Introduction to Composites
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Lecture – 66
Lamination Sequence (Standard Laminate Code)

Hello, welcome to Introduction to Composites. Today is the last day of the ongoing week, which is second last week of the course. Over this week you have been introduced to classical lamination theory, which helps us connect with connect force and moment resultant to the strains in the plate and curvatures in the plate, using in terms of matrices a b and d, and these matrices are specifically named as extensional stiffness matrix, coupling stiffness matrix, and bending stiffness matrix.

Today we will talk about some standards in context of, how do we define and specify the lamination sequence of a laminate. And that is the language which is used across the whole industry and people who use composites in their designs, so it is important to understand this standard laminate code. So, we will spend some time on that; so, this is known as standard laminate code standard laminate code.

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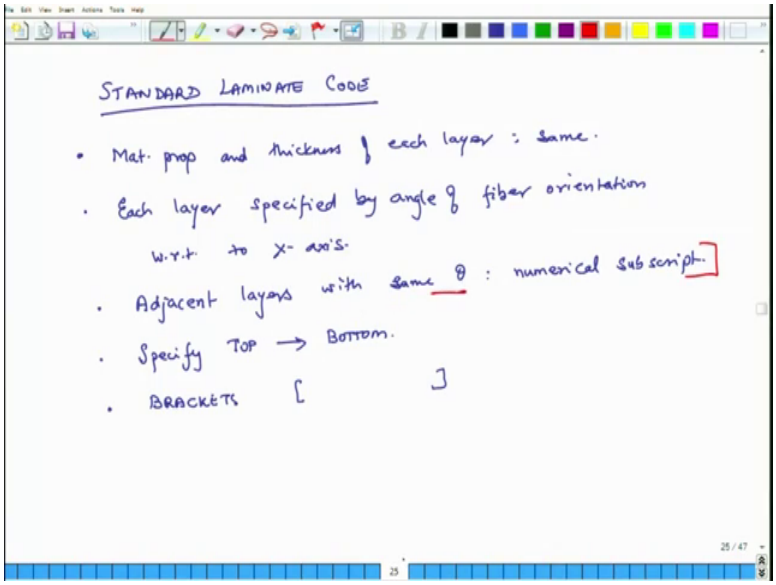

So, if the; so the basic thing is that if nothing is specified and if only angles are specified for each layer, then we assume that material properties and thickness of each layer are same, unless specified we just assume that material properties and thickness of each

layer are same this is one thing. And then there are several points to be understood and then we will do some examples.

So, the other thing is that; each layer is specified by angle of fiber orientation with respect to x axis ok. So, this angle could be a positive number or a negative number and we always use degrees some other conventions we always specify; so if there are adjacent two layers having the same angle. So, if there are two layers or adjacent layers, adjacent layers with same theta with same angle and we will see examples. So, there are two layers lets a two layers are 30 degrees, 30 degrees and they are just taking to each other, then we can use a numerical subscript ok. Another convention is we always specify from top to the bottom you specify top to bottom, and we start the lamination sequence with a bracket and end with a bracket.

So, we use brackets ok. So, this is the start and this is the end of the lamination sequence. So, we will do some examples, which will make things clearer.

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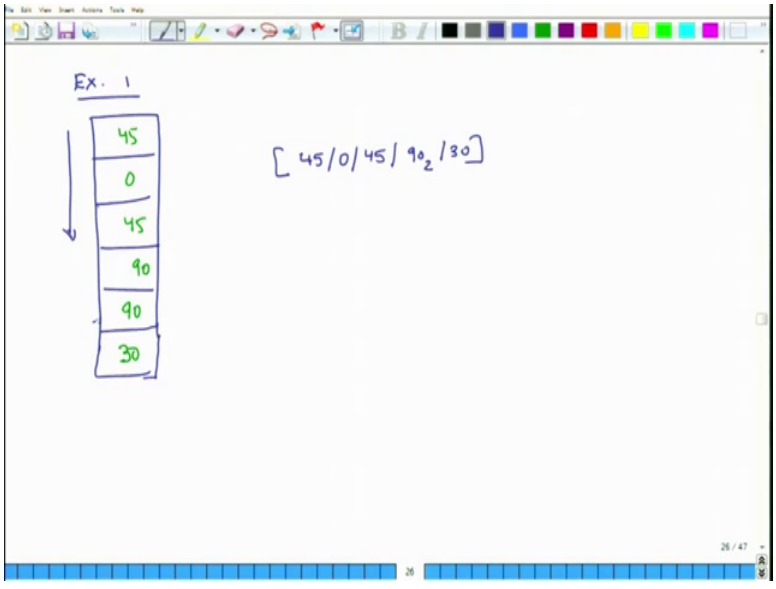

Example 1 ok; so let us say we have a stack up. So, we are assuming that each of the thickness is same even though I may not be drawing correctly. So, let us say that these angles are 45 degrees 0, 45, 90, 90, 30.

