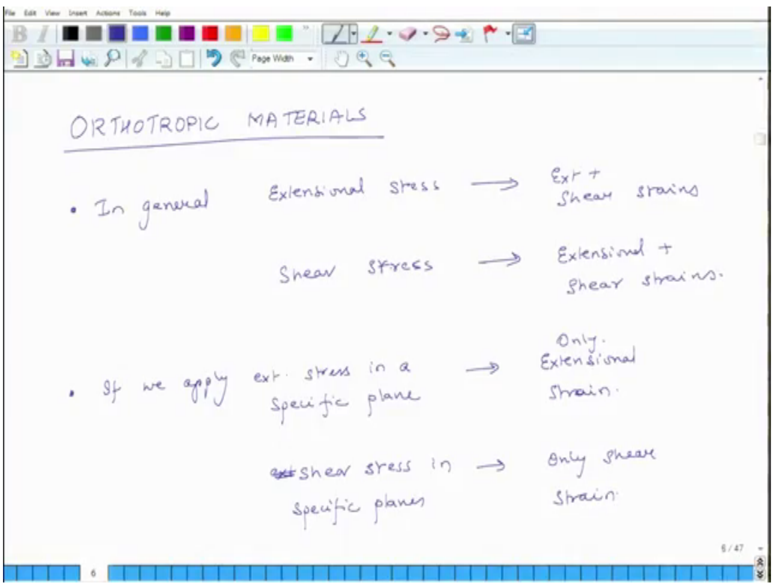
Introduction to Composites
Prof. Nachiketa Tiwari
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

Lecture – 26
Orthotropic Material

Hello, welcome to Introduction to Composites. Today is the second day of the ongoing week which is the fifth week of this course. Yesterday we introduced two terms anisotropy and isotropy, anisotropic materials and isotropic materials, and we also explained these materials or explained the characteristics of these materials in terms of the loading and the associated strains. What we had explained was that if the material is isotropic then if you exert it with the pure shear strain it will only; a pure shear stress it will only exhibit shear strains and if you exert purely extensional stress on the material then it will exhibit only extensional strains.

For anisotropic materials this need not be true. In fact, when you exert or you apply extensional strain on isotroph anisotropic material it will exhibit not only extensional strains, but also shear strains. And when you exert or apply only shear strains on an anisotropic piece of material it will exhibit again extensional as well as shear strains. So, this is a very fundamental difference between the behaviors of isotropic material and anisotropic material.

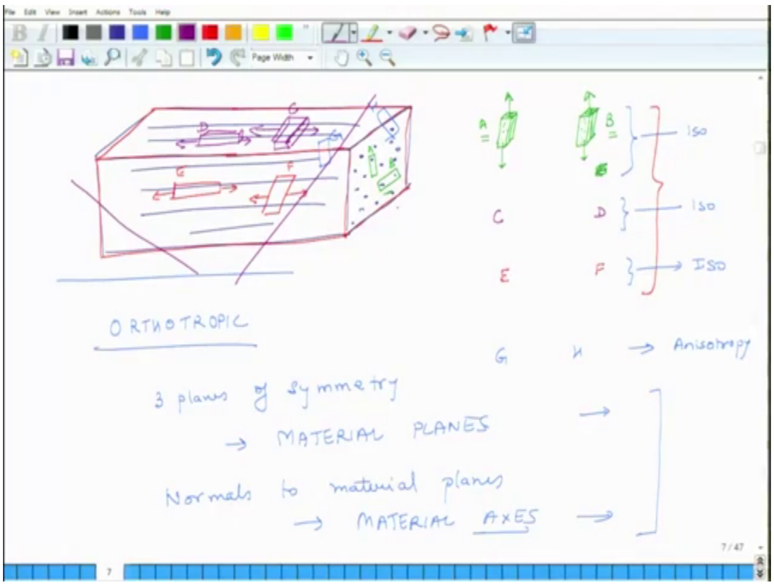
(Refer Slide Time: 01:57)



Now, we introduce a second third term known as orthotropic materials, orthotropic materials. These are materials, they are special in a way that they are somewhere between isotropic and anisotropic materials. In general if you apply extensional stress they will exhibit what extensional plus shear strains and if you apply shear stress they will exhibit again extensional plus shear stress, shear strains.

So, in general their behavior is similar to that of anisotropic materials. But if you apply along specific planes some specific planes, if we apply extensional stress in a specific plane and we will explain this, what you will see is that it will exhibit only extensional strain. And if we apply external or shear stress in specific planes then you get only shear strain and here you get only extensional strain. So, generally they behave as anisotropic materials, but if the load happens to get applied in a specific plane then you can keep on changing the orientation of the stress in that specific plane only, it will behave as a isotropic material. Let us understand this further.

(Refer Slide Time: 04:45)



So, consider a piece of wood and if you look at the structure of wood carefully it has a lot of fibers and these fibers just run along the length and at the end you will see the end points of the fibers. So, this is my wooden block and I have cut the wooden block in such a way that its length of the block is aligned to the length or the direction of the fibers. So, the fibers and the length of the block are in the running in the same direction.

Now, I can let us think about it I can cut a piece of material like this. So, let us call this sample A in the, so I am cutting a piece of material in such a way that the length of the sample, the length of the sample lies in this plane the cross section and then I can cut another material sample B, I can get another material which is sample B.

