Introduction to Composites
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Lecture – 24
Fabrication of Thermoplastic, Metal and Ceramic Matrix based Composites

Hello, welcome to Introduction to Composites. Today is the last day of the ongoing week. Throughout this week we have been discussing different ways to produce composite materials. Today we want to continue that discussion and we will discuss how are thermo plastic composites produced and also how are metal matrix and ceramic matrix composites produced. So, we will start with discussion on thermoplastic composites.

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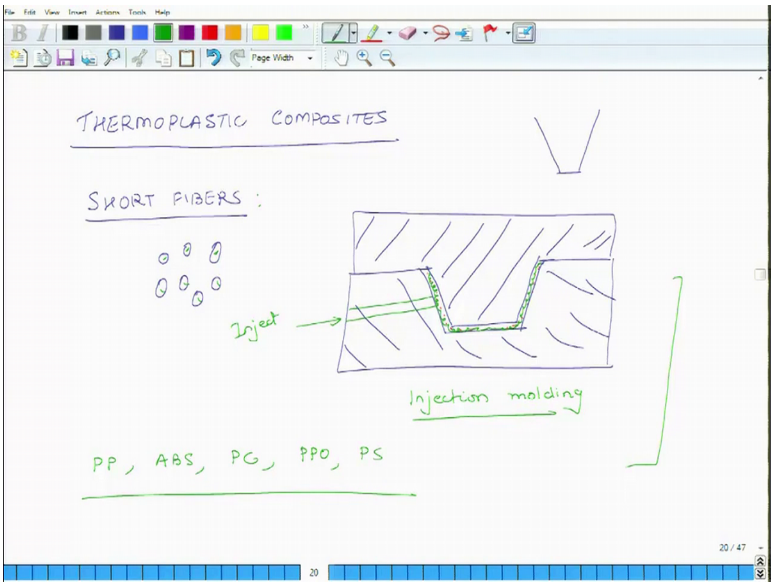

Now, these thermoplastic composites may have short fibers, they may have continuous fibers. So, first let us discuss composites which have short fibers. Now, typically when these fibers are short the raw material of these composites as I explained earlier also are small pellet us. So, each pellet has some fibers embedded into it and it is surrounded by a thermoplastic material, thermoplastic matrix.

So, these short fibers composites the way they are processed is that you take this material, heat it and because it is a thermoplastic it will melt and then a lot of times you take these materials and provide them the right form using a die, at high pressures. So, suppose you have you want to make a part like this. So, the way what you do is you have a die and you have a top part, excuse me, I will just do this again. So, you have a bottom part and you have a top part.

So, this is the top and this is the bottom and of course, between the top and the bottom you have a cavity and this is the gap you want to fill. So, what you do is you have a passage for composite to flow in and from here you inject at very high pressures molten form of this composite molten form of these short fibers composite. So, all that material flows in and occupies the cavity and then you let it cool and then you remove the two parts top and bottom part of the die and you get a material out. And the reason this can happen is because we are talking about thermoplastics, we cannot have injection molding in thermoset systems. So, this process is known as injection molding.

And a very large number of regular parts products chairs pipes all these things not pipes or complicated shapes they are made from this particular process, this is a very popular process. And common thermoplastics which are used have metric systems made up of either polypropylene or ABS or poly carbonates or poly phenylene oxide PPO or polystyrene and so on and so forth. So, these are very common thermoplastic matrix materials which are used and they are embedded with fibers. So, the fiber adds some strength and stiffness to the system. So, that is the general process used for short fiber thermoplastic composites.

Then we also have situations where we may have short and or continuous fibers.

