Introduction to Composites
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Lecture – 39
Poisson's Ratio of Unidirectional Composites

Hello, welcome to Introduction to Composites. Today is the third day of the ongoing week which is the 7th week of this course. Till, so, far we have covered the response of the material when it is subjected to longitudinal loads and transverse loads. And in that context we have discussed how to predict E L E T and in the last class we also figured out how to estimate the shear modulus of the material.

Another very important property of materials is it is Poisson's ratio and in context of unidirectional composites the same is also true to a fairly large extent. So, what we will do today is we will discuss a method how to predict the Poisson's ratio of a unidirectional laminate.

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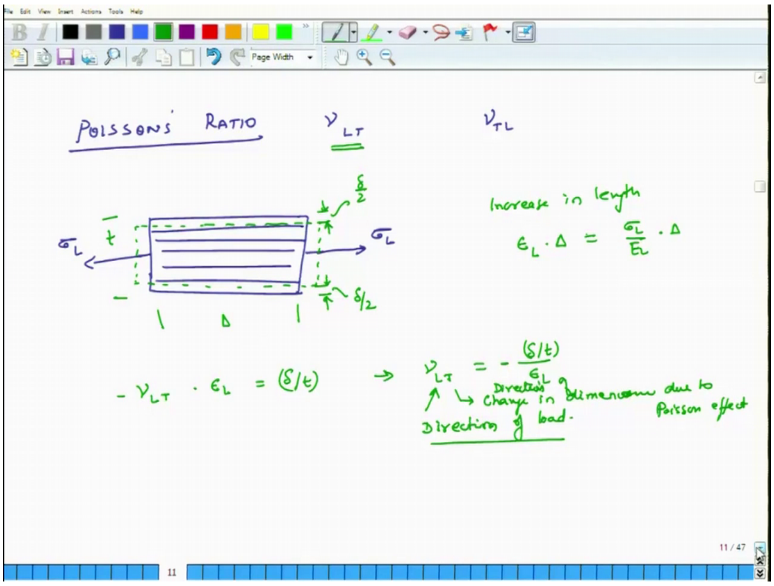

So, we designate the poisons ratio for isotropic materials we just designated by nu.

But for composites as we have explained the Poisson's ratio is directional is dependent on the direction. So, we have 2 symbols for poisons ratio 1 is nu L T and the other one is nu T L.

So, first let us understand what is the physical meaning of these 2 parameters and then we will figure out how to compute these values? So, suppose you have a composite and the fibers are running in this direction. So, that is our L direction and if I pull this composite in the L direction using with the stress in the of sigma L, then because of this longitudinal tension what will happen to the composite it will become a little longer and it will become a little thinner.

So, the increase in length I can compute. So, what is the increase in length, increase in length I can compute by epsilon L times suppose this total length is delta times delta. And epsilon L is nothing, but sigma L over E L and then this is times delta. So, this is the increase in length in the length direction, but it not only becomes longer it becomes a little thinner.

So, this is the reduction in thickness, let us call it some parameter let us call this delta by 2 and then there is also a reduction in thickness on the other side. So, this is delta by 2. So, total reduction in thickness is delta by 2 delta and this reduction in thickness is related to this nu L T. So, nu L T times epsilon L negative of that will give us delta.

So, my nu L T is equal to delta over epsilon L and the negative of that. So, this is the definition. So, what do you see here the first index is the direction of loading? And the second index is the change in dimension due to poisson effect.

Student: Dimension is the change.

Thickness.

Student: (Refer Time: 05:09).

Ok.

Student: (Refer Time: 05:10).

Yeah.

Student: (Refer Time: 05:11).

Yes yes sorry. So, one modification I would like to make is that this delta is the total change in the thickness. And suppose this overall original thickness is T then the transverse strain will be delta over t. So, this is delta over t. So, I forgot to me that distinction earlier. So, nu L T in nu L T the first index tells us the direction of load and the second index tells us the change in dimension due to Poisson effect.

The direction of change there actually it is the direction of change, direction of change in dimension due to Poisson effect. So, that is why it is called nu L T.

