Introduction to Composites

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Lecture – 25
Terminologies and Basic Concepts

Hello, welcome to Introduction to Composites. This is the start of the fifth week of this course and what we plan to discuss over this week is essentially behavior of unidirectional continuous fiber composites.

So, we will discuss how to model these types of composites, how to predict their densities their moduly in different directions the Poisson's ratio their strengths and overall mechanical behavior of these types of composites. But before we start actually doing this we have to become familiar and comfortable with certain specific terminologies. So, we will start with understanding some basic terminologies because these terminologies will be used again and again over the entire duration of this course.

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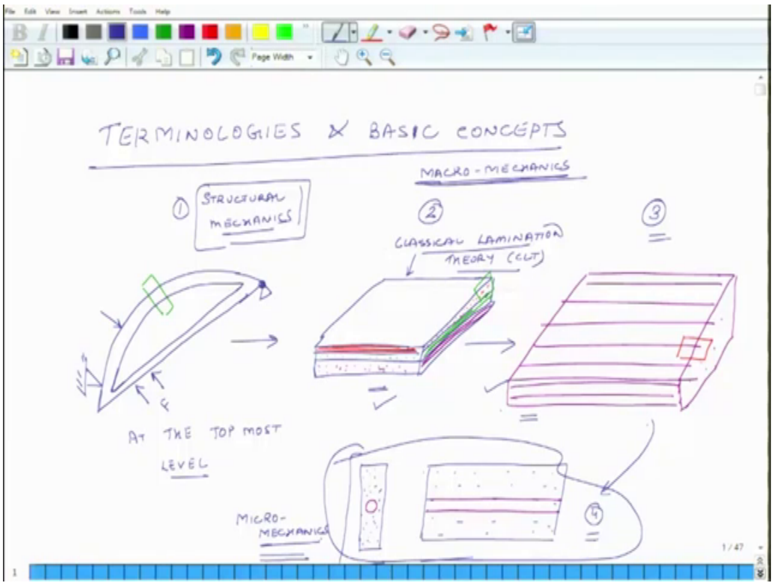

So, that is what we plan to do. So, what we are going to discuss is terminologies and basic concepts basic concepts. So, we have explained earlier that composites are essentially materials which are mixtures of two or more different materials and these mixtures exist at a macroscopic level not at a microscopic level and eventual fallout of these types of mixtures is that, the material properties of the overall composites material are significantly different than those of the individual constituents.

So, if you look at a composite material carefully you will see several layers of the structures for instance at a macroscopic level you may have a composite let us say composite wing. So, it may look something like this. So, this may be a composite structure. So, this is at a super macroscopic level. So, at the top most level and then if you look at this material a little more closely you will say. So, what you do is you take this small piece and you look at it more carefully you will see that the material is composed of or it may be composed of several layers. So, it may, this small piece may look something like this and this may be made up of several layers.

So, for purposes of simplicity we are just putting 3 layers and it could be that the fibers in the top level may be oriented like this. So, when you look at from the side you may see the end of these fibers, may be the fibers in the middle layer if you look at this side you only see the ends and may be you see the entire fiber along this length and this could be the third layer. So, here may be the fibers again you only see the ends and they look continuous from the end from this side. So, this is the top most view this is a little detailed view of a small cross section of the material and then if you take a small piece of this material just one layer a small piece of this material then what you will see is you will have just a single layer and it may have several fibers.

So, we are just looking at and here you see the cross section. And then if you look at this even more closely and you are just taking one single fiber, so this is view number 3 and then here. So, you go from top most view to somewhat detailed to more detailed view and then if you look at a smaller piece of this puzzle what you will see is. So, here I am going to plot two different views. So, you will see a c F matrix and imbedded in this c may be just a single fiber. So, we are looking at just a single fiber and from the end side, if we take end view of this it will look something like this. So, this is view number 4.

So, the way we do analysis of this structure which is at the top most level at the top most level. So, this is level four which is the finest possible level. So, the way we, our what is our end goal our end goal is to understand the mechanics of the top most level we want to know that if I put a force on this and if I constrain it at this location I con may be I put some force here and I constrain it at this location what happens to the overall structure that is what I am interested in; what is the mechanics of this overall structure at the top most level that is our goal. But to understand the overall response of this system we have to understand the mechanical behavior at several levels. So, we have to understand the mechanical behavior at level 2 and we have to understand the mechanical behavior at level 3 and level 4. So, unless we understand the mechanical behavior at 4 3 and 2 we cannot understand how the overall structure behaves because it is not one homogeneous material it is made up of several layers and each layer there is a mixtures of fibers and matrices.

