Advanced Composites
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Lecture - 06
Strength of Single Layer Continuous Fibre Composites Part-II

Hello, welcome to Advanced Composites. Today is the concluding day of the first week of this course, over the last several days we have received quite a good amount of feedback from all of you. And one question or one point which I did not address in previous lectures was; if there are some texts which you may be referring to, or which mean you may want to refer to while trying to learn whatever is being covered in this course.

So, I will suggest 3 or 4 different books in the context of this course. The 2 books which you will find really useful at least in context of this advanced level course I am going to list them.

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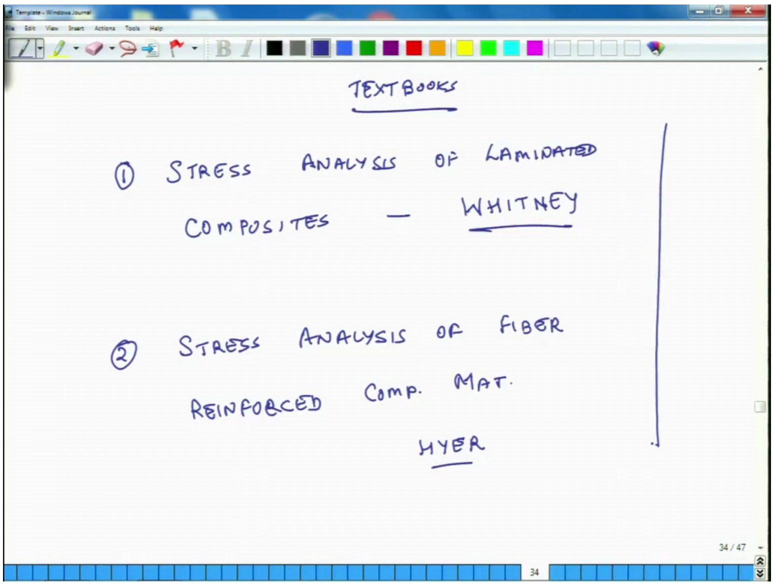

So, the first one is Stress Analysis of Laminated Composites. So, these are textbooks, and the author is Whitney. The other textbook which you may find very useful is the Stress Analysis of Fibre Reinforced Composite Materials and the author of this is HYER.

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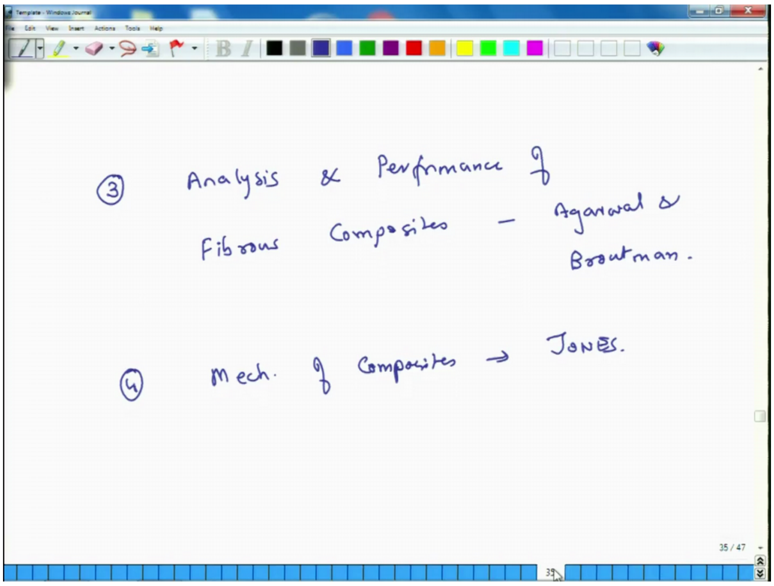

And of course, you should also refer to these books, but some of the advanced stuff may not be in these books. So, the one is Analysis and Performance of Fibrous Composites and this is by Agarwal and Broutman. And the last text is Mechanics of Composite Materials and this is by Jones, but the first 2 books you will find particularly useful because they provide some more de tailed discussion of governing differential equations and their solution mechanisms.