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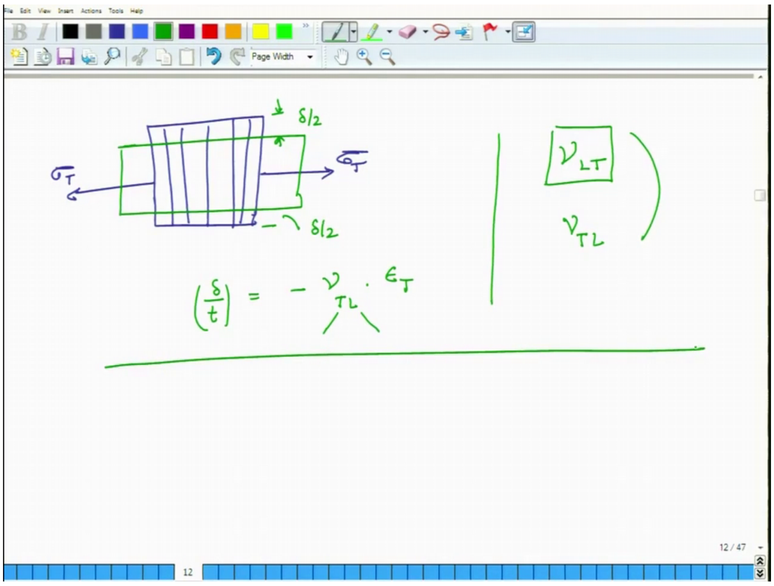

Similarly if I have a sample, like this and here the fibers are aligned in this direction and I am pulling it in the transverse direction and then as I pull it becomes longer and slimmer. So, this is again delta over 2, this is again delta over 2 in this case delta over 2 delta divided by thickness of the composite is nothing, but minus poisons ratio, but not L T, but T L times the transverse strain.

So, once again the loading is in transverse direction and the reduction of thickness is happening in the longitudinal direction. So, we have to be careful when we are discussing Poisson's ratio for there are 2 values one for L T and the other one is nu T L nu T L. So, what we will learn today is how to compute nu L T?

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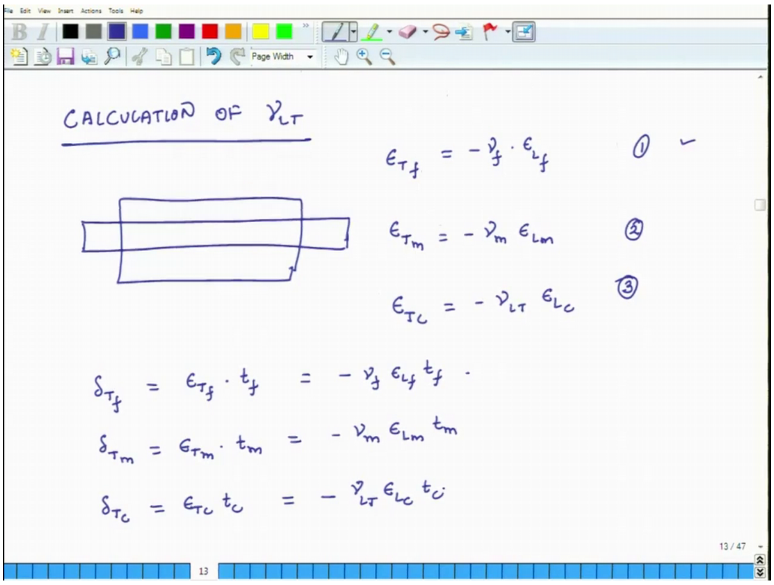

So, our focus will be calculation of nu L T.

So, we will make that picture one more time. So, you have the composite and you have and after I have pulled it becomes longer and it becomes slimmer it becomes slimmer. Now I have thinning of the composite because of 2 reasons one reason is that the matrix is going to thin down and the other reason will it why it will thin down is because the fiber will thin down. So, there will be Poisson's ratio a Poisson's strain in fiber and Poisson's strain in the matrix.