So, sample B also. So, how does sample B look like? Sample B looks like this right. So, this is sample A and this is sample B and if you look in the other direction. So, if it is a 3D sample, so the fibers are running like this, fibers are running and I again see only end points of the material on the top phase, no I am sorry this will also have fibers running like this, like this.

Now, because I have cut the material in a very special way if I pull it in this direction both for sample A and sample B remember the direction of the samples for A and B was different. See this direction is oriented like this and here the direction is oriented like this, but in both the cases I made sure that the length of the sample lies in the plane of this end plane right and then if you test this material in tension sample A and sample B you will find that their material properties are same, material properties are same, and you will also see that if you just pull it, it will only exhibit extensional strain; if you compress it, it will have it still exhibit only compress extensional strain; if you apply shear to it only it will exhibit shear strain. So, this is one plane.

I can also cut material like this and so what happens in this case I can also cut material like this and I can test this material like this and I can test this material like this right the material property. So, let us call these sample C and samples D what is happening in this in sample C and sample D? The length of the sample is still lying in the plane. So, I am the sample is something like this, and same thing for this one. The length of the sample of sample C and sample D lies in the plane is aligned in the plane. So, this line, this line is at all points of this line are equidistant from the top surface of the block, same thing is true for D.

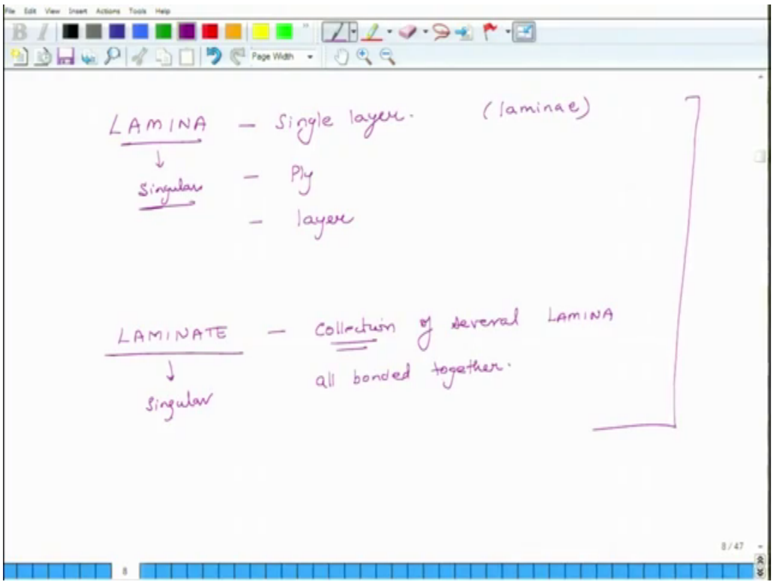
So, I am cutting the samples. So, again if you look at sample C and sample D even though they are cut in different directions their tensile properties will be the same. So, this is sample C and sample D. And then let us consider another one this is sample E and you can test it in tension and this is sample F and again you test it in tension. So, you will see that E and F; they are their also properties will be same which means that for this material these three planes if I cut the materials with respect to these 3 planes then I can within the plane I can keep on rotating the orientation of the sample the properties do not change within the plane.

So, this material is behaving isotropically at least in context of these 3 planes, but if I start cutting the material differently suppose I want to if I cut a material like this and in the other case I cut a material like this the properties of G and H will not be same. So, G and H exhibit when you test them they will show that this is like a anisotropy they will exhibit anisotropy, but in A and B you will exhibit a isotropy, between C and D you will see isotropy, and between E and F you will see isotropy. So, the point is that this type of a material that is why is known as orthotrophy, orthotropic material.

And these three planes of symmetry they are lie, they are these planes of symmetry are related to the orientation of fiber and the material structure, you know they are related to the structure of the material. These 3 planes of symmetry are known as material planes, they are known as material planes and the normals to these planes, normals to material planes they are known as material axes. So, orthotropic materials are materials which behave isotropically when samples are cut from a specific plane, from a specific plane within the plane you can keep on rotating that orientation of the sample and these planes are known as material planes and the normals to those are known as material axes and both material planes and material axes are specific to the overall structure of the material.

So, here we figured out these planes based on the orientation of the fibers. I cannot cut a material plane something like this or like this, it is oriented to the structure of the material. So, this is about orthotropic materials. And in general orthotropic materials behave anisotropically, but in the context of material planes they behave isotropically. So, this is another thing.

(Refer Slide Time: 13:21)



2-3 more terms. So, lamina, what is a lamina? It is a single layer, so single layer. Lamina is also known as lot of times people call it a ply or they call it a layer. So, if there is a single layer it is called lamina. The plural of lamina is laminae, in a plural of lamina is laminae, and then you have a term called laminate, laminate what is it? It is a collection of several lamina, but they cannot be separately floating play lamina you know it is a collection that is why it is a collection of several all bonded together.

So, laminate is also a singular noun, so is lamina. So, a laminate is still a single. So, you have a laminate which has several laminae you have one lamina, laminate which may have several laminae all bonded together.

So, this is the overall terminology and I think this captures the overview of some of the basic terminologies which we will use again and again in our course. Starting tomorrow we will start discussing how to predict different properties of composite materials. Specifically we will start with density then we will move to the prediction of longitudinal modulus and so on and so forth. So, that concludes our discussion for today and we will meet once again tomorrow, till then have a great time. Bye.