Advanced Composites

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Lecture - 03
Properties of Single Layer Continuous Fibre Composites Part –I

Hello. Welcome to Advanced Composites course. Today is the 3rd day of the ongoing week which is the 1st week of this course. And in the last two days, we have given some introductory information about the course and also, we have started quickly covering some of the basic principles and concepts related to composites. Today and also in the remaining part of this week, we will continue this journey, so that in the next couple of weeks you feel comfortable with the basic material which was covered in the introductory course. So, that is the purpose.

So, what we are going to do specifically today and also in the remaining portion of this week is, we will discuss some of the properties of single layer continuous fiber composites, because in most of engineered composite materials which are used for high tech applications. These single layer continuous fiber composites form the building block and you actually lay them on top of each other and you make complicated laminates which are used in several engineering structures. So, we will have a quick overview as to how the material properties of single layer composites which have continuous fibers can be computed. And before we start doing that and start discussing that, I will also like to introduce some of the important technical terms which are very often used in the world of composites.

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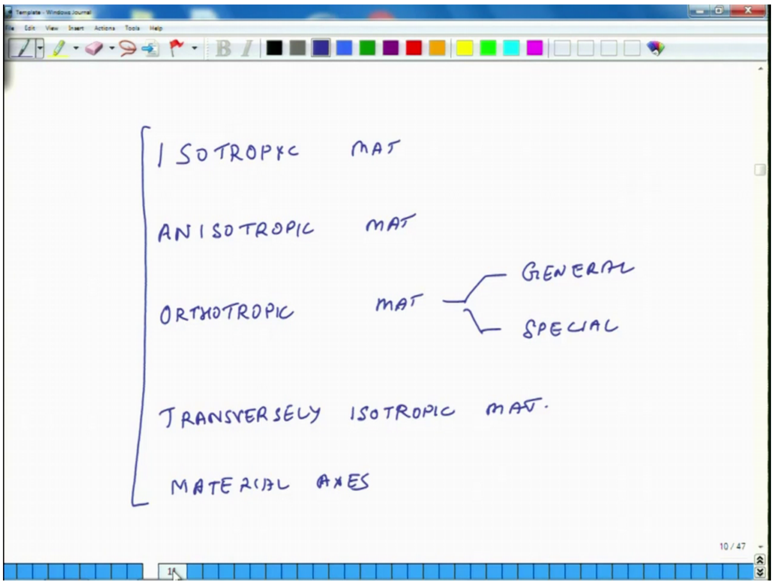

So, let us look at what are these terms. So, one term is Isotropic or Isotropic materials, then there is another term known as Anisotropic materials, then there is a third class of materials known as Orthotropic materials. And we will learn what do these imply and these Orthotropic materials, sometimes they belong to one class known as generally Orthotropic and then, sometimes we say use the term especially Orthotropic. So, we can have two versions general and special. And we will learn what these terms mean and then, there is another term called Transversely Isotropic materials, ok. Then, finally we will also discuss something known as material axes. So, let us look at all these terms.

So, let us start with Isotropic material. So, consider a piece of steel and let us say we have.

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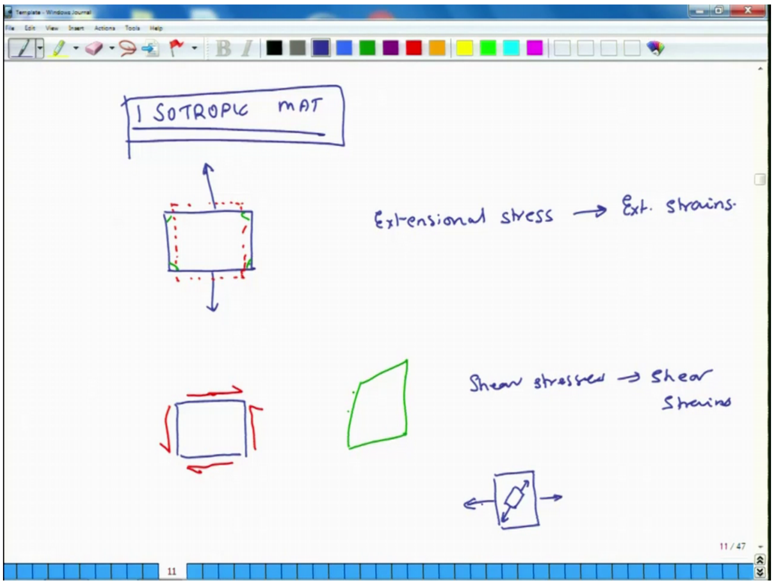

So, this is Isotropic material and consider a case where we have a rectangular block of steel, and if we you know apply some tensile forces on it, then what happens, it will become longer and also it will contract a little bit because of Poisson effect. So, its deformed shape still remains rectangular.

