Manufacturing of Composites
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Lecture – 14
Stacking of Reinforcements

Welcome to lecture number 14, where in which we are trying to talk about stacking of reinforcement in a composite.

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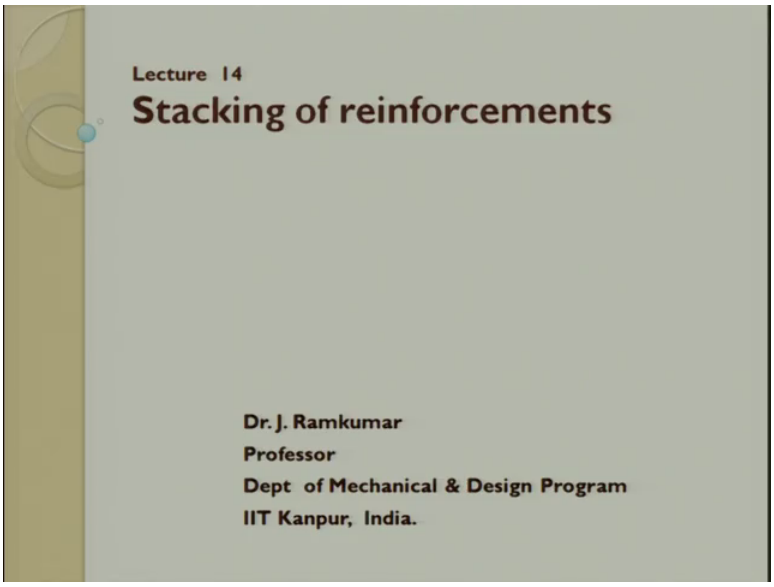

So, we have been discussing all through this course only on polymer matrix composite. So, there were lot of queries raised by students sir can we discuss little bit on stacking of composites and why stacking is a very important phenomena. So, stacking is a important phenomenon because stacking, will try to tweak their requirements of the material such that it can meet out to the functional needs.

So, suppose you were like to have isotropic property, alloys are very good if you want to have an isotropic property; that means, to say longitudinally you would like to have a different strength as compared to lateral. So, then what we do is we try to play with the reinforcement whatever we give, and the reinforcement orientation also plays a very, very important role.

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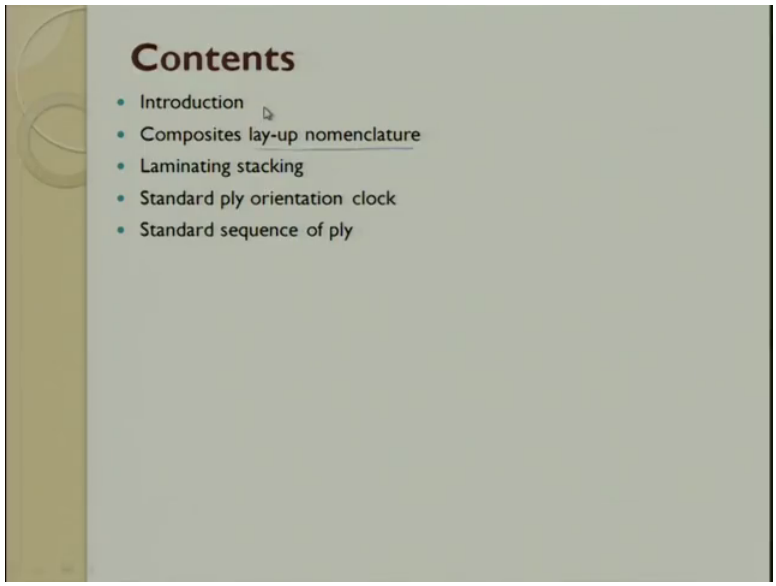

So, here in this we will some small introduction then composite layup nomenclature, we will see then laminating stacking we will see then standard ply orientation in the clock wise in clocks. Whatever it is and then we will also see the sequences whatever we follow.