Coming back to what we have been discussing yesterday we just finished discussion on prediction of transverse modulus for composite material. One the next logical thing would be at what stress levels do these composite materials break when they are loaded transversely in the tensile direction. So, we are going to talk about transverse strength.

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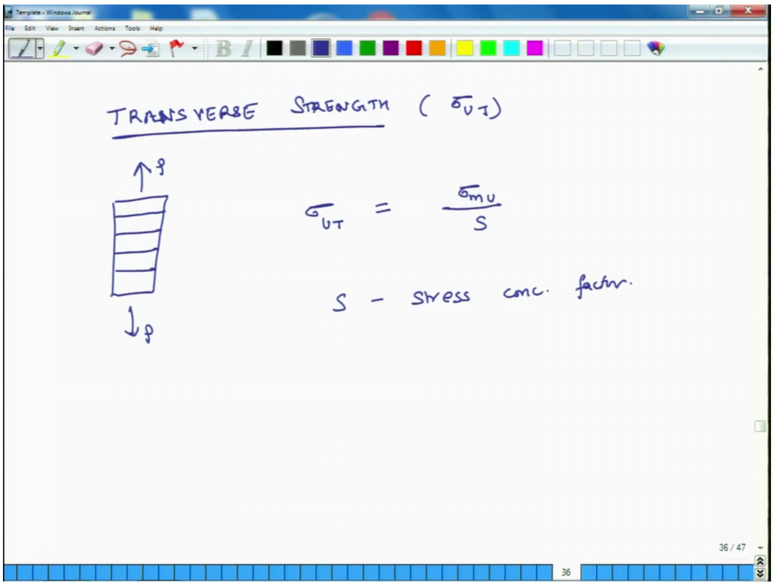

Transverse strength so, what does that mean? And we call that sigma ultimate transverse load in the tensile direction sigma E T. So, you have a sample, fibres are running in this direction. If I pull it in the transverse direction then at what is stress level, this thing is going to break. And it turns out that this value sigma U transverse is dominated by the strength of the matrix material.

Because it is the matrix which resists the breaking of the composite the fibres do not play a positive role. Actually they create a negative role because they act as stress concentrators and as a consequence; the material does not fail at this value sigma m U which is the ultimate tensile strength of matrix, but at a lesser value. So, I am going to divide it by number called S, where S is the; you know stress concentration factor. And you refer to the introductory course you will find relations for this factor or also this value is mentioned in the book from Agarwal and probably also in the book from Jones.

So, the point is that in the transverse direction, a unidirectional composite it is strength is determined primarily by that of the matrix material, but it is less than the strength of matrix material because fibres tend to provide stress concentrations and as a consequence the overall material fails at a lesser value then it would have failed if it was purely matrix. So, having said that we move on we will talk about some other properties, but before we do that we will discuss as a diversion, something more about transversely isotropic materials.

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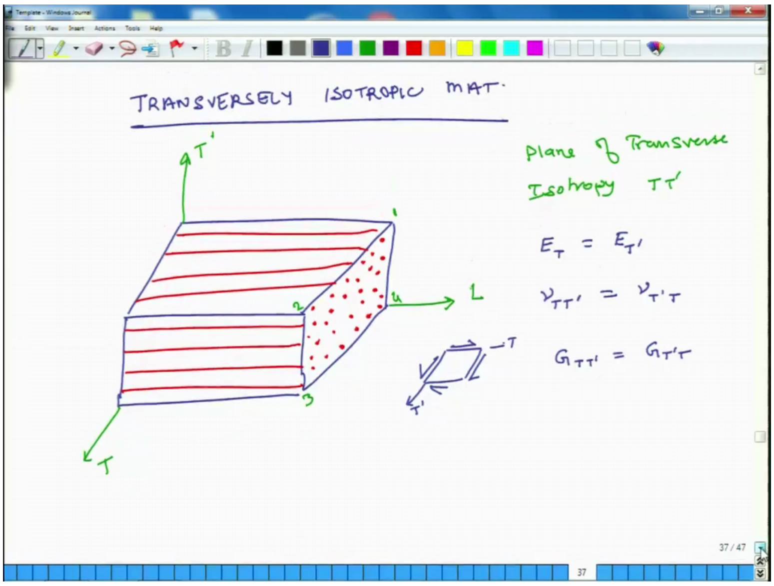

So now that we have become somewhat familiar with this terminology E L, E T and all that; it is probably the right time to talk about what kind of properties transversely isotropic materials have and to understand that let us make a simple diagram. So, the same diagram which we had made earlier. So, here we have a block of material, fibres are running in one direction only and all these fibres have circular cross sections because we are discussing otherwise the material will not be transversely isotropic ok.