So, if I subjected to tension, it still remains rectangular, but it becomes a little thinner and a little longer. So, this is something we observe in isotropic materials. All these angles, they still remain at 90 degrees after deformation. So, what this means is that extensional stresses, they only generate extensional strains. So, this is also if we have the same material and if it is having a rectangular shape and I subjected to shear strains, then what happens is that it deforms and its deformed structure looks something like this something like this, but its overall length and overall width, they do not change. So, that means is that shear stresses, they only produce shear strains.

So, when you apply a shear load on a Isotropic material, it only exhibits shear strain. It does not become longer or it does not become fatter or thinner. So, this is something very typical of Isotropic materials from a mathematical standpoint. What is typical of Isotropic materials is that the properties of the material are same in all the directions. So, that means is that if I have this material and if I pull it in this direction or if I make another sample cut like this and I pull this other sample in this direction, so regardless of the orientation of how I cut the material from the bulk material, the properties of the material for instance Young's Modulus Strength Poisson’s ratio, all these things they do not change with respect to direction.

So, the material properties are not sensitive to the direction or the coordinate system and that is why they are known as Isotropic materials. And they behave in such a way that when you subject them to extensional stresses, you see only extensional strains and when you subject them to shear stresses, you see only shear strains in contrast.

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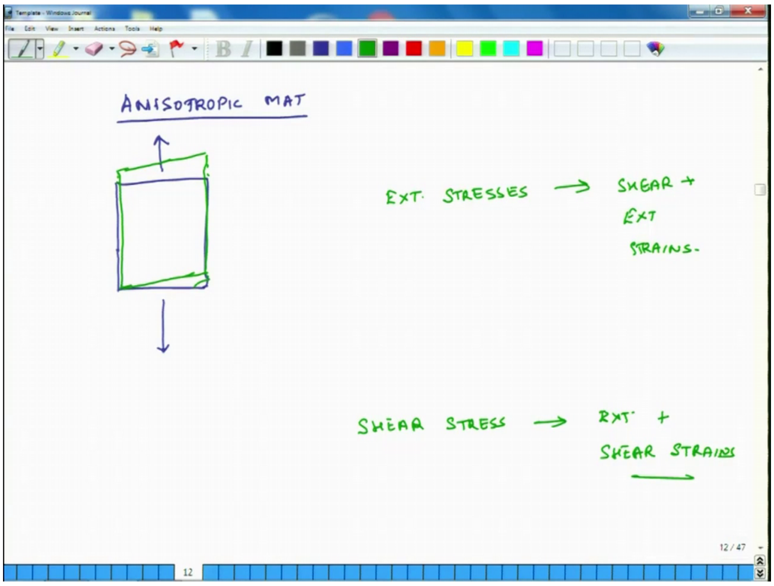

Let us look at the behaviour of an Isotropic material. So, here these materials typically unlike isotropic materials, it depends in which direction you are pulling. So, if you have an isotropic material say a piece of wood and if you pull it in the direction of fibers, it will be very stiff. Its Young’s Modulus in the direction of fibers, it will be very high, but you pull it in a direction normal to the direction of the fibers in wood, its Young’s modulus will be not that high. So, that is why these properties for Anisotropic materials are direction dependent and that is why they are known as an Isotropic materials.

These materials behave differently when subjected to pure extensionally stresses and extensionally strains. So, suppose you have a piece of anisotropic material and you subject it to let us say pure tension and its original shape is just a rectangular block. Then, what will happen is that it will not only become longer, it will not only become slimmer, but it may also exhibit shear strain. So, it may do something like this. So, this may be the deformed shape. So, it has become a little slimmer, because of Poisson’s contraction, it has become a little longer and also these angles which were initially 90 degrees, they get changed.

So, in anisotropic materials, extensional strains, stresses, they can, they generate both shear plus extensional strains and similarly, if I take the same block and I subjected to pure shear stress, then pure shear stresses, they also generate a combination of both extension extensional strains plus shear strains, shear straight. So, this is about Anisotropic materials, and this happens because their material properties are not independent of the direction and because of that we care. We will see later mathematically it implies that when you subject them to an extensional stress, it yields shear as well as extensional strains and when you subject them to shear stresses, it again generates shear as well as extensional strains.