So, how do we specify it? We specify we start with the bracket 45, 0. So, we are going from top to bottom ok, then the next one is 45, and then we had said that; there are two

layers and they are adjacent and they are same angle right same theta. So, we put a subscript; so we put a 90 and because there are two layers with same orientation, so it is 92 and then 30 ok. So, this is one case another case.

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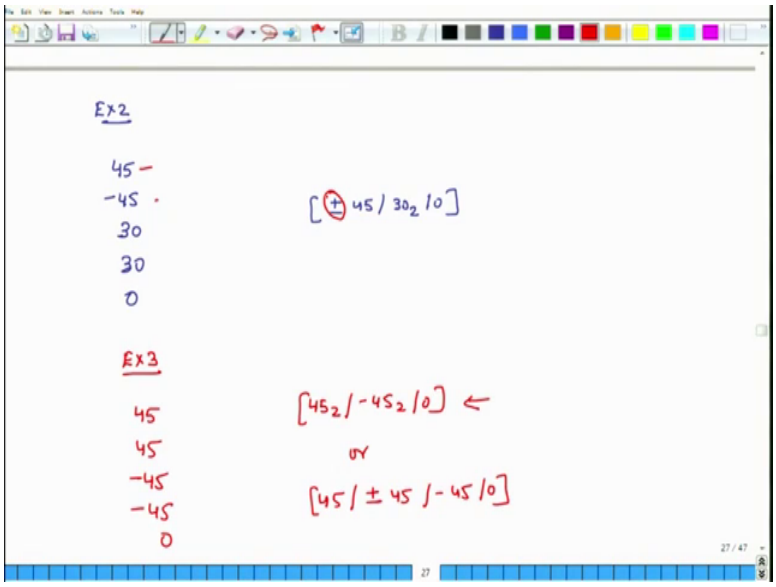

Example 2; so let us say the stack up is 45 minus 45, 30, 30 and 0. So, the sequence would be first is plus 45. So, we can say plus 45 and then negative 45, 32, 0 ok. Another example could be example 3 is 45, 45 minus 45 minus 45, 0 ok. So, this would be 45 2 minus 45 2 and 0 or you can also write it as 45 plus minus 45 minus 45, 0, but this is more common.

Now, in this case the positive layer came first and then we had a negative layer, if it is just the other way around, then we do not use this sign the other we use minus plus sign. So, we will just do a quick example. So, this is just a question of conventions and it is not difficult stuff at all; so 45 0 minus 60, 60, 30 suppose these are the layers. So, this is example 4 ok.

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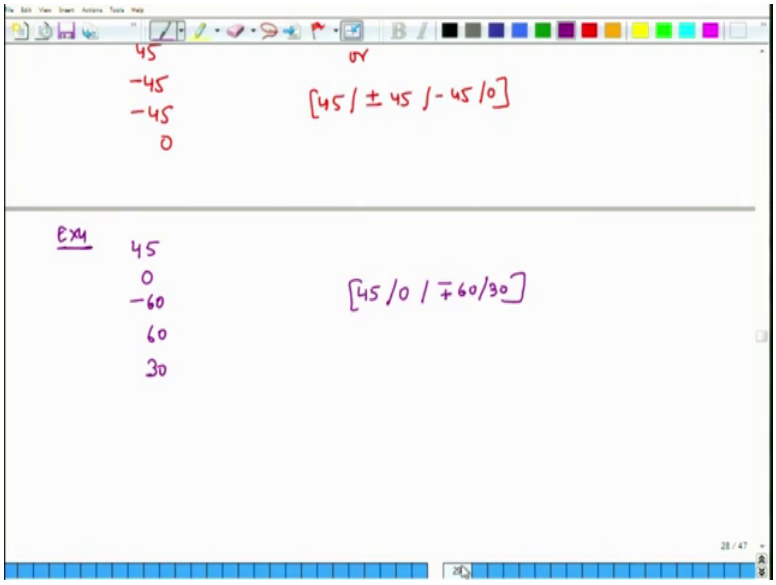

So, this will be 45, 0 minus plus 60, 30 ok. Now, there could be layers lamination sequences, which could be symmetric above and below the mid plane. So, what do we do in those cases? So, let us look at symmetric lamination sequences.