So, what are the material axis? This is my L axis, this is the transverse axis and this is the other transverse axis. So, what is the plane of transverse isotropy? Plane of transverse isotropy, it exists in T T plane specifically it exists in this plane 1 2 3 4 right, because if I pull or test this material in this plane then it is properties will come out as isotropic. And if that is the case then we write some mathematical relations based on this understanding that this is transversely isotropic. So, if it is transversely isotropic then E T is equal to E T prime ok.

The other thing is its Poisson's ratio mu T T prime, what does that mean? That if I pull the sample in T direction; it will experience Poisson contraction in T prime direction that number is mu T T prime. So, that will be same as mu T prime T ok. In the other this case mu T prime T, I am pulling the sample in T prime direction and the Poisson contraction is happening in T direction. Then G T T prime which is the shear modulus. So, G T T prime so this is T direction, this is T prime direction. So, I am applying like this so this is same as G T prime T.

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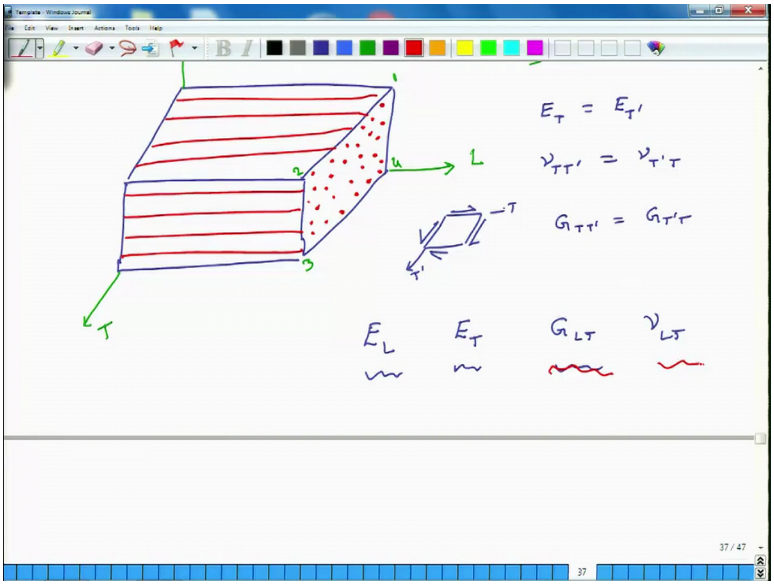

So, these are some of the things related to transverse isotropy. And it turns out that mathematically and we may see some of this mathematics later in the course, mathematically transversely isotropic materials have 4 fundamental elastic properties. So, those are E L and we already know how to compute E L. The second elastic property is E T and we already know how to compute E T because using the Halpin-Tsai relation and this E T is same as E T prime the third independent elastic property is G L T so we will learn how to compute this.

And the 4th one is mu L T, which is the Poisson's ratio, and we will explain what does mu L T mean and we will also learn how to compute these. So, what we have learned till so far is how to compute E L and how to compute E T. So, the next 2 relations which we will discuss are the relations for the Poisson's ratio and the Shear modulus; the Shear modulus and the Poisson's ratio.

So, let us just look at the relation for Shear modulus G L T.