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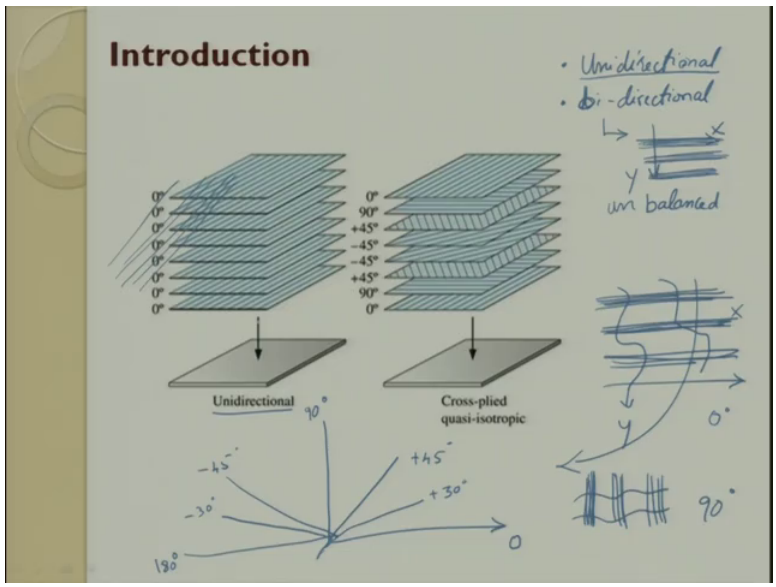

Generally what happens is in reinforcement, you can have unidirectional mat or bidirectional mat, unidirectional or bi directional bi directional mat or bi directional reinforcement.

When I say bi directional then the fiber in both x direction running and y direction running x direction, and y direction it is balanced; that means, to say if there are 100 glass fibers running in this direction, same 100 will be running in this direction. So, then here what happens it is predominantly balanced mat. So, when we talk about stacking orientation, and other things we are focused only on unidirectional mats; that means, to say the mat runs in one direction with lot of fibers, in the other direction it is just neated such that it tries to hold the fibers running in one direction. So, it is something like this. So, this is called as unbalance mat. So, this unbalance are otherwise called as unidirectional mat; that means, to say you will have running along one direction a bundle of fibers, several bundle of fibers and all these bundle of fibers are held together by a wire or by a glass fiber. So, this is in the y direction and this is in the x direction right.

So, the running direction is called as 0 degree orientation, if I rotate this fellow by 90 degrees rotate, the entire fellow mats now what happens the mat becomes something like this. Now what I have done? I have rotated by 90 degrees.

So, I have rotated it by 90 degrees, now what is happening? I will have the glass fibers which is perpendicular to this which is stacked on top of it. So, if you go to this fiber which for to this figure where in which we talk about unidirectional, you can see this is the fiber running direction which is called as 0 orientation. And depending upon your strength requirement depending upon your thickness requirement, you can keep stacking this mats one above each other. If I wanted to have some an isotropic property so then what I do is, I try to cut the fibers in the same direction, and while placing it I place it at different orientation.

For example this if you take this is your 0 degrees, this is your 90 degrees, this is your 180 degrees, 180 again becomes 0. So, you can have this can be plus 45 and you can have this way you can have minus 45 plus 45 minus 45. Does not make much of difference, but plus 30 and minus 30, if you can cut in this direction then you can always have a different orientations.

So, what I do is I try to cut at all in running direction of the glass fibers. So, these are called as 0 orientation, I stack them one above each other and then I this can be a prepreg or this can be a fiber where in which a matrix is put. So, that you try to get a composite material. So, if in the cross plied quasi isotropic. So, what we do is we try to stack the

glass fibers in various directions, such that it needs out the requirements. So, the top layer is 0 followed by s is 90, followed by s is plus 45, then minus 45. Then if you look at it interestingly there is a symmetry which it follows beyond this. So, minus 45 and then you will have plus 45 you will have plus 90 and plus 0.

So now if you stack the mat in this orientation, and then if you try to make a composite. It is called as cross ply quasi isotropic. Now in the nomenclature you will ask me a question sir you have put so many 0's. So, how will I express it in the nomenclature? So, what we do is we just put 0, and you say like may be 10 times you follow symmetry. So that means, to say 10 mats will be put. Or you will have numbers for symmetry will be 10 you can have this to get the functional requirement.

