Introduction to Composites
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Lecture – 19
What is an Appropriate Fabrication Process of a Composite?

Hello, welcome to introduction to composites. Today is the start of the 4th week of this course and what we plan to do over this entire week is discuss different methods which are used to produce composite materials and structures. So, over the last several weeks we have discussed some introductory information about composites, we have discussed different types of fibers, different types of matrixes some details on additives which are used in during fabrication of composites and now we will finally, start discussing how are overall composite structures fabricated.

We expect that this discussion would be over by the end of this week and once that is done then we will move into the second phase or second part of this course, which is detailed discussion about the mechanics of composite materials. So, 1 3rd of the course is dedicated towards processing and materials or aspect of these composite materials and structures and the remaining 2 thirds is will be focused on the mechanics of composite materials.

So, we will start discussing how are composites fabricated? But, before we start that discussion we should have some; I would like to draw some contrast between how our traditional structures fabricated from regular plastics or metals and then how are composites fabricated? So, there is a very fundamental difference between these 2 classes of structures. So, suppose I want to make structure of let us say steel, let us say I want to make a table you know made the of steel.

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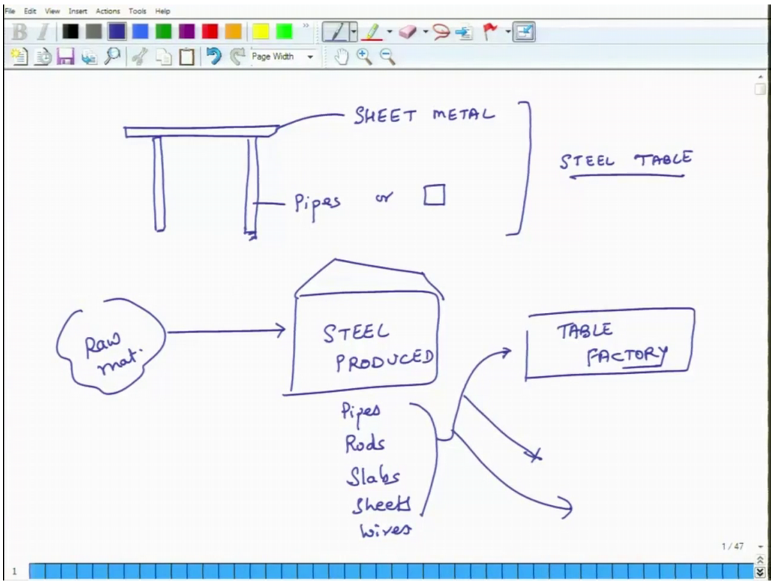

So, the table which has made up of steel would consist of what? So, I want to make a table, so it will have a top and it will have some legs basically. So, what do I do? To make the top typically a lot of these tops are made from sheet metals and the legs, so this is the leg and typically these legs are made up of pipes or maybe some other cross sections maybe some rectangular cross sections. So, this is how a regular steel table is configured.

Now, for purposes of fabrication we will use steel because it is made up of steel and so what happens is that you have raw materials, which are used to make steel the material itself all these raw materials go to a factory and here steel is produced. So, the material is produced in some facility and in this facility or in several facilities you may be producing pipes, rods, slabs, sheets and so on and so forth wires and then all these materials then go to different application areas.

So, in this case this these materials go to the factory, where the table is being produced. So, this goes to the we will call it the table factory. So, raw materials they get fabricated into standard you know forms pipes, rolls, sheets, slabs, wires and so on and so forth and these simple shapes are then used in factories to make different components.

So, you will have thousands and lakhs of different factories where individual components are produced. So, the point what I am trying to make is, that the material itself is produced at 1 stage and the end product is produced at in the 2nd stage or in subsequent stages, this is how traditional products; the products made from traditional materials are fabricated.

Now, in case of composites it is a little different.