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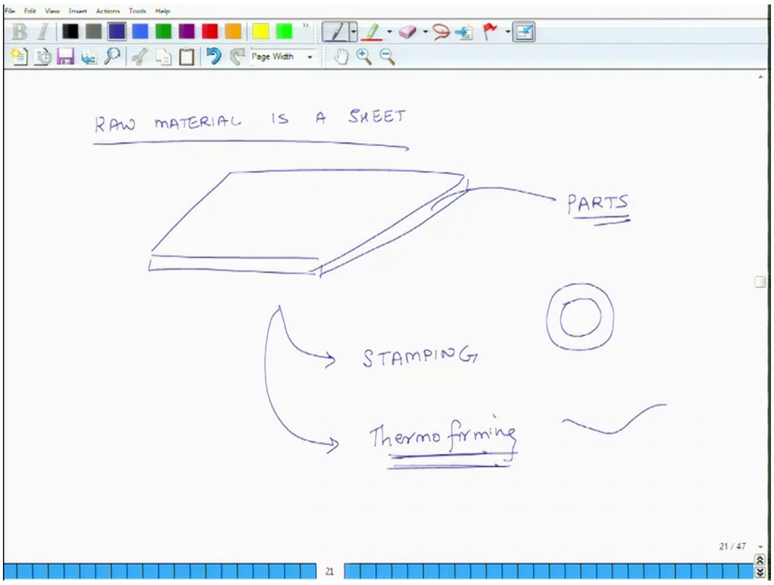

So, they are the raw material is a sheet. Now, this is different than the sheet metal compound which we talked about because in thermoplastics we do not worry about curing right, it is already if it cools, it is cured, if it is hot, it is fluid, fluid right. So, here the raw material is a sheet and the sheet is of some thickness. So, this comes in different thicknesses it comes in different thicknesses you can get it, and the sheet may or may not have continuous fibers it can have randomly oriented short fibers or you can have continuous fibers it depends what you want.

But you can use this sheet to make parts also. And how do you do that? You can do it in two ways, one is through stamping. So, suppose from this sheet you want to make a ring. So, you make a tool which stamps out this ring and through the stamping process you can stamp out this ring and you will get a part of the shape you want, if the this part is flat or you can also have a process known as thermoforming. So, what happens in thermoforming? There is a die, a positive side of the die a negative side of the die you put a sheet in between and at a higher temperature and the temperature is not so high that things start flowing, property of thermosets thermoplastics is that at higher temperatures below melting point things become soft. So, you make the things soft and at an elevated temperature you press it into the desired shape, you press it into the desired shape. So, that is called thermo forming. So, then you can make bowls and things with moderate curvatures, moderate curvatures and you can get this. So, this is thermo forming. And this can again have short fibres which are randomly oriented or continuous fibres.

And the third process associated with thermoplastic matrix composites is where we have long and continuous fibers, we have continuous fibers and in this case we may have sheets of with fibers of specific orientations and these could be thin sheets. We can stack them upon each other in the orientation we warm and again when we apply heat and pressure diffuse and we can make a layered structure from this. So, this is the third process.

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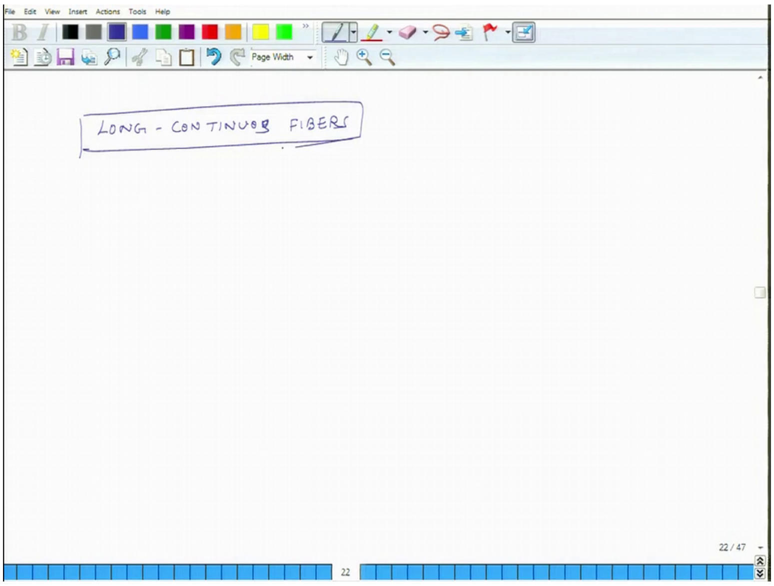

So, this is what I wanted to discuss in context of thermoplastic based composite materials next, for the next 5-10 minutes we will discuss metal matrix composites.