So, let us write down those relations. So, the Poisson's strain which is epsilon T in the fiber is what negative of fibers Poisson's ratio times the strain in the L direction for the fiber that is, what the strain? Strain will be for Poisson's strain will be for the fiber? Similarly epsilon T m is equal to minus nu m epsilon L m and the overall thing will be epsilon T c will be equal to minus nu L T epsilon L c where c stands for the overall composite.

So, this is 1, this is 2, this is 3 the reduction in the thickness I call it delta. So, delta T f reduction in thickness of the fiber will be what it will be nothing, but the strain in the Poisson's strain in the fiber times it is original thickness. So, it will be epsilon T f times T f and this is equal to minus nu f epsilon L f t f. So, I am using equation one in this one this relation.

Similarly, reduction in thickness of the matrix alone will be epsilon T m is equal to epsilon T m, times t m equals minus Poisson's ratio of matrix material times longitudinal strain in matrix times the overall thickness of the matrix. And finally, I can also write delta T c for the composite is equal to epsilon T c times thickness of composite and this is equal to minus Poisson's ratio of the composite. And this Poisson's ratio of composite we have designated as nu L T, times epsilon L c, times thickness of the composite.

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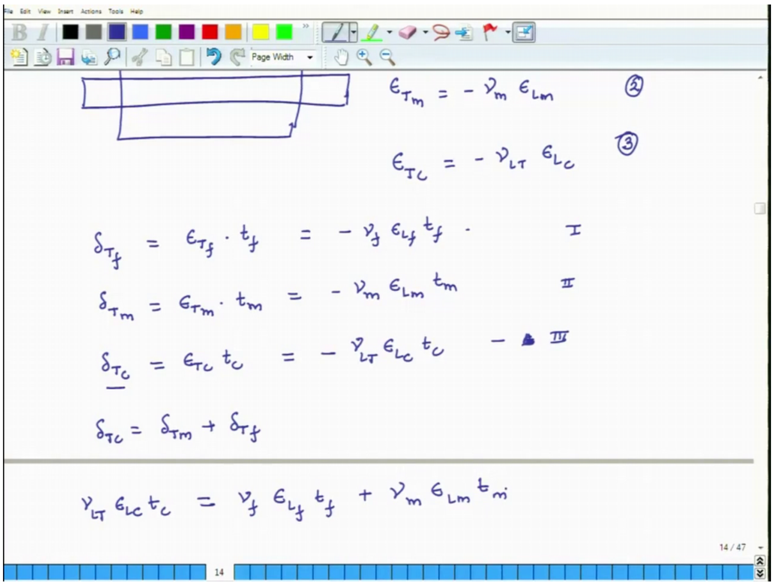

Now, this is equation 3, equation 2 equation 1. And basically the left side of equation 3 is nothing, but the sum of equation 2 and equation 1. So, I can say that delta T c equals delta T m plus delta T f and what that gives me is nu L T epsilon L c t c equals nu f epsilon L f t f plus nu m epsilon L m t m. And if I divide the entire equation by T c if I before I divide the entire equation by T c we note.

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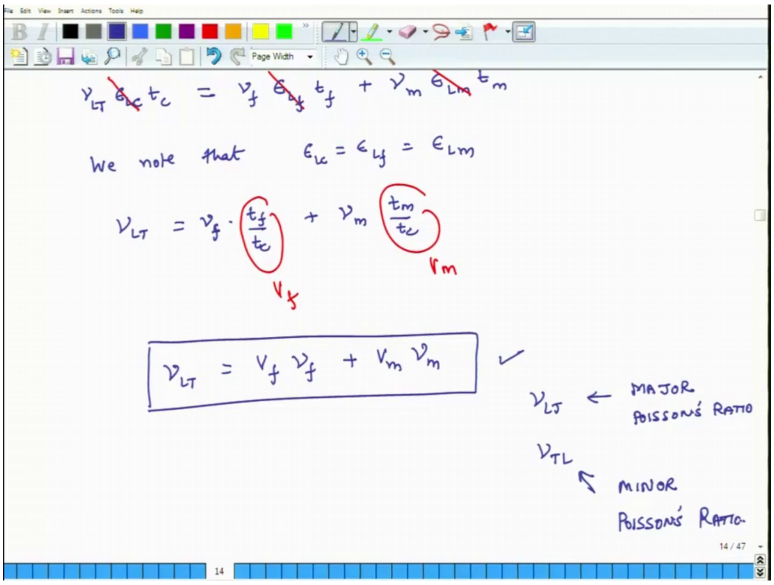