There are materials which are somewhere between Isotropic and Anisotropic materials and before we start discussing them, we will also introduce a concept known as Material Axes.

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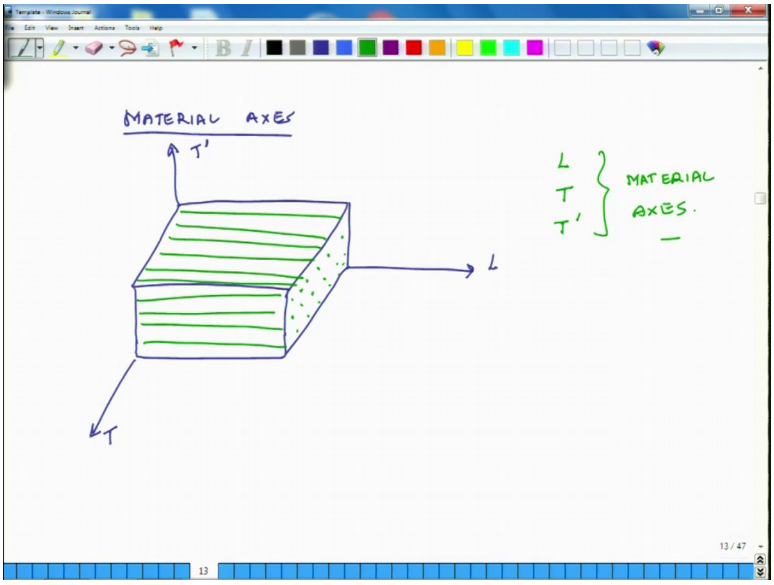

Material axes- So, consider a piece of let us say a single layer fibrous composite. Now, this will have fibers running along its length. So, these things in green are fibers and everything between the fibers is the matrix material and we align our coordinate system in such a way that this direction let us call it L, this direction we call it T and this direction we call it T prime, ok; so three directions. So, L direction is aligned with the direction of the fiber, T direction is normal one of the normals to the direction of the fiber and T prime is the other normal to the direction of fiber and if I see this on this surface, then we will see only the ends of the fibers.

So, if I have especially designed material where fibers are running in a particular direction and all the fibers are parallel to each other, then if I align my coordinate system in such a way that my one of the axis is aligned to the length of the fiber and other two axes are aligned in such a way that they are normal to the direction of the fiber, then these directions L, T and T prime, they are called Material Axes because they tell us a little bit how material fibers and the reinforcement material is oriented in the system. So, these are called Material Axes. So, sometimes they are referred as L, T, T prime and in some other cases, people refer them as 1, 2 and 3 axes, but these are Material Axes.

Now, having learnt what our material axes, let us learn about a third class of materials known as Orthotropic materials.

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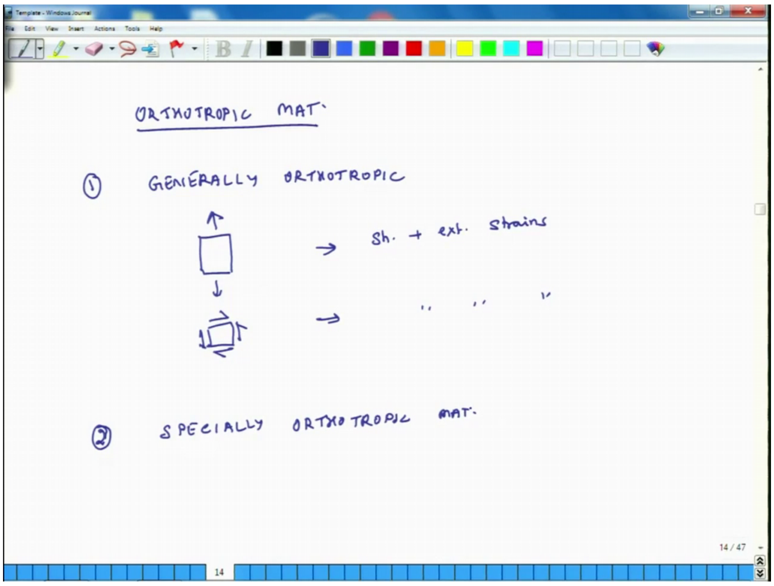

Now, these materials are somewhere between Isotropic and Anisotropic material. If in general, if you have an orthotropic material, so then in general when you subject an orthotropic material to pure extensional strain, again these are two categories. One is generally orthotropic, and you have a generally orthotropic material and you subject this generally orthotropic material to let us say pure extensionally strain like anisotropic material. It will generate shear plus extensional strains and if you have again a generally orthotropic material and you subjected to pure shear strain or shear stress, again its behaviour is similar.