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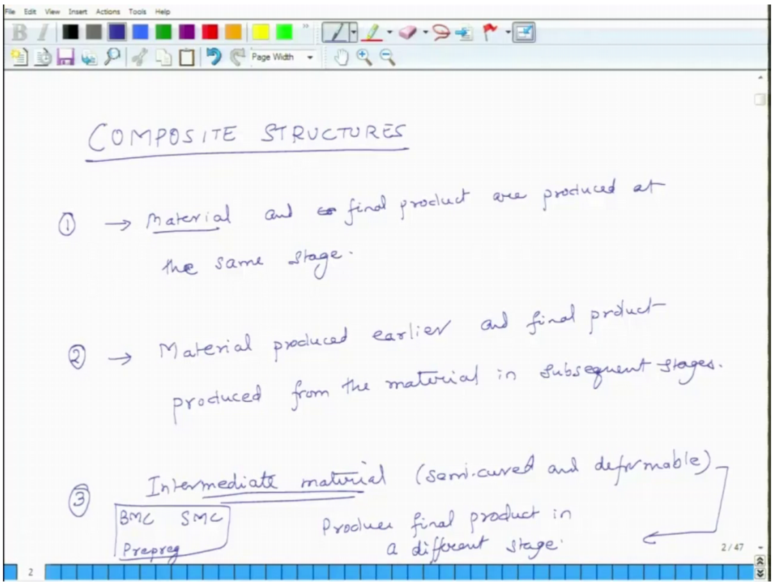

So, in case of composite structures a lot of times the final, so there are several scenarios, in case of traditional structures material is produced at 1 stage and the end product is produced at a separate stage, they are in general not produced at the same stage still, but in case of composite structures there are several scenarios, the first scenario is that materials and final product are produced at the same stage. They are produced at the same stage.

So, it is not that you first produce the composite material and then provide shape to it and you make a table out of it, it is that whereas, you are producing the composite material at the same time you are also putting it in the final form and that is how you are producing a table made up of composite material, so this is the first scenario. The second scenario is similar to what we discussed earlier in case of traditional structures. So, here material produced earlier and final product is produced from the material in subsequent stages.

So, the first scenario is that final product and the material are being produced at the same stage. I will give you a couple of examples, suppose you want to make a boat of fiberglass. So, it is not that first you get fiberglass from some other place and then you make a boat, a lot of times you take a mold and you spray a mixture of glass fiber and matrix, which may be polyester or some epoxy around that mold and then make sure that the mixture sticks to the mold and it acquires the shape which you want and then you somehow cure it.

So, the composite material is being produced in that final stage stealth and also the boat, which is the final product as well as the composite material they are being produced at the same stage. Another example of this would be, suppose you want to make a large plate, you know a rectangular plate of composite material, it is not that you will go and buy large sheets of composite material from the market and then you will cut it out rather chances are very large, that you will actually take individual fibers or mats of fibers, apply some resin over it and somehow cure it using a large different variety of processes, large number of processes and then you at that time you will get the final shape.

So, again the material and the final product is being reduced at the same stage and this has implications and in the 2nd scenario we said that this is something similar to conventional materials. So, in this case the material is produced earlier and then you take this material and somehow give a shape to it to produce the end product, a very good example of this would be a lot of household items like chairs and tables made up of fiberglass.

So, here fiberglass is available in small pellet forms pellets. So, in each pellet is a mixture of fiber and some thermoplastic. So, you take these pellets melt them and inject them, so you already have the raw material in form of pellets, you melt these pellets. So, you get some sort of a fluid and then you inject it at high pressure in, some molds which look like chairs or negatives or chairs and then you cool it. So, you get a chair out of it.

So, this is the second scenario and then there is a 3rd scenario and the 3rd scenario is, that you produce intermediate materials. So, these intermediate materials are not having the properties of the final material for instance a composite is made up of contains fiber composite is made up of matrix and long fibers. So, there are 2 separate parts, somehow makes them and you get composite out of it.

Now, these intermediate materials are where you take matrix, you take let us assume, so you take small fibers, you somehow mix them, you also provide a little bit of accelerator or the trigger. So, the resin starts curing, but let us say it cures only up to 50 percent. So, once it has cured up to 50 percent the whole thing is not fluid, it is some sort of a stiff, but still flexible material.

So, if you press it you can give it whatever shape you want, so this is called an intermediate material. So, a lot of times these are semi cured and deformable, easily you can give them shape. So, you produce some intermediate material and then in the next stage you produce final product in a different stage.