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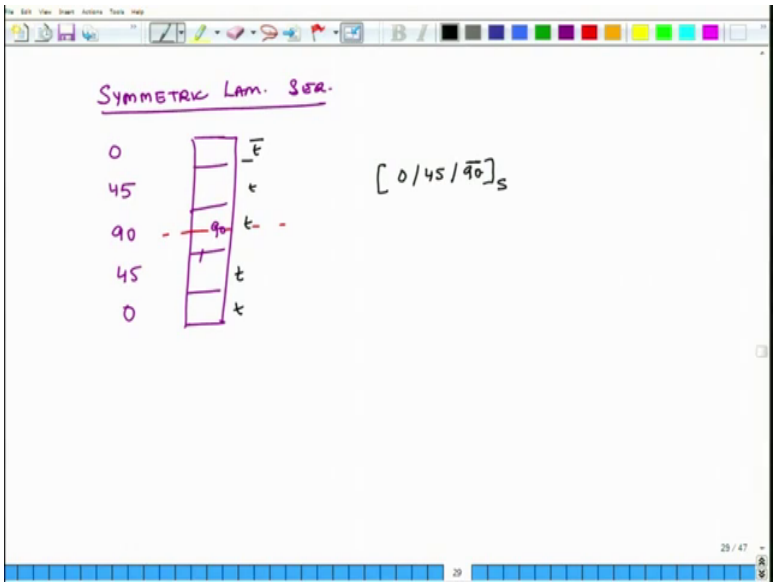

So, let us look at an example 0, 45 90, 45, 0; suppose this is the thing. So, here this is the mid plane, and each layer has same thickness we have as we have said that unless you specify this thing. So, this is 90 and then of course, all other things are there.

So, the mid plane is passing through the middle of the 90 degree layer ok, mid plane is passing through the middle of the 90 degree layer. So, what do we do we specify this as

the top layer is 0, then the layer below it is 45, then the layer below is 90, and then we close the bracket and we say S. So, S means symmetry, but this does not tell us this implies that this 90 degree will be repeated twice, but so, but that is not the case, because the total thickness of 90 degree layer is t.

So, so suppose this is t, this is t, this is t, this is t, this is t. So, we put a bar on top of it which means that the mid plane is passing through the middle of this layer ok.

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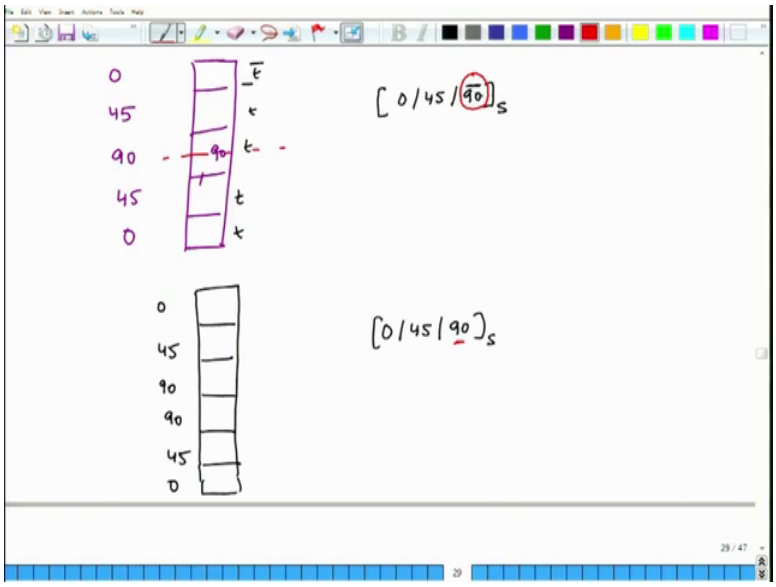

Another example could be something like this. So, this could be 0, 45 90, 90, 45, 0 ok. Here the lamination sequence will be 0, 45, 90, symmetric. So, this bar means that the 90 degree layer is not repeated ok; there is only one 90 degree layer and mid plane is passing through the middle of this, but here because there is no bar this 90 degree layer is also repeated. So, this is important to understand.

Let us do another one in this case we have sets.