So, this is in general how orthotropic materials behave, but there can be special situation and in that special situation, the same orthotropic material generally orthotropic material it behaves in a special way and in such a case, we call it a especially Orthotropic Material. So, what happens in this? What is so special in this case?

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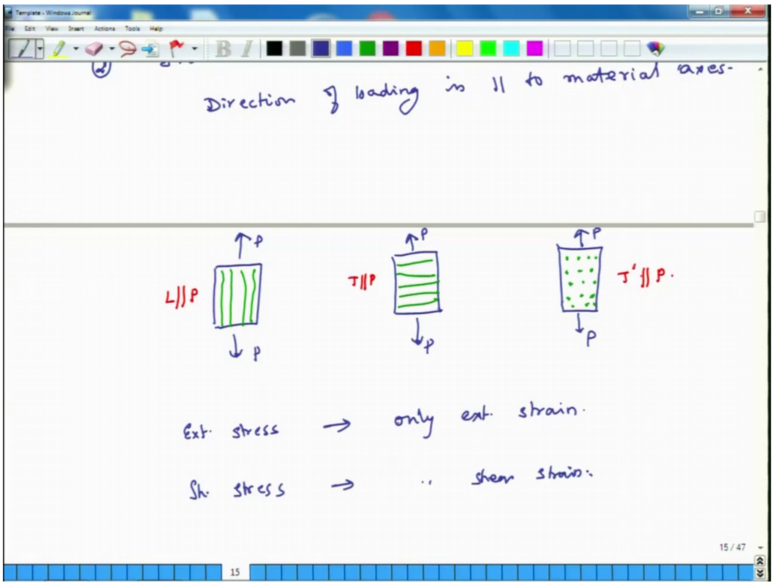

In this case, the direction of loading is parallel to material axes, ok.

So, what does this mean? So, we will draw a picture. So, one example where direction of loading is parallel is suppose I am applying some tensile load. So, this is the direction of loading. So, this is the direction external forces P and it just happens that the fibers are also aligned to the loading direction,. So, in this case, L direction and P, the direction of p are aligned. Another case would be, so here in this case L is parallel to P direction. Another case would be my fibers are at parallel, right and I am still loading in this direction. So, what is the situation in this case here? Let us say we can say that transverse axes is parallel to the direction of loading. So, again one of the material axes is aligned to loading a third case could be.

Again I am having P axis and in this case, the fibers are perpendicular to the plane of this laptop or the monitor on which I am writing and in this case again there is alignment, such that T prime axis is parallel to the direction of P, ok. So, this case, this is the case of special orthotropic and in case of a special orthotropic, the material behaves in such a way that if you subject it to pure extensional stress, it generates only extensional strain, and if you subject it to pure shear stress, then it generates only shear strain. So, this is how generally orthotropic materials behave and which generally as well as especially orthotropic materials behave.

There is a another class of materials known as Transversely Isotropic materials.

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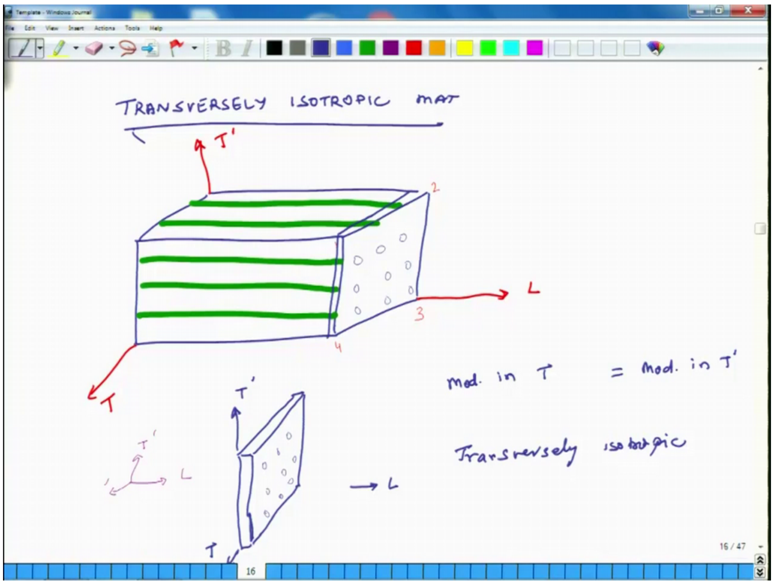