So, whenever I have a unidirectional composite when I pull it in the longitudinal direction, we had said earlier that the strain in the composite strain in fiber and strain in matrix are same.

So, we note that epsilon L c equals epsilon L f equals epsilon L m. So, because of that equality I can cancel out these terms and then I divide this entire equation by T c. So, I get nu L T equals nu f times t f by t c plus nu m times t m over t c and these terms. So, this is volume fraction of fiber this is volume fraction of matrix. So, what I end up with is nu L T equals V f nu f plus V m nu m.

So, this is how I can compute Poisson's ratio this is how I can compute Poisson's ratio in the L T direction. Now remember I had said that there are 2 Poisson's ratio associated with the unidirectional composite one is nu L T and the other one is nu T L and both of them are not same this one is known as major Poisaon ratio and this guy is known as minor Poisson's ratio.

So, what we have learned is there how to compute the major Poisson's ratio. How do we compute minor Poisson's ratio we will learn that, in probably next week we will learn how to compute minor Poisson's ratio, but today I am just going to give you directly the result of how to compute minor Poisson's ratio?

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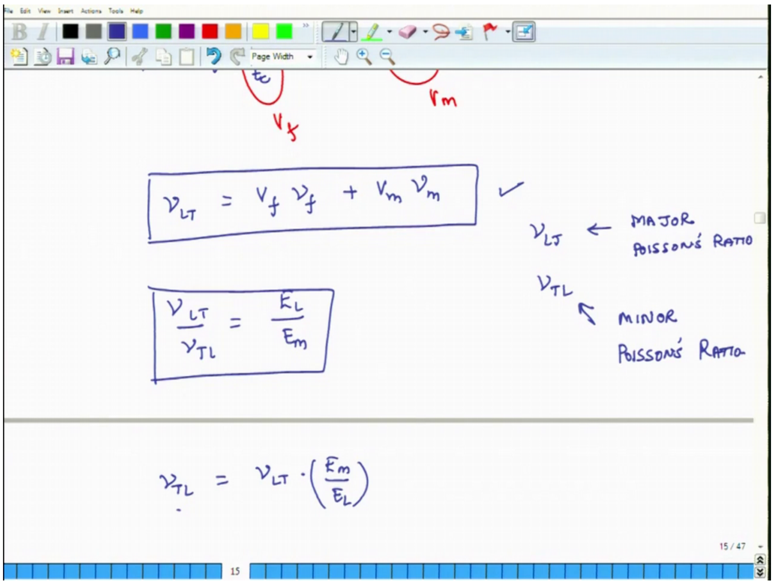

Nu L T over nu T L equals E L over E m or you can say that nu T L equals nu L T times E m over E L.

So, the point what I am trying to make is that whatever is the value of nu L T the value of nu T L is significantly lesser than nu L T, because E m over E L is very small it is less than one and that is why nu T L is known as minor Poisson's ratio. Unless you have a very strong and weird case where the matrix is much more strong and fiber is weak or matrix is stiffer than fiber.

But that is not the case with 99.99 percent of the, and composite materials and reality. So, that is why nu T L is known as minor Poisson's ratio nu L T is known as major Poisson's ratio. So, this concludes our discussion for Poisson's ratio next what we will start discussing our composite failure modes.