So, these are intermediate materials and there are 3 classes of intermediate materials I will just give their names right now. So, 1 is called a sheet metal compound or SMC, the other 1 is called BMC bulk material compound and the 3rd thing is called a prepreg. So, 3 names BMC, bulk material component these are intermediate materials. So, they are already pre mixes of fibers and matrix.

Semi cured, not cured fully they do not flow, they hold their shape, but you can give them whatever shape, so it is like dough, which you use to make [FL] or [FL] you can give it whatever shape you want and then somehow you cure it. So, BMC is bulk material compound, SMC a sheet material component and we will explain this later and then the last 1 is prepregs or pre impact impregnated resin compounds. So, this is another name prepregs.

So, these 3 classes of intermediate materials are also, there in place. So, these are the 3 ways you develop composite structures, you can use option 1, option 2 or the 3rd option. So, this gives you a broad overview of how composites are in general fabricated, the second thing I wanted to discuss is that as we are going to understand different ways of producing composite materials, we should understand; we should have an idea as to how do we select the right type of production process.

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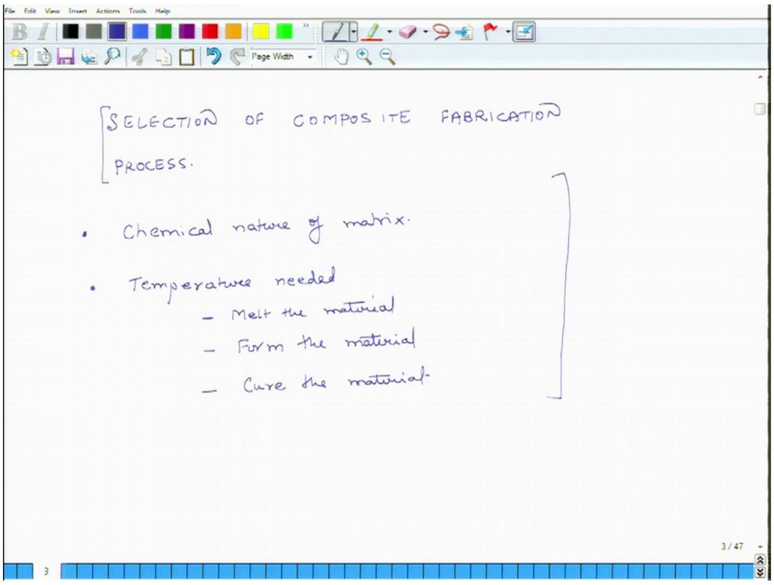

So, selection of production composite fabrication process, which type of process should we choose? There are several processes and we have to think as to what is the right type of process. So, when we do this, we have to be aware of 2 or 3 very important parameters, the first thing is that we should have an understanding about the chemical nature of matrix.

This very strongly influences the nature of fabrication process, I will give you a couple of examples. Suppose, we want to develop a metal matrix composite, so in this case the matrix is made up of metals. So, what do you want to do? You have to, you need you have some fibers and somehow you want to embed them in a sea in a matrix of a metal, how would you do it?

One way to think about it is, that you will like to somehow melt the matrix which is metal. So, you have to apply a lot of heat, this matrix material becomes molten and then you somehow put the fibers in it. Now, this is 1 process, but then there are problems associated with this process because metals melt at high temperatures, even if you take aluminum it melts at around 600, 700 degrees centigrade. So, you have to heat up the whole thing up to 700 degrees centigrade and at that temperature if you embed it with some if you put some fibers in it at high temperatures even if you take let us say glass a lot of fibers at elevated temperatures they have a tendency to react with metals.

So, you have to be cautious or cognizant of the fact that there could be reactions between the fiber at the matrix at elevated temperatures. So, again it is related to the chemical nature of the matrix, another example is that suppose you want to use thermoset reasons. So, in thermoset reasons, you have to make sure that the raw materials before the reason gets hardened, there is a reason and then there is a trigger or an accelerator or an initiator.

So, you have to mix them, you have to be aware that how fast the reaction proceeds because that will define your overall curing time of the matrix. So, again you have to understand the chemical nature of the matrix because that very strongly influences the composite fabrication process.

The second thing you have to understand is temperature needed. Now, it can it can be needed to do couple of different things and they may not be same all the time. In some cases, how high a temperature you want to melt the material? For instance, if you have a thermoplastic material you want to melt the plastic and then embed it with fibers.

