Advanced Composites

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Lecture – 69
Introduction of Short-Fiber Composites

Hello a very happy Navratri to all of you. Today is the 3rd day of the ongoing week which the last week of this course. And what we will do in the remaining part of this course that is starting from today till the last day of this week. That is that we will be switching gears and we will discuss some important aspects of the behavior of Short-Fiber composites. So, this is the switch off gears and the reason we are doing this is that in a lot of applications in very significantly large number of applications.

These short fiber composites with fibres oriented in all sorts of directions that is randomly oriented they are used. For instance if you look at in boats or in a lot of fiberglass applications, doors, the structural applications, a lot of places these composites which are used have two important properties or characteristics. One that the orientation of fiber's is randomly oriented, and second that the length of these fibres is relatively short. So, it is not the length of the fibres is not long. Now why do we what is the need of these composites. So, let us discuss a little bit about the need of this composites.

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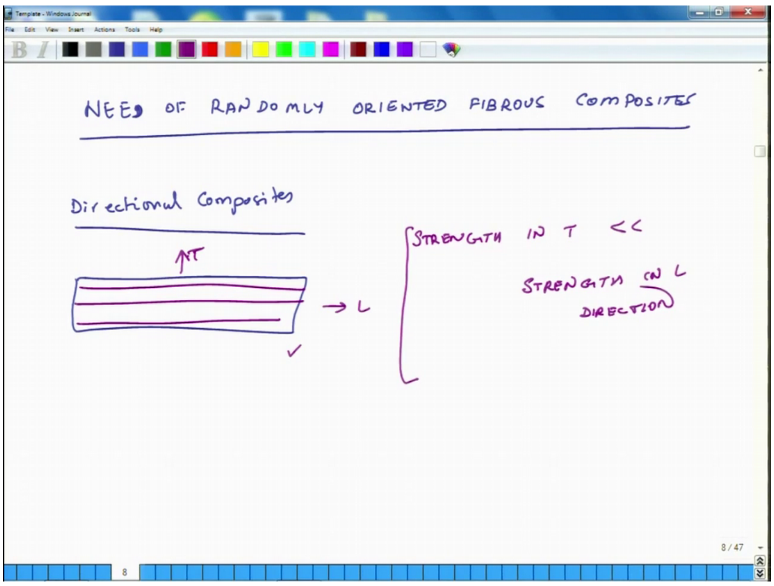

So, need of randomly oriented fibrous composites. So, we know that directional composites, so what is an attribute? Suppose we have just a single layer so it is a unidirectional composite and all the layers let us say are like this ok. So, this is my L direction and that is the transverse direction and we know through this course and also the course earlier. That the strength in T direction is very less compared to strength in L direction.

So, if we have a unidirectional composite and if we know that in real application it will only see forces in the L direction, then it make sense to use this kind of a composite. But if in real applications even if by chance there is a possibility that there may be significant amount of loads which the composite will see in T direction then, this composite is going to fail immediately. So, direction composite are particularly useful when we are fairly certain that the nature of loads is such that it can be managed by orienting by strength of the composite in a particular direction.

But if you are not certain about it, you know because of random sequence as whatever, then having these types of composites may be a risky fair so that is one. So, there are lots of applications where you may have randomly oriented loads and in those types of situations if you try to use directional composites then they may not be advantages. The other thing is, the other reason there is a need for direction there is randomly oriented composites.

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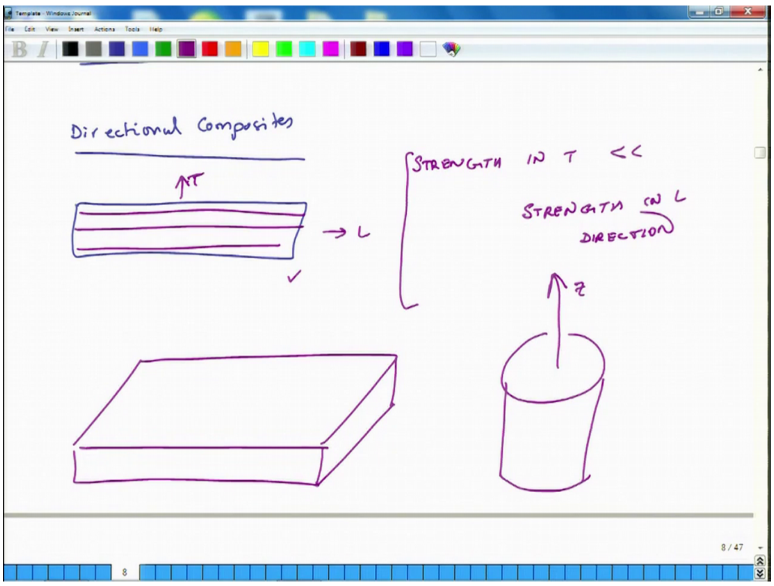

Suppose I have a laminate, now this laminate could be either flat or it could be in form of a cylinder or whatever. Now each layer has a particular fibre orientation and if suppose I make a cylinder out of it. And suppose I have in this case the fibres are oriented on the surface layer; suppose on the surface layer the fibres are oriented in a particular direction let us say they are of oriented in the z direction.