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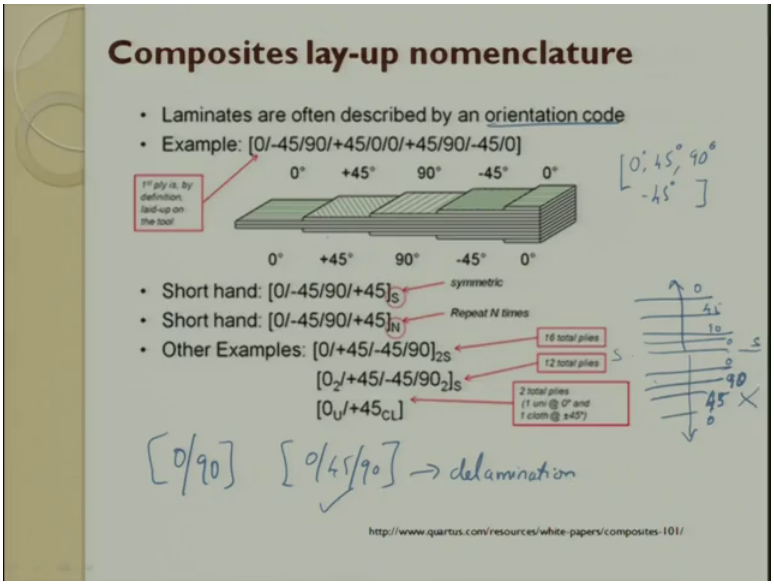

So, if you see that. So, the orientation code it is expressed like this, we always put a square bracket starting and ending. And this is the first ply you have and this is the last ply you have right.

So, I was telling you this is of 0 orientation, the running direction along the mat, and then if I cut it at 45 degrees this is one. And then I cut perpendicular to it is 90 degrees, then you can see a mirror of this will be minus 45. So, you can see minus 45 here and then you can have 0 degrees. Most probably majority of the time we use only these geometries like 0 degrees 45 degrees 90 degrees, and then we also have minus 45

degrees. These are the 4 orientations you have, and based on certain requirements, we can also have 30 and 60 to meet out a requirements.

So, here if you see this example 0 is the first ply. So, which is on the top then you have minus 45, then you have plus 90 then you have plus 45 then you have 0. And then I said last time itself a symmetry is followed. So, the symmetry what happens you will have 0 145, then you will have 90 then you will have minus 45 and then you will have 0. So, in short this full expansion instead of writing it what we do is we always write it as 0 minus 45, 0 minus 45, 90 plus 45. And then what we say is we say it follows symmetry. If it has to be repeated n number of times then we say n into s. Is it clear? S is for symmetry is the top half and the bottom half of all the reinforcement. So, this is the symmetry plane symmetry plane.

So, this is what. So, whatever you are laid it on the top I am relaying it on the on the bottom, but it is just a mirror image. Please see many a times while fabrication we always make a mistake for example, we take 0, 45, 90 and then for example 0. Then people what they do is they repeat it like 0 45 90 and 0. This is wrong. It has to be a mirror image of this. So, this has to be 90, and this has to be 45, and this has to be 0. It has to follow something like this. Is it clear? If you do it just repeat the top one again at the bottom one you are not fabricating to the requirements, and why is this very, very important? Because when I try to drill a hole in the composite material. If the fiber the orientation changes drastically. For example I have 0, 90. And then I have something like 0, 45, 90. When I use 0, 45, 90 the fiber orientation change in the direction is gradual. So, I would try to avoid delaminations happening during machining as well as during curing.

So, the orientation helps in composites fabrication also. If you want to have a sound quality product, we should have the gradual variation of the orientation. Is that clear? Please note it you should when I say symmetry it has to be a repeat of what you put on the top. The other example you can see is 0 plus 45 minus 45 92 s. So, 2 s is I twice I said. So, 2 times it is getting repeated. So, 8 plus 8 it is going to give you 16 plys. The other thing you see you can also represent it like this. I say 0 2 plys instead of say for example, here it was 0 45 minus 45 and 90 right. Suppose if I want to have 0 0 2 times 0, and then I want to have 2 times 45 45. And then I want only 1 times minus 45 then that has to be represented. So, how do you represent I say that 0 2 times plus 45, and then I

say minus 45 then I say 92 times and then please follow a symmetry. When I do this if you see that 2 plus 2 4 right 4 plus I have 5 and 6. So, what 6 into 2 items I will get 12 plys, is that clear? So, are able to distinguish this difference.

If you want to repeat the same orientation 2 times in a laminate, you right that orientation and on the suffix you write number of times it is getting repeated. So, so here you can see here it can be represented to you. The other way round is it can also be say I am writing it here 2 total plys are be done, one it is unidirectional at 0 degree orientation, and one at cloth I have with 45 degrees orientation. You can also have a cloth. So, cloth at 45 degree orientation this can be represented. This layup is very, very important. You can use this for dry fiber which can be made out of carbon, which can be made out of glass, which can be made out of kevlar. You can also use prepregs. So, the running direction is always called as the 0 direction. Keeping the running direction you make a stencil and then you start putting the stencil at varying orientation, and the start cutting the fiber then you get different orientation.

