1 minus mu. So, that you can write that gamma p is gamma times mu by 1 minusmu and gamma p also is when we use on the place of gamma.This expression also derived earlier; gamma p is this expression(Refer Slide Time: 19:21).

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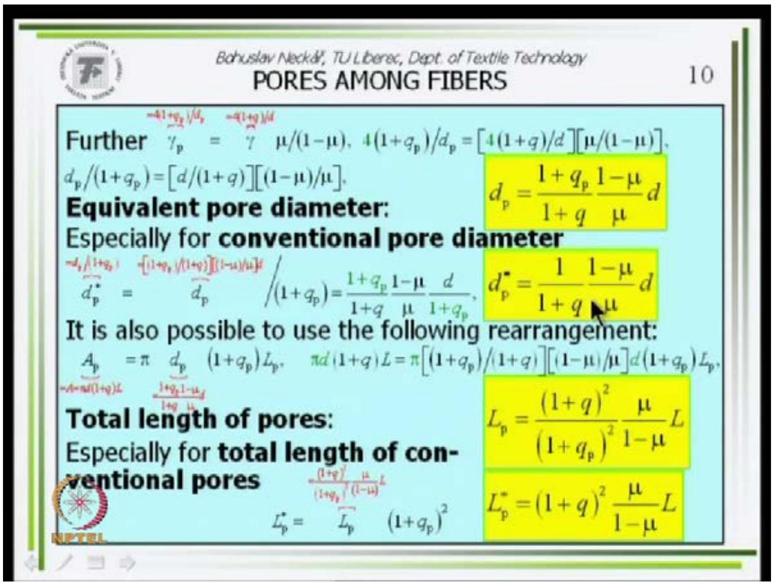

Furtherusing the gamma p, earlierderived equation for gamma 2 we obtain this equation.Here is 4;here is 4.It is going out and after rearranging we obtain such expression for d p, equivalent pore diameter.It is nice. q is our crossas a shape factor of fibers; mu which is a packing density how many how is thedensity of fibers in our structure; d is fiber equivalent, fiber diameter.Only onequantity on the right hand side bring us difficulties; q p.

What is it q p? q p is a shape factor of pore, but shape factor of pore related totwoinfluences.The first is how is the structure of our fibrous assembly, if another fibrous assembly evidently in other shape?Second - how was your subjective idea to create fictive borders? It is your red pen because these 2 influences we do not know how is the value q p.We do not know the value of q p.

This moment is an idea how to very roughly say something to the dimension of these gaps andfibersindependently to then that we do not know the quantity q p and the people say,let us use some convention.

Let us say that q p is equal 0 point; you know that it is not may be, but because we do not know what is it,let us use for a roughevaluation;let us use convention,convention only that q p is equal 0.If q p is equal 0,Iobtain this equation (Refer Slide Time: 21:54); is it not? And it give me new program; such diameterto calculate; such diameterIcall as a conventional pore diameter.

Conventional pore diameter you can calculate without knowledge of your, in the momentIsay,knowledge of youra structure of yourmaterial, of yourfibrous assembly and you neednot have the knowledge about your earlier work with red pen.It is a convention pore.

How is the total length of pores,area of pores A p, surface area of poreswe said we assumed that it is equal tosurface area of fibers A and for A we know thatsuch equationand because A p was pi times d p times this one (Refer Slide Time: 23:00).So, we can use it.On the place of d p, we use this here and after rearranging we obtain we obtain l p total length of pores as 1 plus q by 1 plus q square by 1 plus q p square times mu by 1 minus mu times L.L is total fiber lengths possible to calculate it it is from from knowledge of our fibrous material,packing density q, butq p also same problem and same idea whenIknow nothing.ThenIwill use some convention.You know the term convention.Only convention that q p is equal 0;thenIobtain for fiberpore total pore lengthssuch equation becausethis isthe one - q p equal 0;this is the length, total length of conventional pores in our fibrous material.