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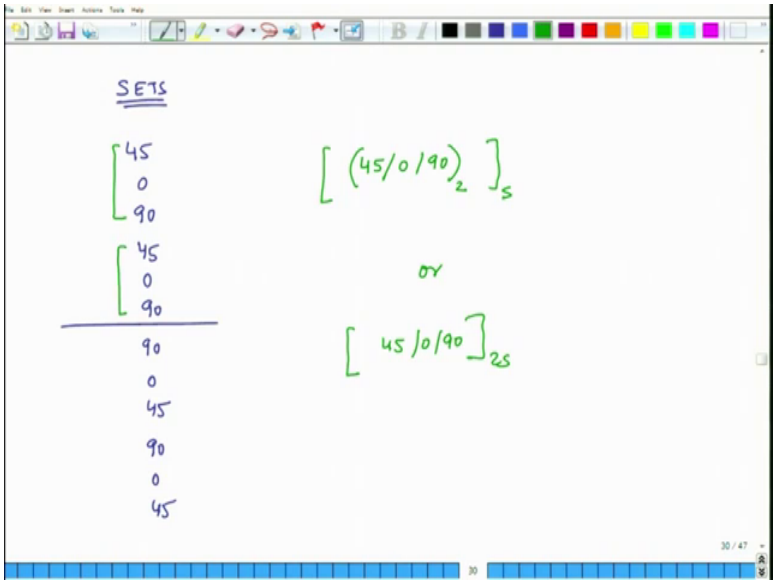

So, what happens in several sequences layers come in sets, they do not come individually, but they come in sets. So, will see an example, so one example is 45, 0, 90, 45, 0, 90 and this is symmetry, so 90, 0, 45, 90, 0, 45. So, this is coming as a set and this is again coming. So, this set is being repeated hum.

So, how do we specify it? We specify it as 45, 0, 90, and if this is a set which is being repeated, then you put it in brackets and you put it like this and this entire thing is symmetric ok. An alternative way to do the same thing is 45, 0, 90, two symmetric. So, first you repeat it twice and then you make it symmetric. Now the last case we will do; is when we have more than one type of fibers being used.

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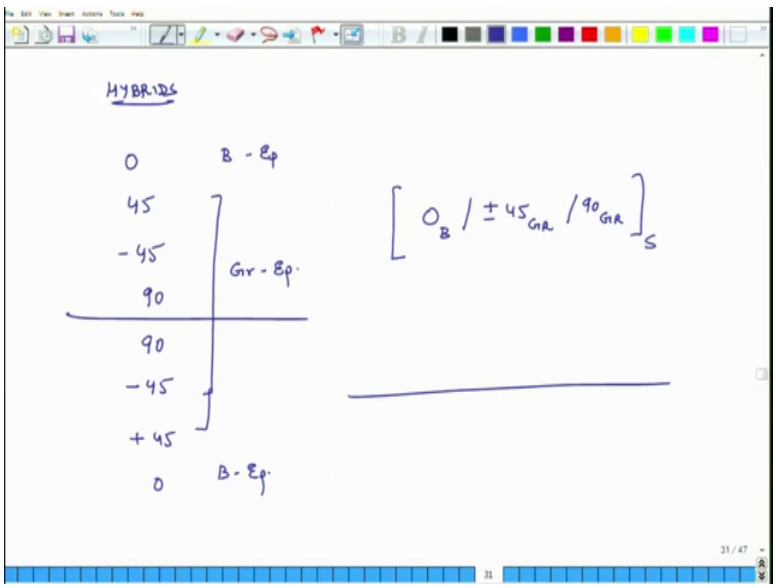

Now, by default we said that each layer has same thickness and the same material properties, but in some laminates you may have different fibers.

So, the person should not get confused, so he should be a watchful that oh this is a different material and so this standard load this code has been has been adapted to give that information also. So, we will give you an example. So, suppose the first layer is 0 degrees, second layer is 45, third layer is minus 45, fourth layer is 90, and then 90 minus 45, 0, but the materials are different.

So, here we have boron fiber and epoxy composite and on all these guys we have graphite fiber and epoxy composite. And this is a boron fiber and epoxy composite. So, what do we do we specify something like this. So, first one is 0, and then we also specify boron, so we put B and then plus minus 45 and these are graphite fibers. So, typically we specify the fiber, so that makes the person careful and then he goes and figures out the exact properties. And then we have 90 degrees graphite and the entire thing is symmetric about this mid plane. So, it is symmetric yeah.

So, this is plus 45 and 0. So, this is still boron and epoxy ok, but at least in context of this course you will not necessarily use this, but you should be aware that, if different material systems are used then you may want to give some indication that it is not that things are different in this case. So, that is pretty much what I wanted to discuss today in context of lamination sequence and also this closes the theme of our discussion for this week.

Next week, which is starting Monday, which is the last week. We will continue this discussion and we will also talk about failure of laminates when they are subjected to external stresses and strains and how we can predict that and that will complete the overall objective of this course, but till then that is till Monday have a nice weekend and I look forward to seeing you on Monday bye.