Then the outside surface will be strong in z direction, but it will be weak in the hook direction. And on the surface you may have some accidental load so support something strikes on it or some bending happens, or whatever. So, the surface layers are always in directional composites prone to failure if there are loads which can get exerted on the surface layer in the transverse direction.

So, this issue is also there, so even there may be cases where load direction of loads is fairly certain, but even then because of the presence of surface layer this problem may be there. And the third reason is that when we face corrosive atmospheres suppose the atmosphere in which the composite is working is corrosive. Now this corrosion is going to happen in from all directions, it is not that the chemical corrosion will happen only in one direction.

So, in that context you need properties at least related to corrosion which are equally strong in all directions. So, theses are several reasons why randomly oriented fibres of some advantages which are not offered by directional composite. That does not mean that randomly oriented fibres are superior was vis a vis directional composites.

But for certain application which is quite large, directional composites offers advantages which composite randomly oriented fibre composites offer certain advantages which directional composites do not and vice versa so this is the overall context. Now, how do we make directional this randomly oriented composites there made by several processes. One so we have discussed this in the introductory course introduction to composites. But very quickly in a minute or so we will just go over it.

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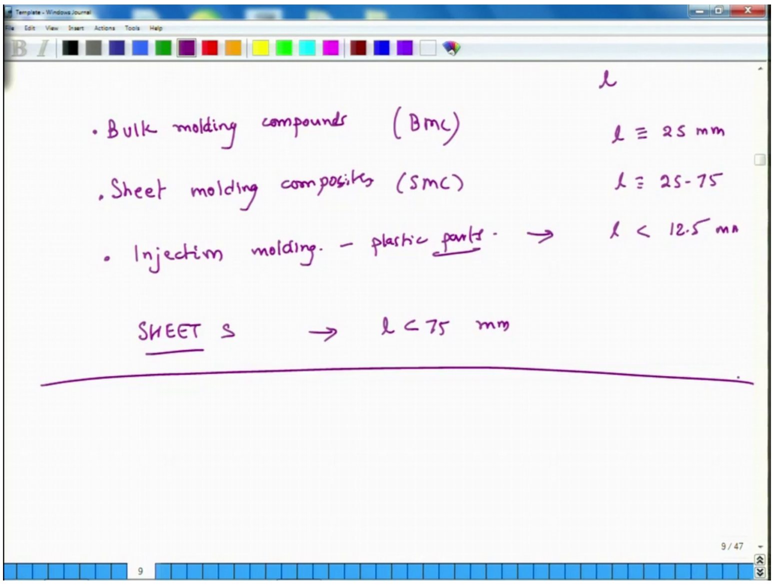

So, one is by use of bulk molding compounds, the second method is by use of sheet molding compounds. So, what is in bulk molding compounds? You get a block of material which is a mixture of the matrix material the reason and fibers and in this fiber's are oriented in all sorts of directions. These fiber's are small in length, they are not very long so it comes has some sort of a DOU. And you shape this DOU in whatever form you want and you make a composite out of it.

So, that is why it is known as bulk molding compound because it comes in a bulk form, so these are BMC's. So, you make the right form and then send it through some curing cycle by subjected it to some temperature and pressure and all that and you get the composite which you want. And then there are sheet molding compounds where composite comes as a sheet. Now, the sheet molding compound and there also the fibres are oriented in random they are randomly oriented.

But the material comes in form of sheet so you take the sheet and if the surfaces of some sort of sheet metal type of a surface if it is thin and does not have very complicated features. Then you can use this sheet molding compound also to fabricate these composites so these are known as SMC's. And the third method is through the process of injection molding.

So, this is typically used to make plastic parts. So, what happens is that typically in India, when we try to make plastic parts a lot of plastic parts. For instance this part is made up of plastic; how it is made is first you make a mold of it. So, the mold has the top side and the bottom side and the molds cavity is basically the negative of this the negative. So, wherever I see a whole there is a solid there in the mold, wherever I see is material there is space there.

And then you get plastic material and this plastic material comes in form of pellets. So, these are small pellets and you heat these so you put them in hopper and the pallets come through some tube. And as it passes it is heated and it is so as it heats this, this plastic pallets let us become very soft and fluid in nature. And then the flow and this flow is exerted very high amount of external pressure.