So, we define based on convention the quantities related to the conventional pore every times we are able to calculate conventional properties of conventional pore.The second question is, if in these are the textiles lecture, it corresponds what are bad to real dimension or lengths of pores?We will see it.Because to illustratethe convention in this moment,Ido not know q p,So, that in I, but Ican say something about conventional pores.How is a conventional equivalent diameter of conventional pore diameterof conventional pore is shown here is based on our earlier equation these equation direct curves.

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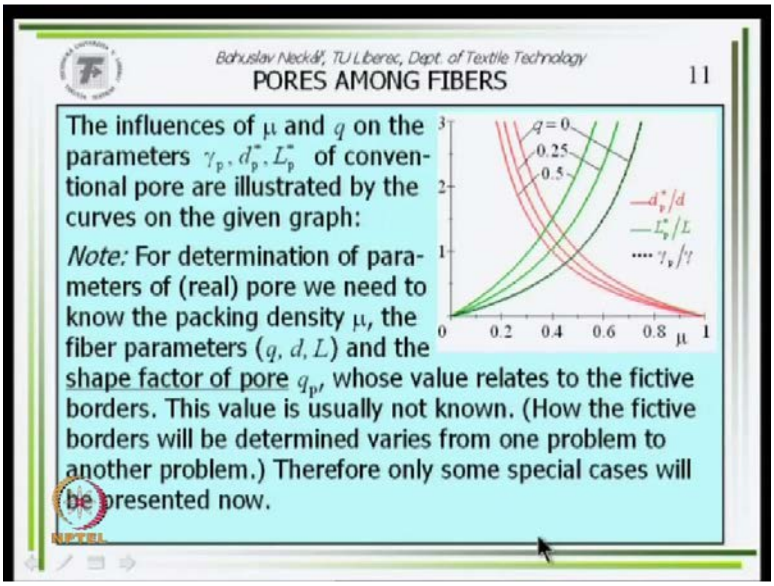

So, these are packing density for 0 to 1 on the ordinate ofquantities of functions used here.q equal 0.What it means?Cylindrical shape of a fiber cross section or fiber cylindrical fibers;then,the curve.The curve is now a d p; then d d p start by d by yarnby fiber diameter, this ratio (Refer Slide Time: 25:46)convention of pore diameter by fiber diameter; this ratio is possible toshowto tototo show here.The function the course of this function isfollowing.It is with higher packing density. So, smaller is diameter of conventional diameter of pore and theoretically if packing density is 1,then the volume of air is 0;in each pore must the volume of pores 0 certain diameter of pore is equal 0;it is well.

When we use another type of fiber shape, these different values of q here are shown. 0.25 and 0.5 shape of the fiber cross section; then the curvesare little there, but not too much. So, is the the relation of conventional pore diameter in a relation to packing density.How is thistotal length?Here are the ratiototal lengths of conventional pores by total lengths of fibers L, the green curves.

When q equal 0,the curve is increasing; what it means?

When we compress our structure, then thesymbolically intuitively saying big hole is derived through fibers which are going inside to theset of smallsmall parts within fibers, among fibers,so that the lengths is increasing.The length is really increasing.Your higher is a packing density. So, higher is increasing is increasing function.Yes.By the way, alsoit isgamma p which is thethe dotted black curve.Identity of it is green curve by q equal 0;we can see it too. So, it is the tendency with a conventional pore.