Understanding the mechanical behavior at this level at level 4 is known, is done through a body of knowledge which is known as micromechanics, micromechanics. So, this is how we understand through this body of knowledge known as micromechanics. And understanding the behavior, what we do is we understand, that what happens if you place a single fiber in the c F matrix and you pull this thing, basically and then the same approach is used to understand level 3 and then once we have a good understanding at level 3 and level 2, level 4 and level 3 then using that knowledge we develop another theory to understand the behavior when several such layers are staged up together, several such layers are staged up together. So, that is known as classical lamination theory, CLT, classical lamination theory.

And this comes from a body of knowledge known as macromechanics, macromechanics. And once we have this understanding classical lamination theory basically the theory tells us how rectangular plates of a structure behave when they are subjected to external forces and constrains. And then once we have knowledge of this classical lamination theory then using the method of structural mechanics we can understand the overall behavior of the structure. So, we have to have knowledge of micromechanics, we have to have understanding of classical mechanics, we have to integrate all this in and incorporate into structural mechanics equations and then only we can understand the behavior of a composite structure. So, it is a cleared structure.

So, the point what I am trying to make is there are scales of analysis to, so at the bottom most level you have to do micromechanics to understand a single layer and multiple layers you have to understand macromechanics and at multiple layers specifically you have to get a feel of classical lamination theory and then at the top most level you have to have a structural mechanics approach to solve the overall problem. So, this is one basic framework.

So, in this course what we will learn is how to do this and how to do this. We will directly use some results from micromechanics because that can become one separate course, but we will use some results of micromechanics integrated with macromechanics results to develop an understanding of classical lamination theory. So, that is the overall goal at which we will seek to meet by the end of this course. Once you have a understanding of classical lamination theory then may be in advanced composite courses you can use that theory integrated with laws of structural mechanics and you will be capable to understand the behavior of composites three dimensional composite structures at the top most level.

So, this is one frame work I wanted to explain and then let us look at some of the important terms. So, the first term we are going to talk about is homogeneous material.

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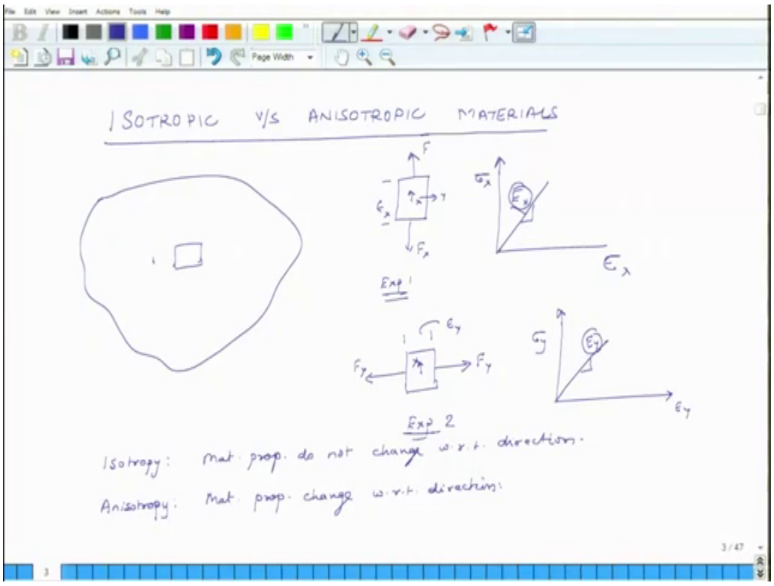

Now, we have discussed this earlier, but for the sake of completeness we will again retreat it, so homogeneous material. So, what is a homogeneous material? So, suppose you have a chunk of material and you want to find the properties of this material. So, what you do? You can take different samples of the material. So, you can say take sample number 1, sample number 2, sample number 3, sample number 4 and suppose you want to find the Young's modulus of this material. So, what do you do? You take sample one number one you pull it in tension meant do generate a stress strain diagram and find the Young's modulus and the same thing you do for sample number 2, sample number 3, sample number 4.

If the material, so the point is that these samples are coming from different regions of the material. If the material is homogeneous then all the properties of the material based on sample 1, sample 2, sample 3, sample 4 and so on and so forth they will be the same. So, that is the material which is known as homogeneous. If the material is inhomogeneous then material properties change with respect to position in the material. So, this is inhomogeneous. So, this is about homogeneity.