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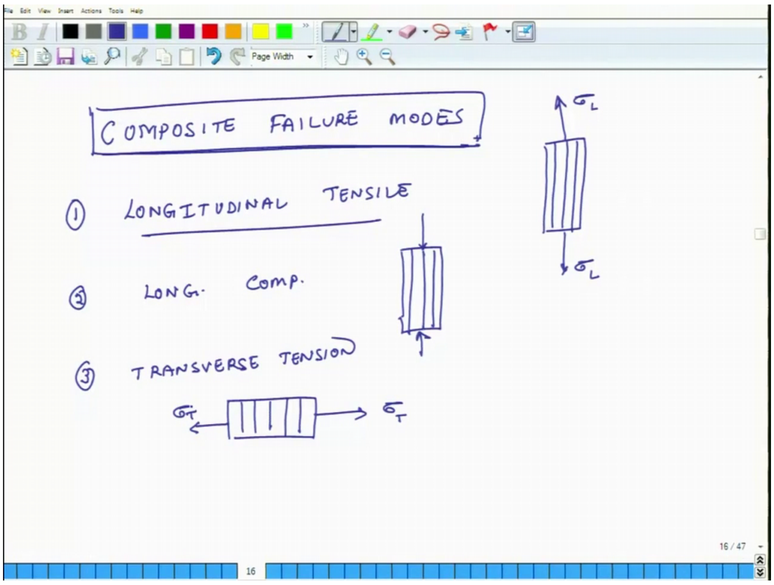

So, what will we cover in this.

So, first thing is that the discussion on composite failure modes will be primarily subjective in nature there is one thing. So, we will still touch upon some mathematics, but most of the discussion will be subjective in nature and what we will discuss is that when composites fail? What physically happens to the fiber? What happens to matrix? What happens to the junction or the interface of fiber and matrix? And we will discuss 5 different scenarios, actually 6 different scenarios.

So, we will discuss 6 different situations that what happens when composite fails. So, the first situation we will discuss is failure when it the load is longitudinal tensile, this is the first situation we will discuss and in this the composite can fail in different ways we will discuss those ways. So, what is happening in this case, which is you have a composite fibers are in aligned in the length direction and you are pulling the composite in tension.

So, this is sigma L sigma L. So, this is one scenario we will discuss the second one is longitudinal compression longitudinal compression, here the loading will be something like this. So, these are my fibers and I am pressing on to the composite rather than pulling it and again we will discuss, when composite filled what physically happens?

The third one is transverse tensile transverse tension. So, in this case our fibers are in this direction and I am pulling in the transverse direction. So, this is sigma T sigma T transverse tension.

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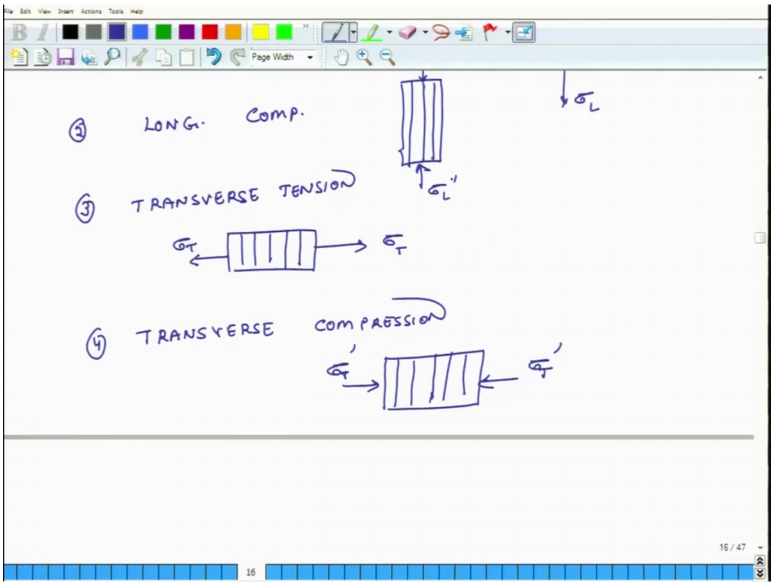

The fourth scenario is transverse compression because in each of these 6 different scenarios different physical phenomena actually happens during the failure process so transverse compression.