So, different orientation gives different strength properties. So, it induces an isotropic property in the composite material.

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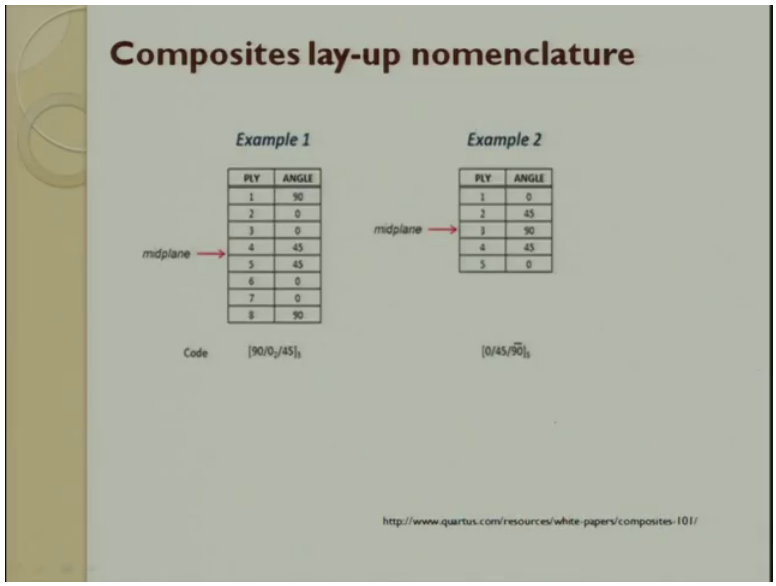

So, the same example we have put in one more example. I am repeatedly giving lot of importance, because this will be very important from manufacturing point of view. So, the first ply is 90 degrees. You can for a beginner to start up you can put it like this and

then start writing it, so that when you start placing it in for manufacturing it can be one. So, first ply is 90 then it is 0 then it is 0, then 45 then there is a symmetry followed, so 45 0 0 and 90. And here I have put 2 0s. So, I have represented it yes, and then I have written 90 0 2 times and 45 and I said symmetry, yes. If I want to do it at 10 times then I just write 10 s. So, I get that. So, the next example you can see is see I have taken 0 45 90 and then I said please follow the symmetry 0 90. So, here I have said I can represent it by this over the top dash; that means, to say the ply is used for both maintaining the symmetry. Why is this important? There might be a case where thickness puts a restriction. See when a thickness puts restriction. So, then you would try to reduce the number of plys. When you reduce the number of plys this can be expressed in this form.

So, is this clear? So, this example and this example, is it clear? I think you should make a note of it. So, you can do it, for any fiber can you do it for chop strans mat. No chop strand you cannot do why because chop strand mat is already glass fiber is cut into and then there are just packed stacked. So, there is no orientation, where ever you have orientation, fibers orientating in one direction meaning. So, there only you can use this.

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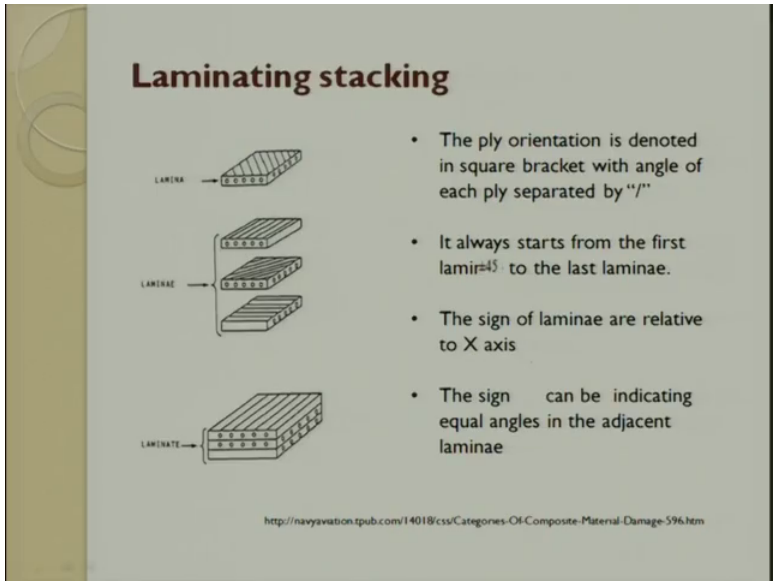

So this is a laminae. So, apply orientation is denoted in square bracket with So, I have written it whatever I have said here. So, this is a laminae, this is a laminae that 3 and then this is a laminate. I have written it very clearly. So, it has to be the ply orientation is denoted by a square bracket right. With an angle which separates 0 45 this is what I said

90, it always starts from the first laminae, and then goes to the last laminate. So, it is starts from the first which I said and goes to the last laminate.