So, all these pellets in a fluid form they come and fill up all the space in the mold. And then once the mold is full you stop the flow and you remove the top half of the mold. And then you pull out the material or the part which was fabricated. So, this is how injection molded parts are developed. Now in context of randomly oriented composites their lots of times these pellets are not just pure plastics, but they are impregnated with randomly oriented fibers.

So, when you are heating those pellets you get basically plastic material in fluid state, in molten state. And in that fluid you also have randomly oriented fibres. Now when these fibers flow through the pipe line because the material flows and it flows through some pipeline to enter the cavity. So, as they flow through the pipeline, even though initially their orientation is random. But as they flow through pipe line this somewhat get aligned with the direction of the flow.

So, in injection molded for plastics there is some orientation it is not 100 percent aligned in the direction the flow because the duration of the flow is not for several minutes, but it may be for few seconds. But that amount of time is sufficient to ensure or to cause some sort of directionality in the fiber orientation. But still by and large these can still be considered as randomly oriented composites. So, in injection molded composites; so what the other thing I like to mention is that what are the length of fibers, typical length of the fibers.

So, in injection molded composites it is l, is less than about half an inch 12.5 millimeters. Then in sheet molded compounds the value of l is between 1 is to 3 inches. So, this is from 25 to 75 millimeters. And then bulk molded compounds the value of l is about 25 millimeters about an inch. And then there is another way to make these randomly oriented composites is through the sheet process sheets.

So, what do you do you have a nozzle through which risen comes. And in the nozzle through another end you also inject small chopped fibres. And there is a mixing part in the nozzle mixing unit in the nozzle. So, there reason in fluid state and these fibres they gets mixed. And that entire thing is then spread on some surface on which you can deposit this mixture of raisin and fibre in some sort of a sheet from.

So, so you can generate sheets of fiberglass and these sheets may not be necessarily straight. If you have a curved surface on which you are depositing then the sheet will be the curved it will be carved in its profile. And that is how a lot of times these big things like swimming pools or boats and things like that. They are made that you first make some sort of a surface and on that surface you spray this mixture of raisin and fibers. So, in this also are fibres are initially oriented in all sorts of directions.

But as they are sprayed they tend to get aligned with the direction of the spray. But still by and large they are still randomly oriented and in these sheets the length of the fibres is much larger. So, it is sometimes more than 75 millimeters or more than 3 inches. So, this gives you some idea so this is actually I am sorry it should not be more, slightly less than 75 millimeters or so. But in all of these cases the length of the fibres is not more than something like this is about 3 inches.

So, we will certainly not called these types of composites which have fibres orient which are about this long as continuous fibre composites because they are mechanics starts changing significantly. So, this is some background information about fibrous composites. The next thing what we will do is, we will start developing some mathematical relations and terms of how to predict their bulk modulus. So our method will be fairly straight forward first we will.

So, what is our n goal are n goal is to get an estimate of the Young's modulus of a randomly oriented fibres composite which has short fibres which has short fibres. So, our goal is that what is the Young's modulus of the composite which has randomly oriented fibres and also with the where the fibres are relatively small. So, when I say small it is less than 3 inches. And the way we are going to do is that first we will look at short fibre composites, but you look at these fibrous composites where the length is small.

But you will not consider the orientation to be random, but we will consider directional composites. And then using some mathematical approximations the knowledge we learn from mechanics of directional short fibre composites we will use that to calculate the modulus of randomly oriented fibres composites; so this is our overall game plane.

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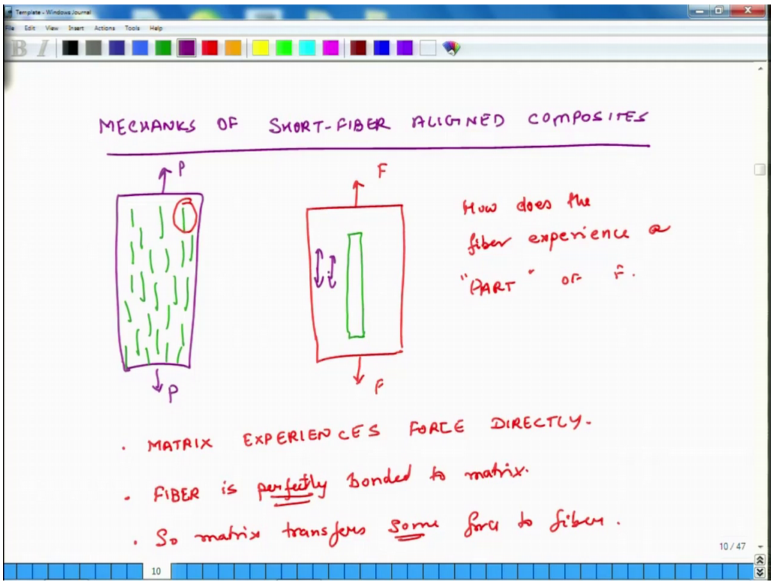

So, the first thing we will look at is mechanics of short fibre aligned composites or you can say directional composites. So, what does that mean that you have a sample? Then here the fibers are relatively short in length but all of them are aligned in the length direction. And what we will see is we will develop some mathematical models which we will tell us about the importance of the length of the fiber. And how it influences the strength or the modulus of the fibre. So, if we just consider one such fibre which is embedded in a c f matrix then it looks like this.