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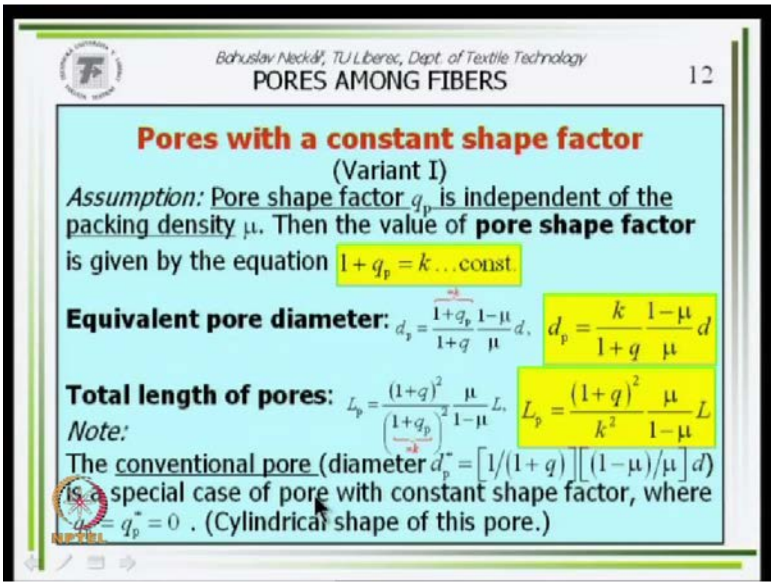

We want to be a little more precise and therefore, we willuse now another ideas than the easiest idea related to conventional pore that q q p is equal 0.The version 1 the variant 1 based on the assumption pore shape factor q p is independent of the packing density mu.

It means whenIpressure a material, the dimensions of pores the pores will be smaller and smaller, butthe shape, the character of shape shall besame.It is some board of ideahow it will be if this is valid?Then q p is permanently same value; 1 plus q p is alsofor each packing density same value,sothatIcan andIcall 1 plus q p 1 plus q pequal k. q p generally can be function of packing density.Now, based on my assumptionIsay it is constant,so that 1 plus q p is constant too.

So, equivalent pore diameter using our starting equation is now this here (Refer Slide Time: 29:52) and total length of pores because 1 plus q p is k is this here.You can say thatconventional poreis a special case of of this variant 1 when the k is equal 1.Well, this is version one.

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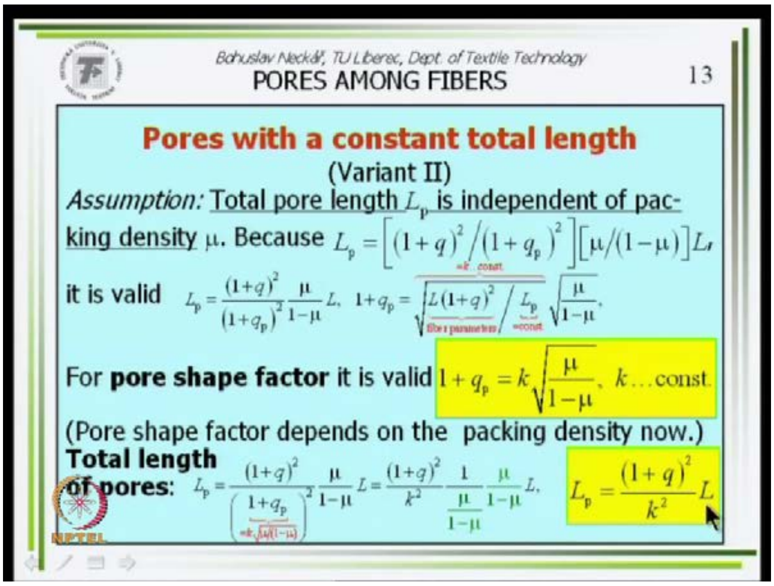

Let us study another prior assumption.Is here somebody who has smoked sometimes?Somebody, sometimes; may be nevertheless you allknow what is in the filter in cigarettes.In the filter of cigarettes, we can imagine that the air is going beside the fibers and therefore, the effect of filtration.This filter we can compress more ororless nevertheless the total lengths of pores, the pores will bebigger or thinner, nevertheless the total lengths of pores may be same.Then from this is goingto be called the second idea prior idea.

Let us imagine the total length of pores is independent of packing density; total lengths, now, shape of pore the total lengths of pores. So, we derivedearlier such general equation we said the problem is our q p.