So, what happens here? I have transversely aligned unidirectional composite and I am subjecting it to compressive stresses sigma T and it is compressive. So, if there is a prime here. So, this is sigma L prime and then the next 2 cases are for shear.

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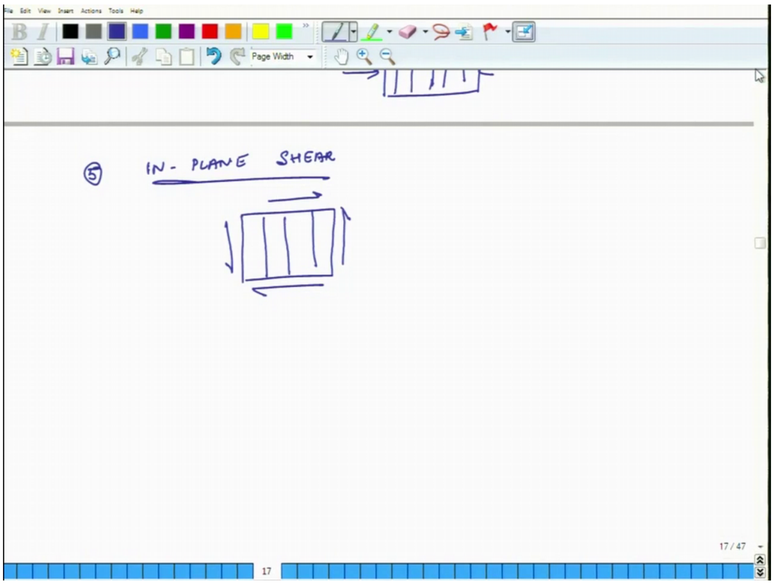

And then we have in plane shear. So, what does that mean I have fibers let us say they are aligned like this and I am applying shear forces like this? So, these are the 5 scenarios there is a sixth scenario if we have time we will cover that also, but these are the 5 important scenarios. We will discuss the discussion is going to be subjective in nature. And the point is that as you get deeper into composite should be aware that if you are subjecting your structure to let us say a tensile load in the longitudinal direction, what is it that you should expect, when failure happens and how do you design your systems that those kind of things, which you do not like do not happen?

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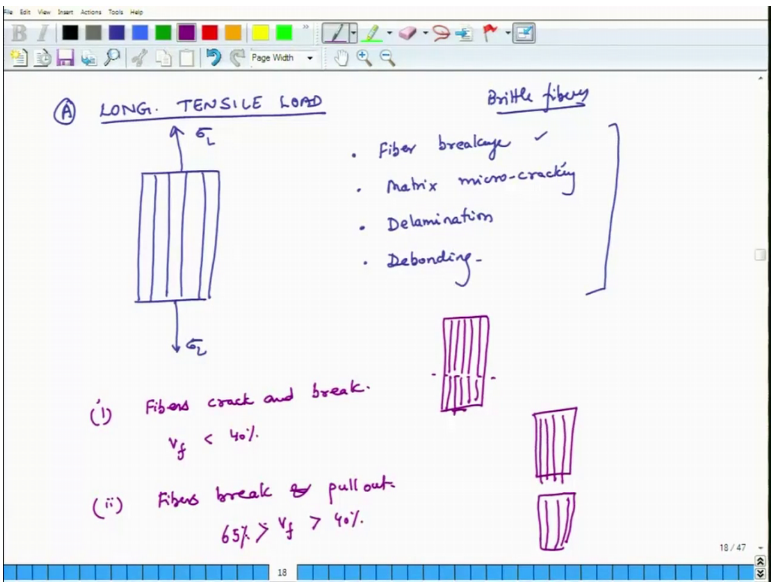

So, the first scenario is longitudinal tensile load longitudinal tensile load. So, this is my external load sigma L excuse me and the fibers are aligned in the direction of the external load. Now when failure happens several phenomena could occur either in sequence or at the same time what are the different phenomena, which could happen one is the fibers could break fiber breakage and this is assuming that fibers are brittle. So, here we are discussion is limited to the situation that we assume that fibers are brittle.