Next term we will look at isotropy, isotropic versus anisotropic materials, isotropic versus anisotropic materials. So, once again we consider some material and we want to figure out whether it is isotropic or anisotropic. So, how do we find out? What we do is you take a sample from a location, let us say sample number 1 and let us say you want to find out its Young's modulus. So, this is the sample. In the first case you apply. So, let us say this is my x direction and this is my y direction. So, you do two several experiments you do experiment 1 and in this case you apply F x that is force you pull it in the x direction and you measure the strain in x direction and you plot strain, in x direction versus stress in x direction and if the material is linear then the graph will look something like this. So, then the slope will be E and because this slope is being computed based on x sigma x and epsilon x let us call it E x.

In another experiment you take the same material, but instead of pulling it in x direction you pull it in y direction and when you pull it in y direction it till elongate in y direction and it will develop a strain in y direction let us call it epsilon y and once again you make a plot epsilon y versus sigma y and you will get another slope. And this is Young's modulus in the y direction. And then you can do it for different directions, you can do it for z direction and other, so this is your second experiment.

If the material is isotropic then these properties E x, E y the material properties with not change with respect to the axis of the orientation of the experiment they will not change. So, the material properties, for isotropy material properties do not change with respect to direction. So, material can be homogeneous but anisotropic, a material could be homogeneous and isotropic, a material could be non homogeneous or inhomogeneous and isotropic or a material could be inhomogeneous as well as anisotropic.

So, material properties do not change with direction, if the material is anisotropic then material properties change with respect to direction with respect to direction. So, you think about a composite material.

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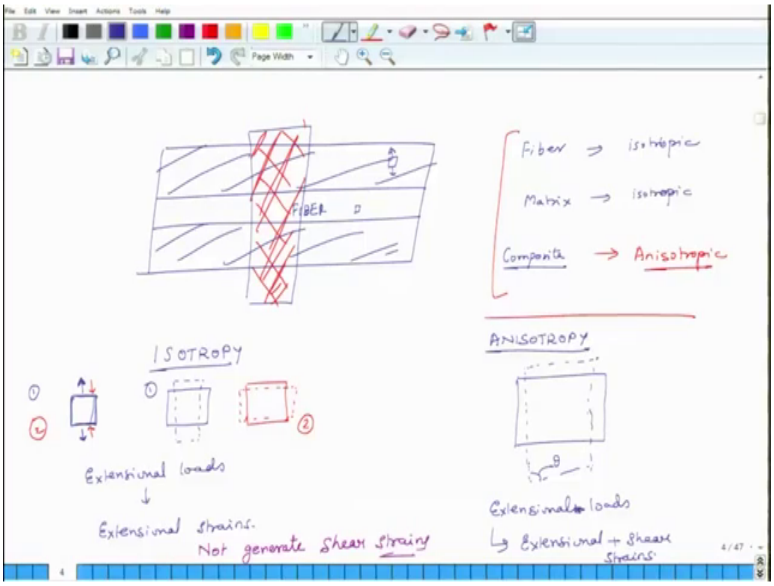

And just let us look at one single fiber imbedded in a matrix. So, this is fiber, and let us say this is matrix. The fiber, let us consider that it is a regular glass fiber then it may be isotropic the matrix because if you take small pieces of fiber and you pull them in different direction you may get same properties you may get same properties. The matrix again you pull it in this direction or in the other direction you will get you may get same things. So, matrix may also be isotropic.

Now, they may be specific matrices which may not be isotropic or fibers, but here let us consider that fiber is isotropic and the matrix is isotropic, but the composite, so if you have to test the whole composite what do you have to do you have to take a sample which has both the fiber as well as the composite. So, you have to take this entire thing. And the composite may be anisotropic, composite may be anisotropic. So, individual constituents could be isotropic, but the composite would be isotropic because you are now testing not at a micro level.

But at a macro level, if you test the material at a macro level the material you will find is anisotropic. The same material if you test it at micro level you will find that the material is isotropic because when you test it at micro level you will either have fiber or you will have matrix and both these materials may be if they are isotropic then you will get results on isotropy.

So, a lot of times when people do micromechanics they handle only isotropic materials because at microscopic level you model the fiber individually and matrix separately, so because matrix may be isotropic and fiber may be isotropic you do not worry about an isotropy. But when you assume that when you do the analysis of the composite as a whole and you want to assign it some average properties which reflect the role of fiber as well as the composite then those averaged out or smeared properties they have to be different in different directions. So, what we will learn in this class is how to figure out those anisotropic properties of at a single layer level and also at a multilayer level. So, this is anisotropy.