Now, we must say thisthis equation (Refer Slide Time: 31:36 to 31:48), this L p is constant.This same equation, after rearranging, we can see this equationrearranged to this this formula. It is only rearranging the same equation.Now, lengths of fibers is constant q; fiber shapefactoris constant q p.Now,sorry q p is not here,L p;L p is total lengths of pores.Based on our assumption, it is constant.This square root is constant. So, is that 1 plus q p is equal to some constant k times square root of mu by 1 minus mu.

Using 1 plus q in this form (Refer Slide Time: 32:36) to our equations, we obtain for L p is only checking if our rearranging is well; we obtained this.Yes, it is right because right hand side is constant; it was our assumption and height is diameter.

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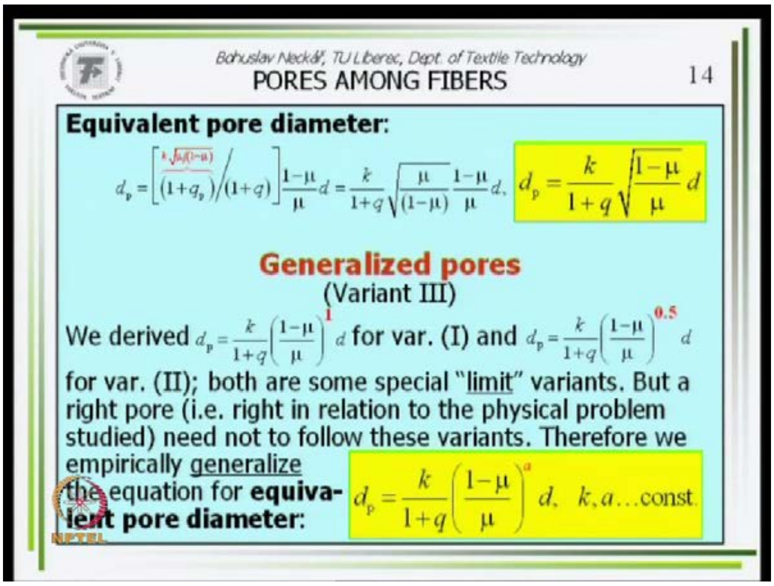

For diameter we had this general equation.This equation we can,, but, 1 plus q p is this here.

After rearranging this square root of mu by 1 minus mu and here we have 1 minus mu by mu, altogether rearranging and we obtained this here (Refer Slide Time: 33:23).This is the equation which is valid by our second version.It means if the lengths of pores are independent to packing density.We derivedtwodifferent equations especially forpore diameter.This is the important quantity based ontwoquite different assumptions.Nevertheless, both equations are little similar.Seeinversion invariant, first in first variant we obtain from d p pore diameter; this equation 1 minus mu by muIcan write power to 1;it is possible.

The second is here (Refer Slide Time:it is this power to 0.5.It is similar.It is same structure, mathematical structure.Differences are only in thevalue of exponent or 1 or 0.5.Nobody know what may be the far variant are 1 is not in our situation is ourfibrous assembly and the version 2 also is not well, butbecause this similarity may be that we canempirically generalize this knowledge and say the hypothesis that diameter, equivalent pore diameter d p is possibly obtained according to this equation, where beside the parameter k, also parameter a is used.

A is sometimes 1,sometimes 0.5 and may be sometimes another value.This kappa k and aare twoparameters.Iwill discuss these parameters, how to obtain for variant 1, 2 and 3 later.

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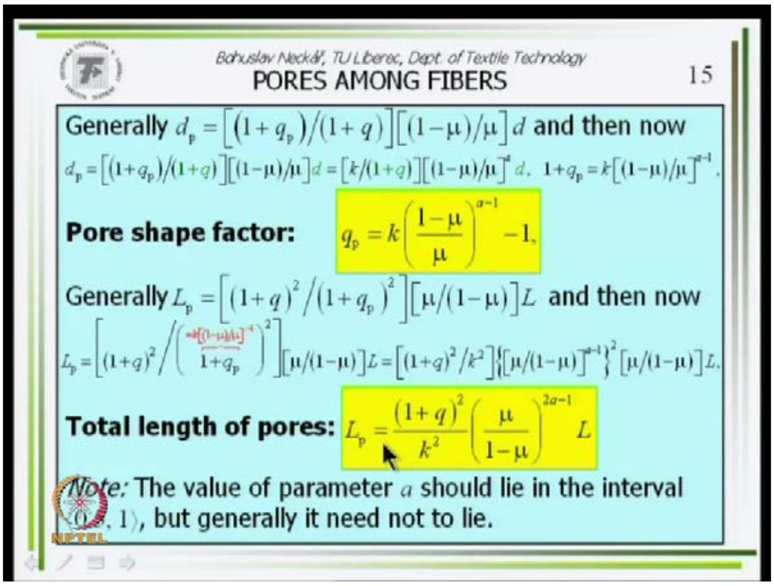