So, this is the matrix and here the fibre is embedded in it. And if I am pulling in the length direction by I am applying some force. So, the same thing is happening here also so I am applying some force. And the fiber also experiences a part of this external force. So, the matrix gets pulled so the point is how does the fibre experience a part, it will not experience all the force a part of f force ok. How does it experience a part of it? And if you look at this picture the answer is simple.

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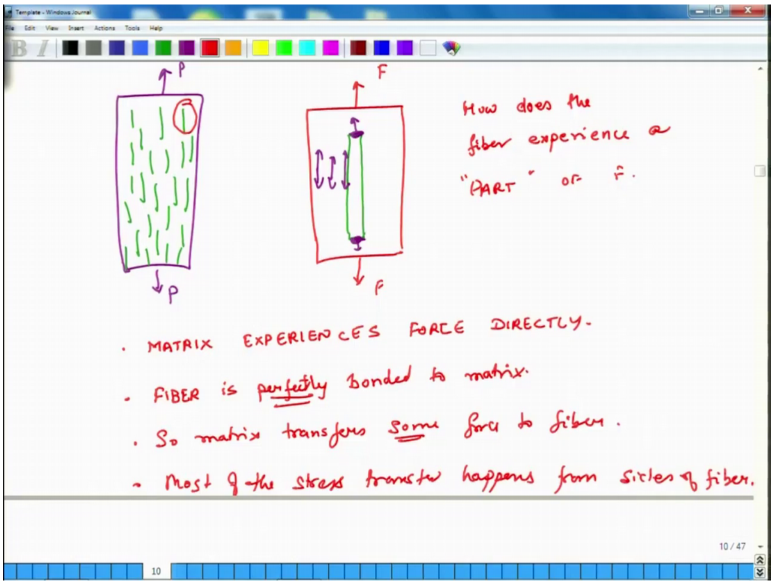

That first matrix experiences force because that is coming in contact with the force directly, it is directly touching the force. So, experiences force directly. And then the fiber is so here we are assuming that it is perfectly bonded to matrix it is perfectly bounded to matrix. So, matrix transfers some force to fiber ok. How does it do that where when you are pulling the matrix essentially there is some stretching the there is some stretching happening everywhere.

So, matrix is trying to stretch everywhere and it is also trying to stretch at the bond at the adjacent surface between the fibres. So, matrix is trying to stretch and fibre is rigid or it is very stiff compared to matrix. So, fibre is resisting that, but there is a perfect bond between the matrix and the fibre. So, the matrix transpose a part of the force to the fibre through this process it transfers.

So, this is known as the stress transfer it transfer the matrix is transferring. And this happens because there is a shear stress at the interface of the fiber and the matrix. It is shear because the forces is in x direction and also the length of the fibre is also in the x direction. So, it is shear stress you may also wonder that there may be perfect bonding at the edges of the matrix edges of the fiber.

So, if it is pulling in this direction it will also transfer some load from the ends. But in general not a lot of load gets transferred from the ends primarily because of two reasons. One is that the surface area of the end of the fibre is extremely small. So, even if there is a very good bond between the fibre and the matrix the surface area is not large enough so, that is one reason.

And the other reason is that these bonds between matrix and fibre they are very good in terms of resisting shear forces so ok. So, if you take some any glue and if you burn two pieces of metal or two pieces of material and you try to slide them you will be very it will be very difficult to slide them. So, because a lot of adhesives and then this case the matrix is the adhesive they are very strong in terms of shear resistance shear forces.

But if you try to rib them off like this, there they have to resist tensile forces. And a lot of these adhesive bonds are not good in resisting tensile forces. So, at the ends, the bond experiences tensile stresses and it breaks very easily breaks very easily. So, not a lot of stress transfers happen from the ends, but a lot of stress transfer happens from the edges or the cylindrical surface of the fiber. So, this is third point we will make most of the stress transfer happens from sites ok. It happens from the sites of the fibre, it does not happen from the end.

So, this is where we would like to stop today. We will continue this discussion on stress transfer tomorrow as well. And we will see, we will develop some mathematical models which will help this as understand this process of stress transfer in a much better way.

Thank you very much. Bye.