The sign of the laminate is relate to only in one direction, this is what I was trying to tell along the x direction. You have y direction we try to talk in the x direction. The sin can be indicated equal balance in the adjacent laminate consider plus or minus.

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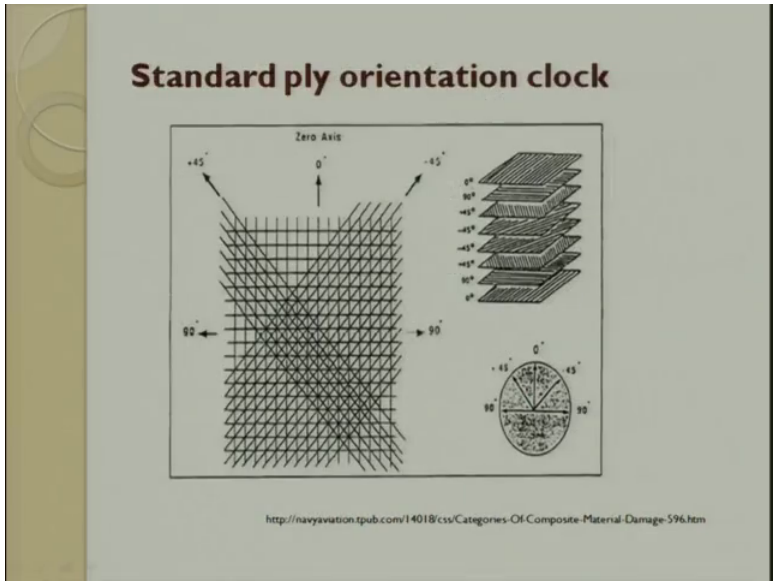

So, this is what it is, this is the standard running direction this 0, this is a standard running direction. This is 90 degrees I said earlier. Or if you say I have just oriented like this. So, this is 0 this is 90 and this is plus 45 and this is minus 45.

So, this is plus 45. So, here this is minus 45 and this is plus 45. So, please keep this in mind. So, if you do it one quarter that is good enough you do not have to very about the others. So, if you see that 0 you see it is exactly perpendicular 90, so at 45. So, you see that minus 45s, in the other direction then it is a symmetry followed. So, you try to get that. So, this is the orientation clock which you should keep in mind. So, orientation clock is very, very important this is what is and here you do any process whatever thermosetting process, we have studied hand layup process rpm process any process which we have seen fibers stacking follows this sequence.

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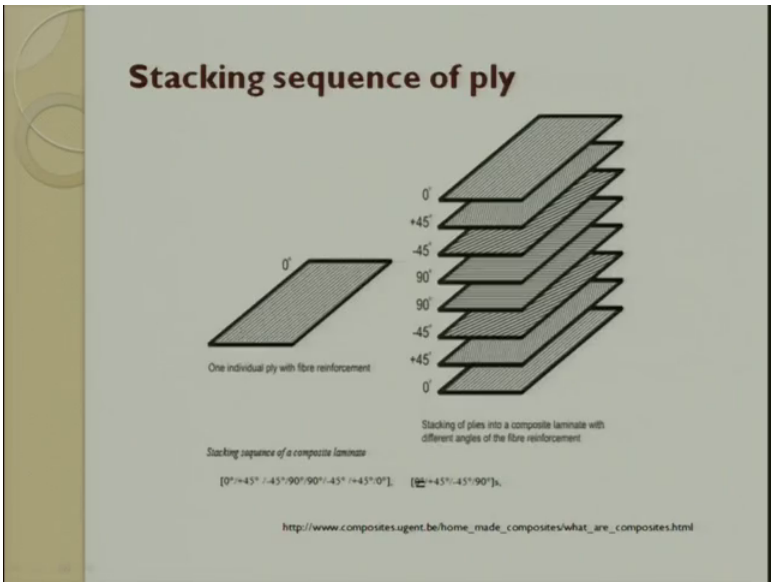

So, stacking sequence of ply. So, this is 0, and I have put one more example here I have also explained this example here. So, so this is a equal to sign which comes here, so 0 plus 45 minus 45, 90, 90 minus 45, 45, 0. So, here it is 2 times getting repeated. So, here you should see does it follow symmetry 0, 0, 45, 45 minus 45 minus 45 90 90 yes. So, it follows a symmetry. So, what I do is I try to cut here. And then I write this and I say it is symmetry so that I can get the orientation.