Now, let us discuss this isotropy and anisotropy a little bit further. So, one property of anisotropy, anisotropy we will discuss in somewhat detail. So, consider isotropic material let us consider a piece of steel and let us do some experiment on it. So, first what we do is that we take a rectangular slab of isotropic material and we pull it, we pull it. So, when I am pulling it this rectangular slab of material experiences a tensile stress. So, I can either pull it or I can compress it. So, case 1, is I am pulling it, case 2 is I am compressing it, in case 2 I am compressing it. So, 1 corresponds to blue and 2 corresponds to compression. So, when I am pulling it what will happen to this piece of steel? It will become longer. So, how will it look like?

So, let us say this is the original shape and it will become a little longer and it will also become a little narrower after pulling. And in case of if I compress it. So, this is the original shape, and what happens? It becomes a little shorter and also a little fatter. So, this is again case 2 and the first one is case 1.

So, what I see is that if I pull it tensile if I apply tensile load, tensile stress I only see tensile strain. If I compress it I only see compressive strain in the length direction, I do see either tensile or, so a tensile load or a tensile stress or a compressive load or a compressive stress is known as an extensional load. So, what this means is that if I am applying extensional loads they only cause extensional strains. So, these strains will be either tensile or compressive, they will not cause, they will not cause extensional loads will not generate shear strains, they will not generate shear strains. So, in isotropic materials if you pull it, it will still remain a rectangle it will become a little longer and little thinner if you push if you compress it, it will become a little fatter and a little longer in the other fat little longer and a little shorter, but it will not generate a shear strain.

In anisotropic cases this is not true in anisotropic cases the material. So, if this is the original material and if I am applying tensile stress on it, it will become, it will not become just longer, it may also exhibit shear strain. So, this angle theta will not remain 90 degrees. So, in this case in anisotropic cases extensional loads they generate extensional plus shear strains or shear deformation this is important to understand in anisotropic cases.

Same thing happens if you compress it, it will not only become shorter and fatter, but it will also bend and twist and it can generate shear strains there also. So, that is the difference between isotropic situations and anisotropic materials.

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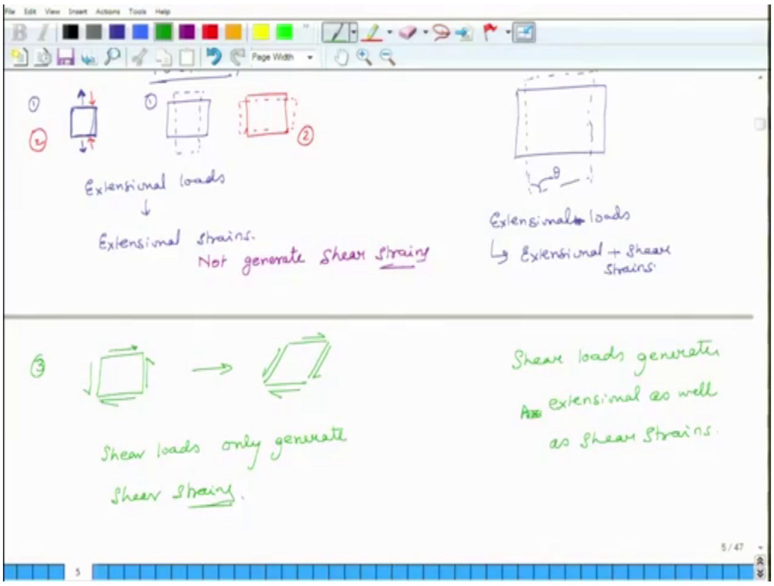

Similarly, the third case will be that if you apply a shear stress to an isotropic material then it will only exhibit shear strains, it will only exhibits shear strains, it will not become longer or shorter only the angles will change.

So, for isotropic cases shear loads only generate shear strains shear strains, but for anisotropic cases shear loads generate extensional as well as shear strains and why this happens we will see the mathematics of this, but right now it is important to understand how they behave. So, this is a very fundamental difference between anisotropic load cases and isotropic materials.

What we will do in the next classes we will continue this discussion may be for 5-10 more minutes and we will also introduce another terminology known as orthotropic materials and they have a different response actually some sort of an intermediate response and we will understand what that implies. So, that concludes the discussion for today and tomorrow we will continue this discussion, until then have a great night and we will meet once again tomorrow that is on Tuesday.

Thank you.