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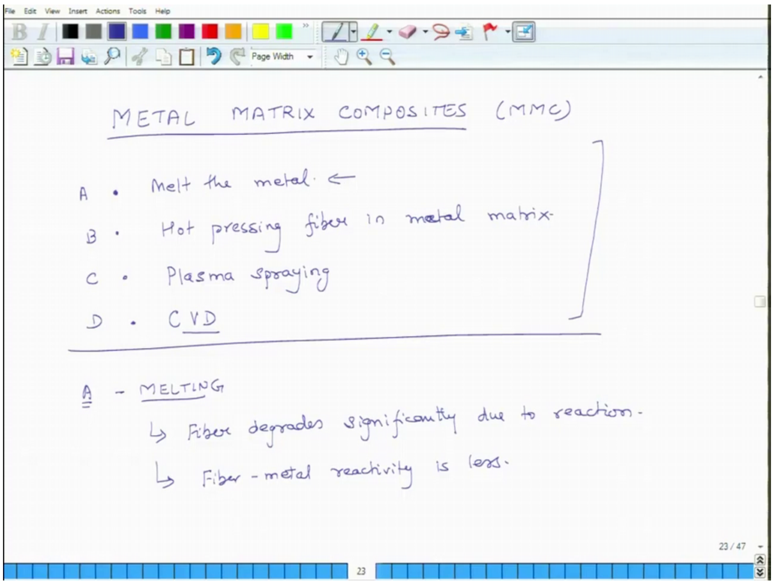

Metal matrix composites or MMCs. So, in metal matrix composites we all know that metals melt at higher temperatures. So, we have to use high temperatures for processing metal matrix composites.

Broadly speaking there are two ways to put fibers which may be non metallic in nature. So, your aim is to embed these fibers in a sea of metal. So, one way is to melt the metal, this is one way and we will discuss both these methods in detail somewhat. The second method is by hot pressing fiber in metal matrix, this second way. The third way is that you can have fiber and on top of it you can spray molten metal. So, that is known as plasma spraying and there are reasons people will come up with these sophisticated procedures and we will briefly discuss this. And the fourth way is CVD, chemical vapour deposition we have discussed this earlier.

Now, in principle you melt the metal and put in the fibers looks to be the most simple and straightforward method. But then there are other methods also and their reasons people have developed these methods. The reason for is that this first approach has some significant limitations. So, this is A B C D. So, A relies on melting. So, if you have a molten sea and add in a molten sea of metal suppose you put in silicon fiber or carbon fiber and then let it cool it will be exposed to high temperatures for a long period of time. Now, a direct consequence of that could be that at elevated temperatures a lot of these fibers tend to chemically react with the metal at elevated temperature, maybe not at so much as the room temperature, but elevated temperature. So, you have melted a molten sea of metal and you put in silicon fiber it will react and it has a long time to react. So, as a consequence fiber degrades significantly due to reaction.

Now, this reaction may vary from fiber to fiber, but this could happen. So, that is why in several cases this melting approach is not a great option. So, what do you do? So, this approach works. So, this melting approach works if fiber metal reactivity is less then this approach works, if it is very high or if it is high then we do not want to use this approach.