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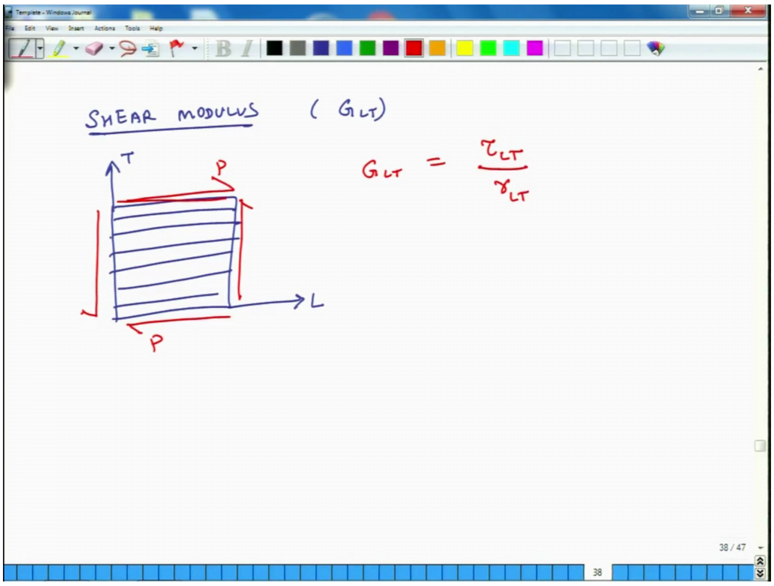

So, if I have a sample and let us say my fibres are running like this; this is my L direction, this is my T direction. So, shear is being applied in the L T plane so this is my L T plane and I am applying shear force like this.

And because I am applying shear force in the L T plane I call n f and the thing will experience a shear strain, then G L T is what is the ratio of shear stress tau L T. So, this is let us say this force is P. Then if I divide P by the cross sectional area then that will give me shear stress and if I measure the shear strain gamma L T, then their ratio will be G L T this is the physical meaning of G L T

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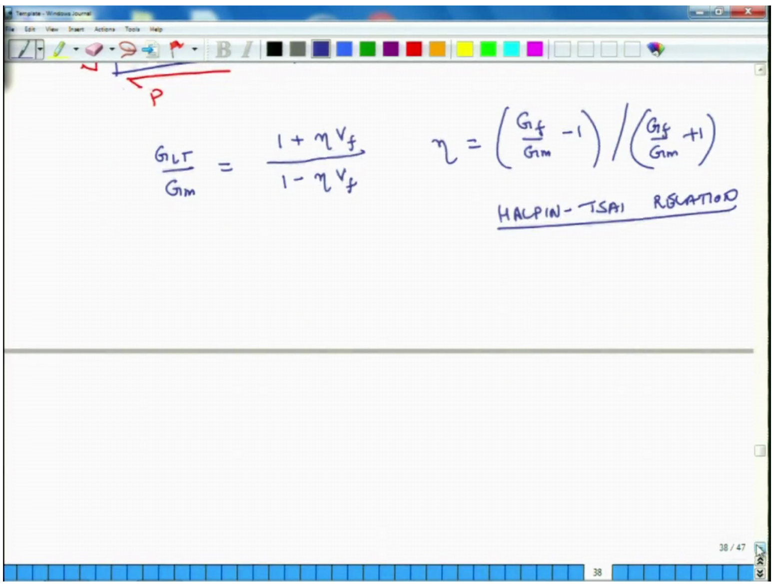

So, in this case so G L T divided by G m equals 1 plus eta times volume fraction divided by 1 minus eta times volume fraction, where eta equals G f over G m minus 1, where G f and G m are shear module of fibre and matrix divided by G f over G m plus 1. So, this is the Halpin-Tsai relation for G L T.

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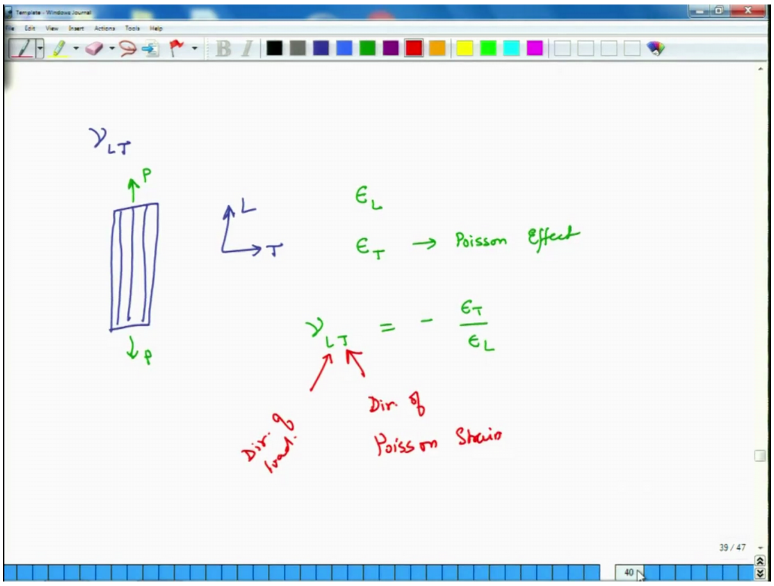

