Introduction to Composites
Prof. Nachiketa Tiwari
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

Lecture - 17
Thermoplastics and Metals as Matrix Materials

Hello, welcome to introduction to composites. Today is the fifth day of the ongoing week and what we plan to do is have some discussion on thermoplastics as matrix materials and also hopefully we will cover some other matrix materials such as metals and ceramics. So, this is our overall scope of discussion and we will start by discussing.

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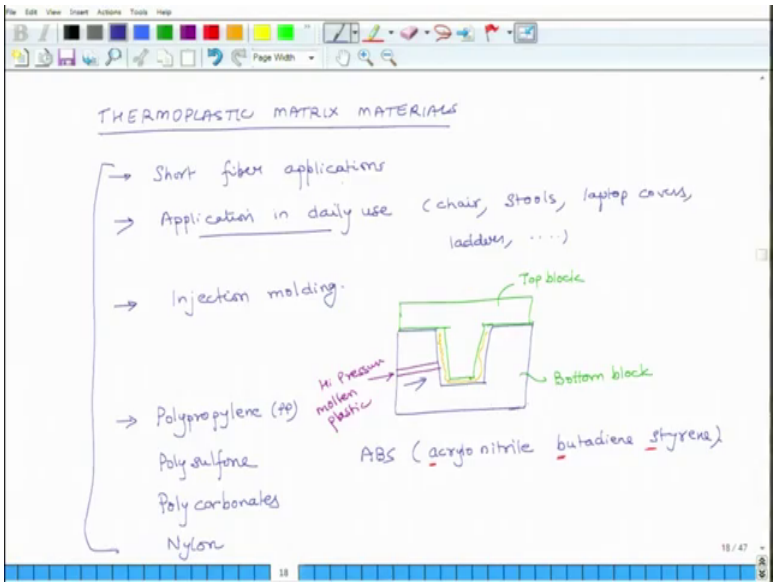

Thermoplastic matrix materials; by enlarge thermoplastic matrix materials are used when we have short fibers.

So, this is in general whenever we want. We have short fibers; we use thermoplastic matrix materials actually. Maybe there is a better way of saying that a lot of thermoplastic materials are used to make regular products. For instance chair, stool, ladders, parts of table, laptop covers and things like that. A lot of thermoplastics are used to make these day to day regular things and in some cases the part may not be stiff enough or strong enough. So, what you do is that in those types of. Suppose you have a plastic chair and most of these plastic chairs they are made from thermoplastics.

So, you want that chair to become stronger. What do you do is you inject in that plastic some small short fibers. You do not put long fibers. That is what you do. That is known as yes. Typically you put some glass fibers. So, that is why I said short fiber applications. So, they are used in applications which are in daily use chair, stools, laptop covers, ladders and things like that. These materials even without fiber the way you make these types of regular daily use products in general through a method known as injection molding. You make it through an injection molding process.

So, what you do suppose you want to make a glass which you know is some plastic glass. What do you do? You make a mold. This mold will have typically 2 parts. This is a block of steel and then on that you will put another block of steel. What you have here is a cavity. This is the cavity. So, you have one block of steel, top block, you have bottom block and I am giving you some basic idea not the detailed description and you have a cavity and in this cavity you inject this plastic through some hole.

So, that is why it is known as injection molding and you send it at high pressure and because it is a thermoplastic you heat it, you melt it. So, you have high pressure molten plastic and this plastic flows in and fills all the cavity and then you let it cool. Remove the top block, remove the bottom block and you are left with that glass which you wanted to make. This is how it is made.

Now, a lot of times if you think that this glass is not strong or suppose you are making a chair, the chair is not strong, not only you inject this plastic. But, what you do is before you inject the plastic you have this plastic. You also mix it. So, this raw material plastic it comes in small spheres pellets and if you want stronger material, you mix it with some glass short fiber glass and then you mix and then you melt it and then you inject that molten material. Which is a mixture of glass and thermoplastic into this and you get this material.