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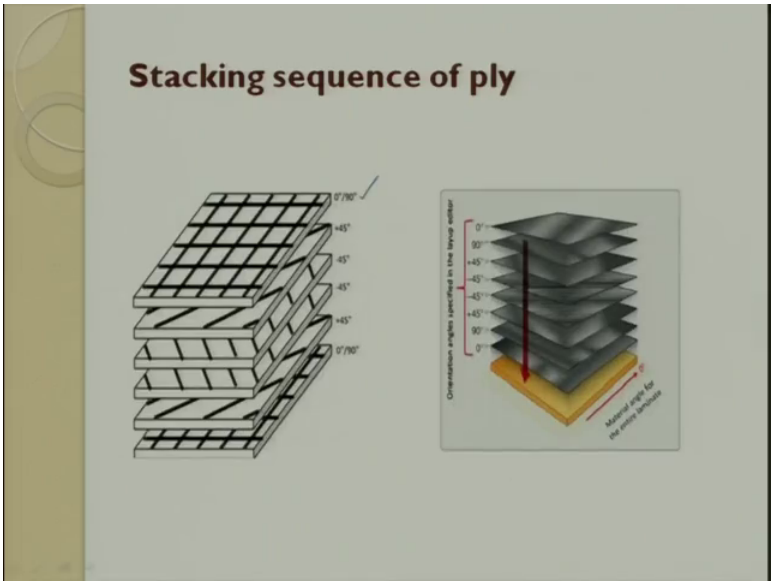

So, this is 0 90. So, this is 45, this is minus 45 minus 45, 45 and this is 90. So, this is what is represented here.

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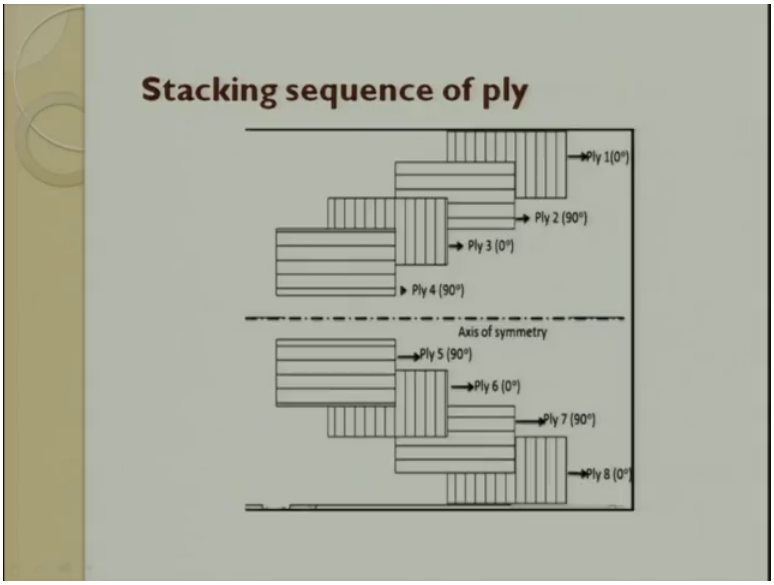

So, another simple example. I am repeatedly putting this example, because this will try to reinforce the clarity in your stacking of sequence which is very, very important. When you do calculations also people some time make mistakes in this. They try to make mistakes in their orientation angle and then when they do calculation e 1 1 e 2 2 all these things changes.

So, 0, 2, 0, 90, 0, 90, 0, 90, 90, 0, 90, 0 symmetry is followed. So, if you look at it. So, what is the big deal? The big deal is if I make different panels you look at different panels made by it, and look at the deflections. What you get depending upon the orientation, you see the deflections whatever you get in meters. So, there is a big difference, if you change the stacking sequence and try to get the required output that is what I said, this plays a very, very important role in manufacturing. And when you do analysis also this plays an important role so that you can meet out the function requirements.

So, with this we try to come to the end of this stacking of sequence, this was based on lot of request from the students saying that sir can please explain. So, I have put some examples for your better understanding. So, with this we come to an end to thermoset processes. So, next class onwards we will start with thermoplastic processes.

Thank you.