We can derive alwaysanotherquantities because d p nowgeneral d p is this here and now we use for d p.This expression we must write that this is equal to this is general equation.This is now our postulate equation and from this equivalent, we obtain 1 plus q p is this here(Refer Slide Time: 36:10 to 36:22) pore shape factor,sothat the pore shape factor is this higher here.Lengths of fiber are for total lengths of pores.General formula was this.Usingusing q p from this thisexpression, we obtain for l p this expression and after rearranging this, here it is only mathematical rearranging;nothing more; very easy.It is rearranging which you used on your high schoolbefore university.So, we haveformula for total length of pores too.

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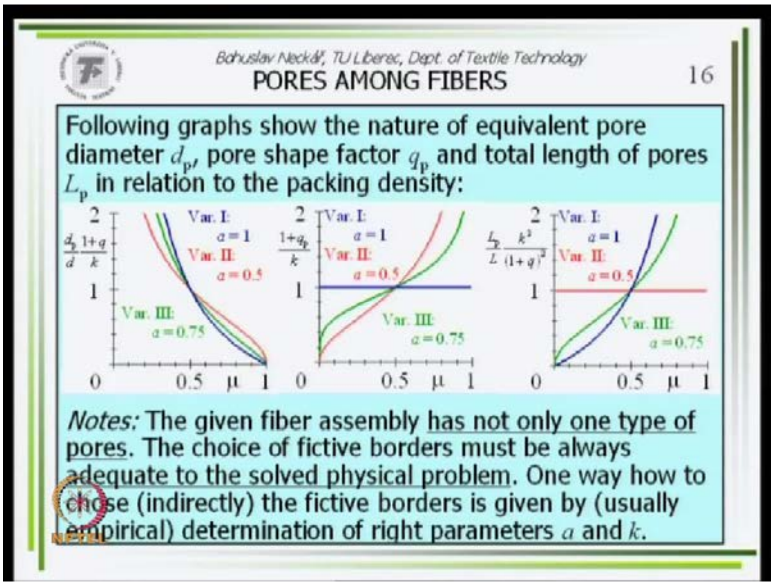

To illustrate it graphically,Ihave here 3 graphs: the firstall are on the abscissa of all is packing density,sothat it isfrom0 to 1 packing density mu; the first graph on this ordinates scale is d p by d times 1 plus q by k; 1 plus q is constant is parameter; q is fiber shape factor; k is a suitable constant for this or that situation; this, our material is constant 2;d isequivalentphi by diameter parameter value 2. So, all thisquantity is proportional to d p is proportional to pore diameter; is it not?

You can see how it is. Invariant 1 -a is equal 1.You obtained a blue curve.The version 2,the variant 2,where a is0.5,bring the red curve also decreasing curve,but a little other shape andgeneral variant 3.Iuse it;for example, a equal0.75,where it is here is the green curve.Here,0.75something in between; then you obtain this green curve; acceptable decreasing curves.

How it is withlength?No, shape factor?Here is a quantity 1 plus q p by k. So, it is a linear function of q p,shape factor of fiber pore.In the version 1,this blue we say the shape of pore is constant. So, the pore shape factor must be constant.Therefore, the blue curve is independent to packing density.Version 2 saidlengths of pores is constant;in this version, the shape factor is increasing its packing density.