So, in some cases the melting temperature is important, in other cases to form the material. So, it could be that you already have a sheet of plastic, which is already impregnated with continuous fibers and all you want to do is somehow make it soft, if it is a thermoplastic and give it a shape. So, here form at what temperature does it become soft enough, so that you can form the material into the desired shape.

The 3rd temperature could be relevant in your case is the cure the material, so this is the 3rd parameter. So, the fabrication process depends on chemical nature of the matrix and how, what kind of a temperature do you need. It could be needed for melting the material or forming the material or curing the material, it is never all the 3 in the same example, so either you have to melt it or firm it or cure it. So, these 2 important considerations play a very strong role in figuring out what kind of composite fabrication process is required or relevant for my particular application.

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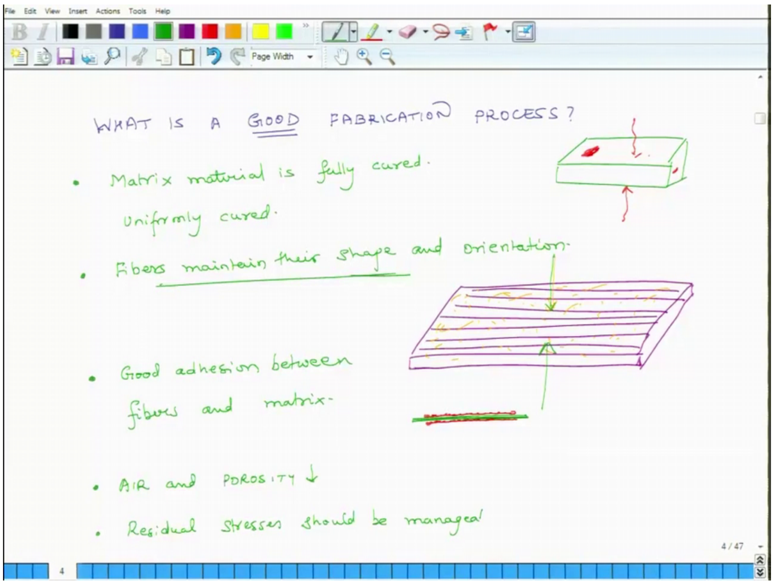

The last thing in general I would like to discuss is, how do I know whether my fabrication process is good or bad? So, what is good fabrication process? So, we will list down several requirements, it is a long list of requirements and you have to see which are particularly important in your context.

So, the first thing we have to be sure is as the process proceeds and it gets over, you have to make sure that the matrix material is fully cured. So, you do not want that in some parts the matrix remains uncured and in other parts it is overcooked and this problem of curing could happen in several zones, it could be suppose I have a sheet of composite material I want to make, it could be that maybe in this area the curing did not happen.

Now, why could it not happen? Maybe for curing I have to apply heat and as I was applying heat maybe this area was not uniformly heated, it got heated by a lesser extent, so the curing did not happen at the same time here. So, this part remained uncured, in that case the properties of the structure will vary, it will be something at this place and other thing is that place, that is not a good thing, so this is 1 important reason.

The other problem could be that maybe in the depth direction, maybe in the middle of the you know in the thickness direction, that maybe curing is not full because the heat travels from top surface and also from bottom surface and it did not it was not easy enough for the heat to reach the middle point or the interior of the composite material nicely and uniformly. So, this is very important that the matrix material is fully cured and not only it is also uniformly cured, so these are related.

The second thing is that fibers maintain their shape and orientation; they maintain their shape and orientation, what do I mean by that? Let us consider a case, so this is the sheet it is not very thick and it has long continuous fibers as I mentioned earlier along the length of the, so for some functional reason I want these fibers to be long continuous and they should be all aligned in the length of the sheet.

Now, I can 1 way I can do it as I place these fibers in this direction and I somehow also spray it with some matrix material, so this yellow thing is matrix material. So, I embed this in a sea of matrix material and then what I do is I want to squeeze out all the air, so I apply some pressure like this from top and bottom and I also apply some heat and this thing starts getting cured.