Now, to explain this I will have to draw a picture. So, consider block of material, and let us say this is my L direction. So, the fibers are running parallel to L direction, this is my T direction and this is my T prime direction and let us assume that fibers are running parallel to L direction and these fibers are circular fibers. So, their cross-section is a circle, and that is important to understand. So, I will just make couple of fibers. So, these are thick fibers in this case just to illustrate the point and these are having circular cross-section and when I look at the cross-section of these fibers, I have circles. So, these are not ellipses or rectangles, these are circles.

Now, if you consider this cross-section, so what is the cross-section? Let us say consider the cross-section 1 2 3 and 4 and I cut a material section material. So, I cut a sample like this, I got a sample like this,. So, I am cutting this material in the transverse plane, transverse to L direction, I am cutting the sample in the transverse plane. So, this material sample will look like this, and it will have fibers and all these fibers will be circular in nature.

Now, I try to find these samples Young's Modulus,. So, I try to find samples Young's Modulus. So, what are the three directions? So, this is my L direction, this is my T prime direction and this is my T direction. So, if I have to find its modulus, so consider the case if I try to find the modulus of this material in T direction. In T direction, you think about it that modulus in T direction will be same as modulus in T prime direction because everything is same geometry of material distribution, everything is same. Also if I have another set of axes, let us say my other set of. So, this is my T and T prime and T and let us say along the L axis, I rotate it.

So, there could be another axis system where L is same but T gets rotated, so is T prime. Once again in the same material if I test it in any direction in this plane, any direction in this plane, its material properties are going to be the same. That is why this material is called Transversely Isotropic because in the transverse plane which is this plane which I have drawn, its material properties do not change with respect to the orientation of T prime and T directions. That is why it is known as Transversely Isotropic. This is true only if we have uniform distribution of fibers and the cross-section of fibers is circular.

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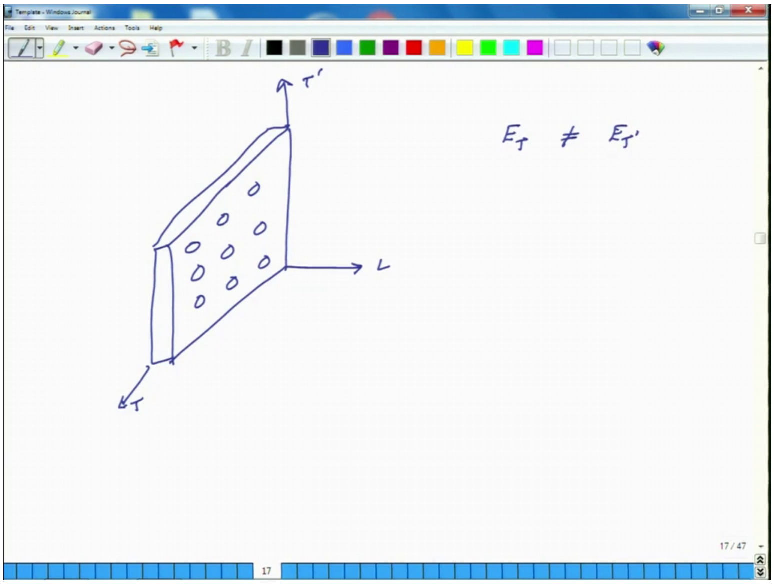

Consider a case where the cross-section of fibers is not circular ok. So, let us say we have elliptical fibers and these represent the cross-section of fibers. So, this is my L direction, this is T direction and this is T prime direction.

Now, in this case there is no reason to say that Young's Modulus and T direction will be same as Young's Modulus in T prime direction, right because the cross-section is different in different directions. So, they may not be same. So, in this case even though the material may be especially orthotropic, but it may not exhibit transverse isotropy because the cross-section of fibers is not symmetrically oriented with respect to L axis in the transverse plane,. So, these are, this is what I wanted to discuss in terms of Transversely Isotropic Materials.

So, this is what I wanted to cover in this class. Next class onwards we will start discussing material properties of single layer long you know continuous fiber composites, and because that will provide us with basic building blocks for behaviour of more sophisticated and complex composites which are known as Laminated Composite Structures.

Thank you.