The shape of pores in higher compressed material is more far from idea of rink is it not?Moresomething;so, you can imagine well.And in the version 3,using0.75on the place of a, it is also increasing function; a little other shape.Now, how it isvis the total lengths of pores?It is shown here (Refer Slide Time: 40:18).Also you can see that this quantity which is possibleto evaluate by using our equations, immediatelyis proportional to total lengths of pore L p are related to 2 fibers.You can see the version 1, lengths of pores is increasing.Its packing density in version 2 the lengths of pore is constant; it is our cigarette filter idea. So, thatred curve must be constant and by version 3,the green is a little larger shape, but also increasing function.

To this moment, we are living in the idea that we have red pencil and we create some borders, fictive borders; we create pores.is it not?In our structure, but Iam sorry,Imust your red pencil take back because weso is that we have not we havenot red pencilWe are not able to create pores.Who will to do it when we are not?It will create physical process which we studied.

For each physical process for which is relevant the influence of poredimensions, each physical profess, this process had its own definition of pores, its own red pen and redfictive borders.For example, by wicking its capillarity,this physical processon the same structure,same sametextile structure define the pores are there,so that the good dimension of pores are there. Then, for example, filtration process is other process.

This process use another other pores, other pore diameter than the wicking process for example, on the same fibrous structuretextfibrous assembly, have a not onlyonetype of pores; it is not.It will have onlyone connector of spaceamong fibers.No more. Adequate pore diameter is sometimes higher, sometimes smaller based on the process which used this pores.Can you imagine this situation? Therefore, how to calculate how to calculate our parameters k in version 3?k and a, we must calculate the suitable parameters in relation to the process which we solved.

When we solve,Ido notknow capillarityeffect.Then, we must do our equationswhichwe use for capillarity,give our general equation for pore, may be according version 3 from the 3,versions 3 is the best.And then we on the whole mathematical model we have 2 parameters which characterize good pore dimension and this must be derivedbased on the study of this capillarity effect in laboratory. Using for example,Ido not know statistical regression, y r andso on.But, it is every time. So, when our colleagues in a mechanical engineeringapply their equations for deformation ofsome metal objects, they derive lot ofsuchequations by theYoung’s modulus.They must find in laboratoryis it not?iterated to situation and to material.The same is by us.Sorry, we havenot optour pencil, our red pencil,have this or that; his own red pencil have this or that physical process.

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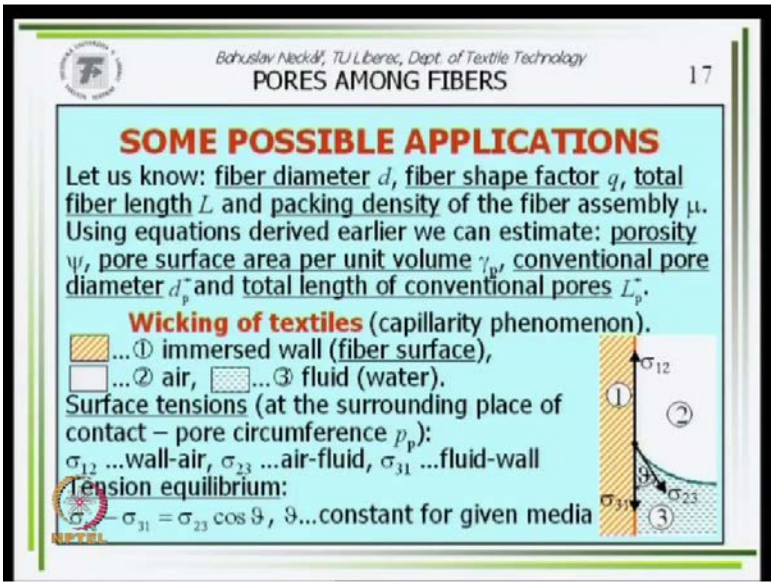

Some notes topossible applications,I want to say in a next lecture,so that in the moment,I thank you for your attention.