But as I apply pressure, if I do not do this job correctly what will happen is that this matrix because it is liquid it will flow and as it flows it can change the orientation of the fibers, the fibers can get bent and twisted and they can lose their original configuration and once that happens the properties of the sheet; mechanical properties will change significantly and that is not what I wanted to begin with.

So, a good fabrication process is which ensures that whatever shape I want that remains till the end, till the fibers are logged into their position this is important to understand. What else, then we also want that good adhesion between fibers and matrix. So, it could be that everything is fine, but the fibers do not stick to adhere to the matrix and that will cause a poor composite material because the transfer of load from matrix to fiber and from fiber to matrix will not be uniform and we will have purely a composite structure with poor mechanical properties.

So, we really want a good bonding and what that means is, that the chemistry between the fiber, so let us say this is the fiber and the matrix material let us say this is the matrix, this red thing which is should be such that the adhesive properties between the matrix and the fiber should be of high quality. What else, we do not want air and porosity, this should be very less as less as possible we want as less as possible because by default they will be here to begin with between fibers and we want that all when the matrix flows through it, all the air should be removed and there should not be any gaps or holes in the thing because if there is our air pockets or porosity in the system then those could act as points of stress concentration and at those locations you can have initial fractures in the system, so we do not want that.

Couple of other things, we do not want residual stresses, but this is some requirement we will never be able to satisfy perfectly because there will always be some residual stresses, so residual stresses should be manageable, they are several other things we want.

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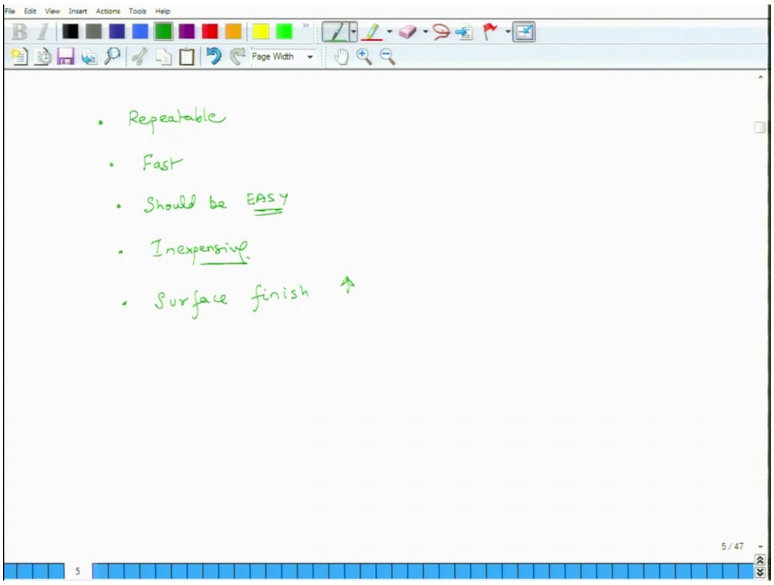

The fabrication process to be repeatable, so each time we make the same composite structure with same chemical formulation, same percentage of fibers, same matrix, we should get the same product with same mechanical properties and other properties, so it should be a repeatable process.

Then, this is important we want that it should be fast, a lot of fabrication processes involving composites take a lot of time and what that means is that if I have to produce more number of parts, I have to be make bigger buildings or large number of buildings to make the thing, but if it is faster then we need less resources to produce more number of products and the last; another 1 is. so it should be fast, should be easy.

Now, this is may sound trivial, but a lot of composite production processes are time intensive, they require several steps, they require experience on part of the uses of the fabricator. So, you need a good amount of expertise, when producing composite structures. So, this is important in that context and then of course, it should be inexpensive, the last thing is that the surface finish should be of high quality.

You do not want to see fibers or rough surfaces on composite structures, you want them to be smooth, nice looking and if they should be aesthetically appealing and smooth surfaces. So, this gives an overview of how our composite production process is different than traditional production processes? What are broad categories of composite production processes? We discussed 3 categories and as we are discussing about different composite production processes what are the important things we should worry about as we start evaluating them and learning more about them.

So, this is, this was an introductory lecture, we will continue this discussion with specific examples starting from tomorrow, specifically we will start discussing how a thermoset composite structures produced and so that is what we plan to start tomorrow, until then have a great day and we will meet once again tomorrow.

Thank you.