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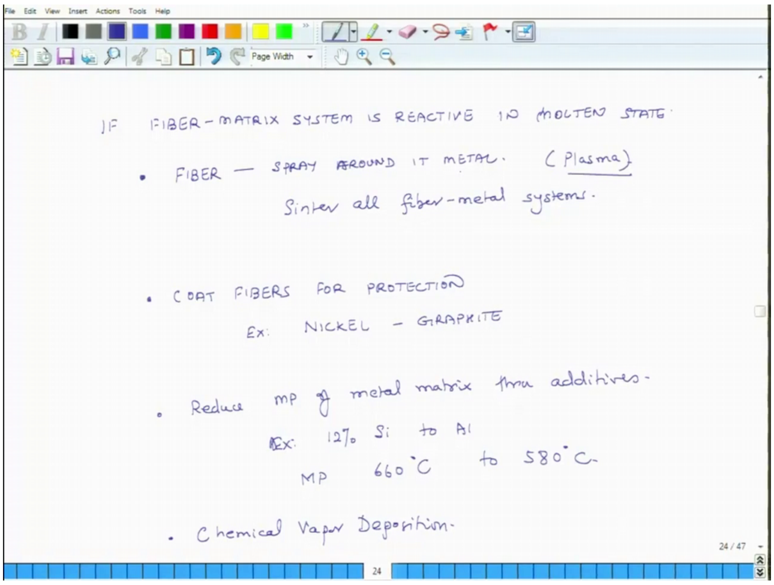

So, if the fiber matrix system is reactive, if fiber matrix system is reactive in molten state then what do people do then people use other approaches. So, what do they do? So, one way is that you take an individual fiber and you spray it, spray around it metal. So, this is that plasma deposition. So, it is spray around it the metal, so this is the plasma approach. So, you have lots of. So, it is still contacting molten metal it is still contacting molten metal, but because it is being sprayed the time it gets exposed to very high temperature is very less because spray cools very fast.

So, the exposure time is less. So, the reaction between fiber and metal is not that for not that much you know because the time duration is short. So, you have a lot of fibers which have metals around them and maybe then you can immerse the whole thing in a c or you can compress them at elevated temperatures or center them and as a consequence the whole thing gets compacted. And then so, in this case you spray it around the thing and then center all fiber, metal, systems this is something like powder metallurgy that kind of a thing or the other thing is that when you have a sprayed it around, there is fiber inside, there is metal inside and because it is very thin it is very flexible.

So, you can give it the right shape you can give it the right shape and then you apply pressure and you center it. So, that is the other thing. What else we can do we can coat the fibers to protect for protection, for protection. Example a lot of times nickel is used to coat graphite fibers. So, you nickel is and then you immerse it in aluminum matrix. So, the melting point of nickel is higher than that of aluminum. So, it does not go away and then you immerse it in aluminum matrix and then you have a composite with graphite fibers and aluminum matrix or aluminum alloy matrix. What else we can do?

We can somehow reduce the melting point of metal matrix through some additives. For instance if you add example you add 12 percent silica to aluminum and mp melting point goes down from 660 degrees centigrade to 580 degrees centigrade. So, these are all different strategies you use. And the last option is CVD, chemical vapor deposition.

So, this is another thing you can use. So, these are again very sophisticated methods of producing metal matrix composites. They are very expensive methods, but we do not use these types of composite materials in our day to day applications. So, for those types of applications cost is not an issue, but for exotic applications as in space systems, aircraft systems and high temperature high pressure systems these expensive methods are used so that we can have a composite system which can survive higher temperatures maybe up to 5 6 700 degrees centigrade. And then if we need even higher temperatures then what do we do? We use ceramic metal matrix.