We are not considering ductile fibers. So, because lot of our fibers graphite glass they are brittle fibers. So, one phenomena which can happen is fiber breakage other one is matrix cracking matrix micro cracking. Another phenomena which can happen is delamination what is delamination one layer could separate from the other layer the entire layer could separate and a similar, but different phenomena is de-bonding.

So, in de-bonding the fibers are sticking to the matrix and they separate out the entire layer may not get separated, but debonding individual fibers may separate from the system. There are different modes of failure in some mode you may have fiber breakage only in another mode you may have fiber micro cracking and delamination and so on and so forth, but when you look at this there are 3 or 4 important modes of failure.

So, in this case so let us look at the first mode. So, what is it happening here fibers crack and break? So, this is a simple mode of failure. So, in this case so you have basically 2 parts of the composite and it is a clean break and fibers just crack they break and once they break all of the load on the fibers gets transferred to matrix and at the same points fibers are the matrix also cracks. So, you have 2 pieces and that is pretty much it.

Now, this type of failure happens typically when volume fraction especially for glass fiber systems for other fiber systems this number may differ if volume fraction for glass fibers is less than 40 percent volume fraction is. Now as you increase the volume fraction of fibers there is a chance that some fibers may not be perfectly bonded to the matrix.

So, in that case the type of failure happens is a little bit different. So, what happens there fibers break and pull out? So, when you have 2 pieces of the thing after breakage you may find that some fibers are popping out of the surface like this and on the other side you may have fibers something like this. So, this happens typically when V f is more than 40 percent and less than 65 percent.

Now, in this case this happens because the vetting between the fiber and the matrix may not be really great. So, when it breaks these fibers also will get pulled out.

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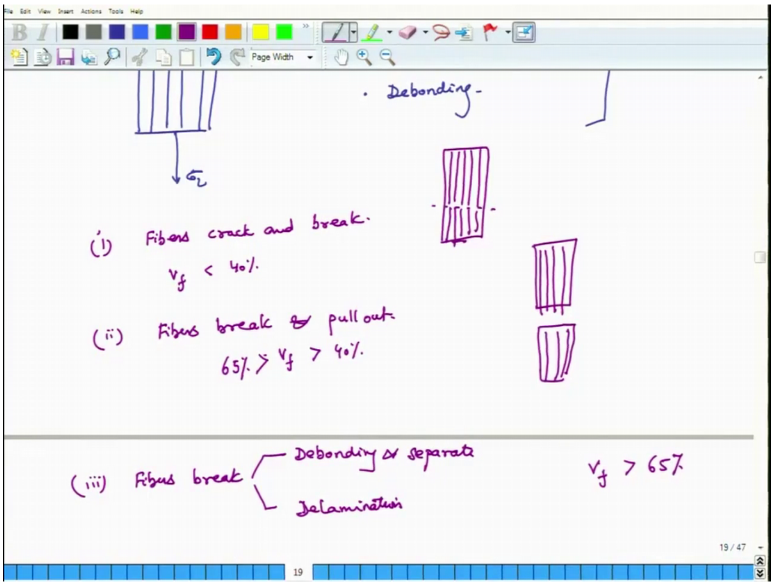

And the third situation happens when fibers break and these are all brittle fibers and then either you have debonding and separate or delamination. So, this is the case when V f is really high more than 65 percent, then it is very likely that the wetting of the fiber may not be adequate when the thing is being cured.

So, there may be lot of dry patches where the bond between fiber and matrix is not that great. And once fiber breaks not only it breaks it also gets totally separated from the matrix material or the entire layer gets separated from the matrix material. So, this is the 3.

So, these are 3 modes of failure when you subject unidirectional composite to tension in the longitudinal direction. Tomorrow we will continue this discussion with other types of loading situations, like longitudinal compression, transverse loading in longitudinal in compression in tension and so on and so forth.

So, once again we will meet tomorrow until then have a great day bye.