The next parameter we will discuss is Poisson's ratio mu L T. So, first let us understand what this parameter means. So, what this means is that if I have a sample of unidirectional fibrous composite, fibres are running let us say in the L direction so this is my L direction, this is my transverse direction. And I apply a force here P and as a consequence of this force it will experience a longitudinal strain. And so, it will become a little longer and it will also contract in this direction. So, it will also exhibit.

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Strain in P direction, but that will be compressive right. So, this is because of Poisson effect; then Poisson's ratio L T is equal to negative of transverse strain divided by longitudinal strain so, that is the physical meaning. So, what does this mean? That L is the direction of load and this T the second subscript is the direction of Poisson strain ok, this is the direction of Poisson strain.

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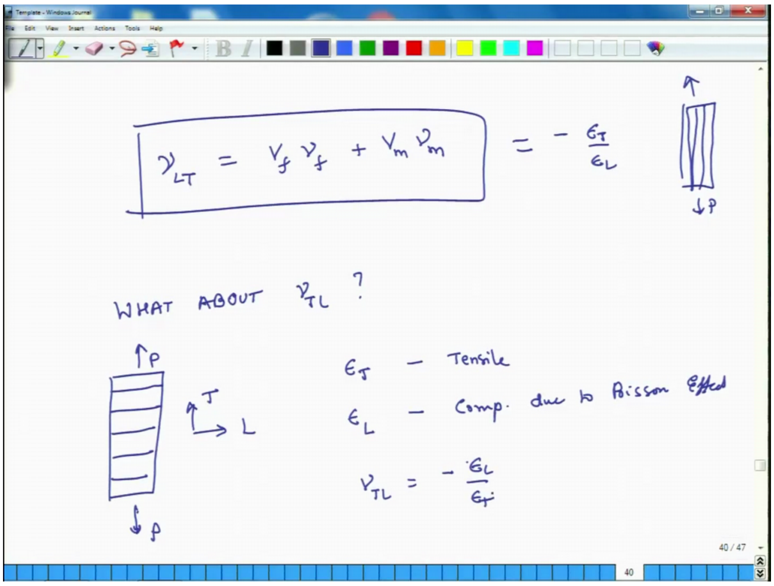

And the mathematical expression if we want to compute is Poisson ratio nu L T is equal to volume fraction of fibre times Poisson's ratio of fibre plus volume fraction of matrix times Poisson's ratio of matrix material. So, it is a pretty straightforward formula, and physically what it means is we have already decided shown that this is equal to minus epsilon T divided by epsilon L for the situation, where force is being applied in the L direction.

Now, you may wonder what about nu T L. So, physically what does that mean; what it means is that suppose you have a sample and fibres are in the transverse direction. So, this is the longitudinal direction, this is my transverse direction and I am applying a load in transverse direction because the first subscript is T, which means the load is being applied in transverse direction.

Then because of this the primary strain will be epsilon T and it will be Tensile. And the secondary strain will be epsilon L it will be compressive and it will be due to Poisson effect. And the nu T L is equal to minus epsilon L by epsilon T and how do you compute it.