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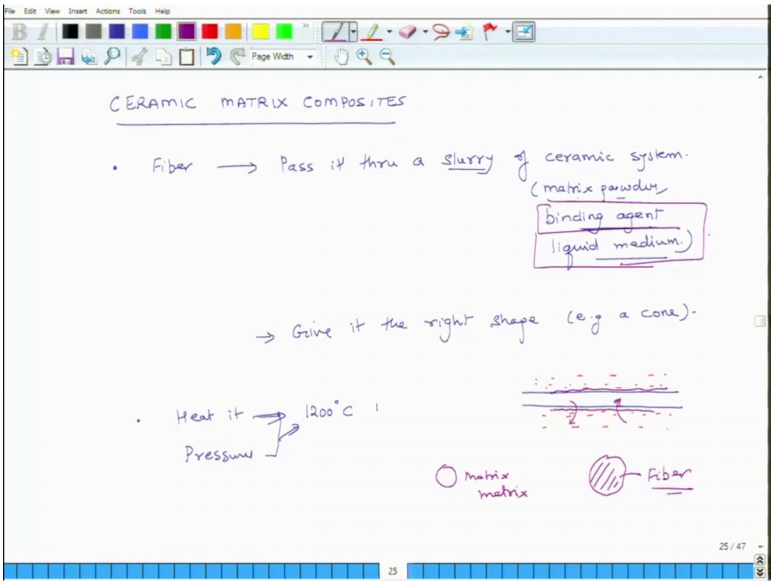

So, again our discussion will be very brief, but what people do is that. So, you have fibers and you have a matrix. So, a lot of times people use a two stage process. So, first thing you take fiber and you pass it through slurry, slurry of ceramics system slurry. So, what does slurry contain? It contains the matrix powder, it also contains a binding agent and it also contains a fluid medium, liquid medium.

So, at room temperature you have fiber let us say graphite fiber or metal fiber and you pass it through slurry and slurry is a mixture of matrix powder, a binding agent and a liquid medium. So, now, you have the slurry is sticking to the fibers, slurry is sticking to the fibers and you are doing this in tension. So, the fiber is being pulled in tensile state and it goes through slurry. So, it is straight, it is straight and then you can suppose you want to make a cylinder, so you make give it the same shape using some mandrel or something like that.

So, you pass it to the slurry and then you give it the right suppose you want to make a nose, missile nose. So, you can wind it in that shape, give it the right shape, e.g. a cone. And this thing can still differ because it is not compact yet and then you heat it, and you heat it in some sort of an inert and atmosphere and so you heat it, maybe something like 1200 C to maybe even higher degrees of temperatures and when you fire it all this liquid medium goes away winding agent keeps things together and then it evaporates and the only thing which is left is in that compact from the matrix and the fiber and it is held in that shape. And while you are heating it you also apply pressure.

So, you have a high strength metal, no ceramic matrix composite in shape and then once you have done it. So, at elevated temperature what else happens? This binding agent it is job is not to bind the matrix and the fiber at elevated temperature the binding agent is not unstable is not stable it decomposes the elevated temperature, it keeps things in place at regular temperatures.

But when you heat it what happens is that let us say you have a fiber. So, I am going to enlarge the cross section of the fiber and then you have of course, the matrix at elevated temperatures what happens is that there is diffusion of ceramic material of the fiber material into matrix and matrix material into the fiber diffusion and diffusion becomes fast at higher temperatures. So, once that diffusion happens there is bond which gets developed at the interface. So, all this extra stuff binding agent and liquid medium, it goes away and the only thing you are left with is matrix and the fiber and that is the product you can use at very high temperatures. So, this is important to ensure.

Now, one important parameter is that this diffusion will be effective only if the size of the matrix material see it has to go into what the fiber right and this is your fiber. So, this is my fiber cross section this matrix material will diffuse easily into the fiber only if the size of the matrix material is smaller than that of the fiber right. So, you really want very fine matrix material powder particles. So, you have to make sure that when you are making the powder of the matrix material it is ground to extremely super finished, that will ensure good diffusion.

So, this is how ceramic matrix composites are developed, and again today's discussion we did not go in great details because these are very exotic and special applications, but I just wanted you to have some idea as to how these different categories of composite materials are produced. And this concludes our discussion on production and fabrication of composites. Starting next week we will move into the next phase of our course and we will start discussing the mechanics of composite materials and structures. So, till then have a great time and I look forward to seeing you on the coming Monday.

Thank you.