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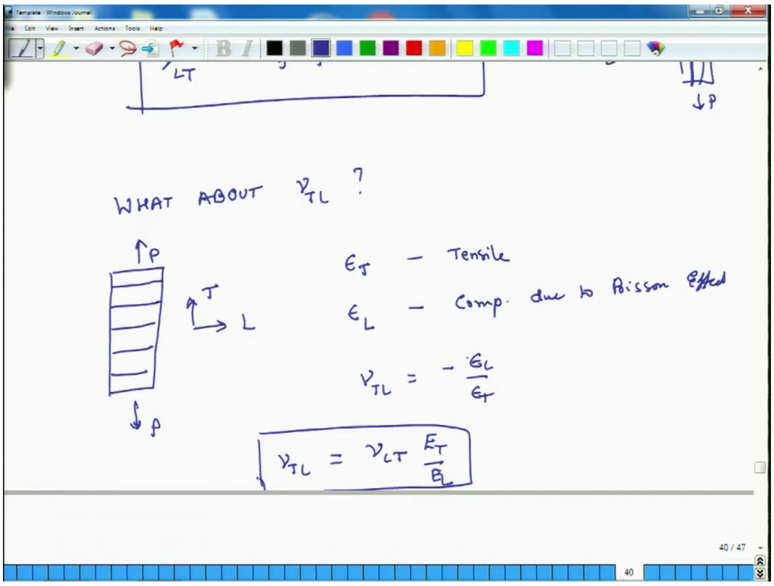

So, nu T L is equal to and this can be shown mathematically; that this is equal to nu T L is equal to nu L T times E T divided by E L; E T over E L.

So, what we have discussed till so far are several different elastic properties. We have learned how to calculate E L, how to calculate E T, mu T L, mu L T, G L T. And last couple of minutes I will spend talking about different strengths of unidirectional composite materials. So, at a fundamental level there are 5 independent strengths of composite unidirectional composites.

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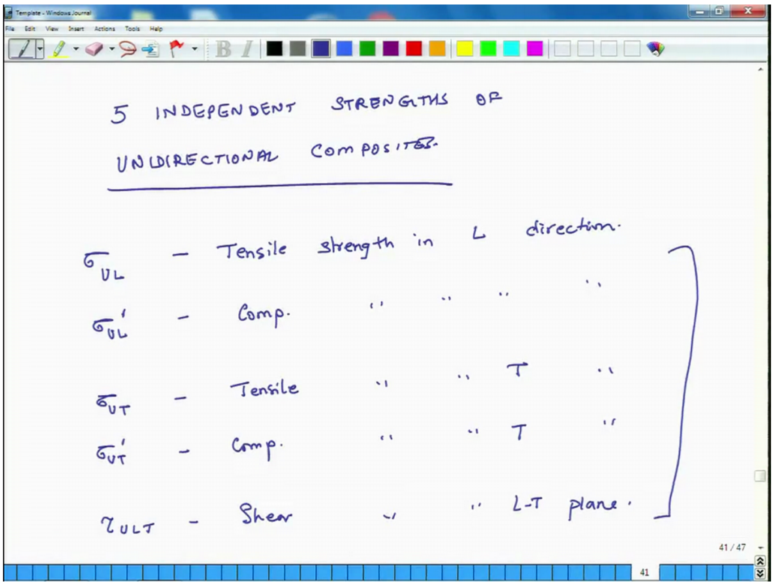

So 5 independent strengths of unidirectional composites what are those.

So, first one is sigma U L, it is ultimate tensile strength, it is tensile strength in L direction. Then there is another strength sigma U L prime and this is compressive strength in L direction. Then similarly we have 2 strengths in transverse direction. So, sigma U T it is Tensile strength in T direction then similarly, we have sigma U T prime. So, this is the nomenclature we will use so we should be familiar with so that is compressive strength in L direction and the last one is tau L T.

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I am sorry, so this should be T direction. And the last one is sigma U L T excuse me it is actually shear. So, tau so this is shear strength in and here we do not talk about direction, but we say in the L T plane. So, we know these 5 strengths of unidirectional fibrous composites, then we can we are well equipped to predict their failure when they are subjected to external stresses or strains.

So, that is what I wanted to discuss, in today's class and this also concludes pretty much most of the stuff which I wanted to cover related to properties elastic properties of composite materials. Next week we will move in a similar direction, but we will quickly graduate to prediction of stresses and strains in generally, orthotropic material that is when the stresses external stresses and strains and external loads are not necessarily aligned to the material axis of unidirectional fibrous composites. Thank you and I look forward to seeing you on day after tomorrow that is on Monday.

Thank you, bye.