So, some of the very popular materials which are used in these types of applications are Polypropylene. Quite often it is known as PP. Polysulfone, Polycarbonates and there is a very popular material known as ABS and this is a short form of a long name acrylo nitrile butadiene styrene. That is why it is ABS. This is ABS. So, in all these different types of materials you can also have Nylon. All these materials you can mix short fiberglass because you cannot put a long fiberglass. These are small pellets and you

cannot inject long fibers. Otherwise this whole channel through which material is flowing, it will get blocked.

So, you put short fibers and you press it. When the thing comes out that product is stiffer and also stronger and it can also take higher stress and higher temperature because glass is stable at higher temperatures also. So, this is where a lot of thermoplastic matrix materials are used when we want to make short fiber composites. But, there are some cases where we use thermoplastics with continuous fibers also, but there the process is totally different is not injection molding.

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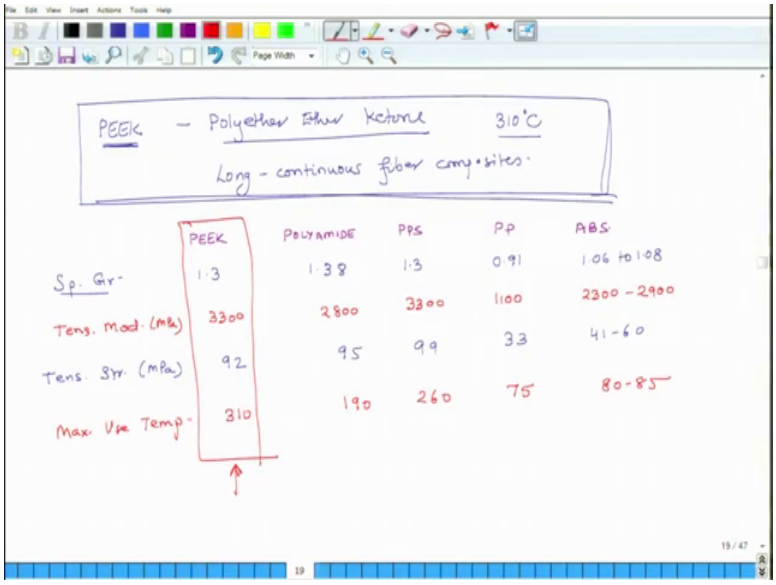

So, one very important material is known as PEEK and it is used in a lot of aerospace naval space applications. Once again what is it Polyether Ether Ketone? This is a thermoplastic material and the interesting thing about this material is that it can be used at pretty high degree temperatures up to 300 and 10 degrees centigrade. So, a lot of our thermosets will not survive this temperature, but this can survive this 300 degrees temperature. So, here for aerospace applications, naval applications a lot of times peek is used and it is used in conjunction with long continuous fiber composites. It is used with long fiber composites.

So, this is PEEK. But, here the process of production of the composite is not injection molding. It is something different. We will see that maybe next week different ways of making the composite material. Finally, in context of thermoplastics we will very quickly

look at some of the material properties. Again we will construct a table a specific gravity. So, what are the properties? These are different materials PEEK, polyamide. Remember polyimide and polyamide. They are different things. Polyimide is a thermoset material, polyamide is a thermoplastic.

Then you have PPS, Polyphenylene sulfide, Polypropylene and ABS. So, a specific gravity 1.3, 1.38 they are about the same 1.3. But Polypropylene this is very popular material for day to day products chairs, tables, glasses because it is density is very less, 0.91 Polypropylene and then ABS is about 1.06 to 1.08. The next material we will property is Tensile Modulus and this is an MPa. So, 3300, 2800, 3300, 1100.

So, see polypropylene even though it is light, it is not that stiff. But for regular applications it works and it is also very inexpensive. It is probably the cheapest matrix material available. Then we have Tensile Strength again in MPa. Tensile Strength is 92, 95. So, polyamides and PEEK have similar strength. Then PPS is again 99, but then Polypropylene would be very weak 33 and ABS is more than that 41 to 60 and the last thing I will write here is Max Use Temperature.

So, this is where PEEK is very important 310 degrees, 190, 260, 75 and this is 80 to 85. This is what makes PEEK distinctive. It can take a lot of high temperatures and that is why it is popular in aerospace applications. So, that concludes our discussion on thermoplastics. Next very quickly in a qualitative sense we will look at metal matrix materials.

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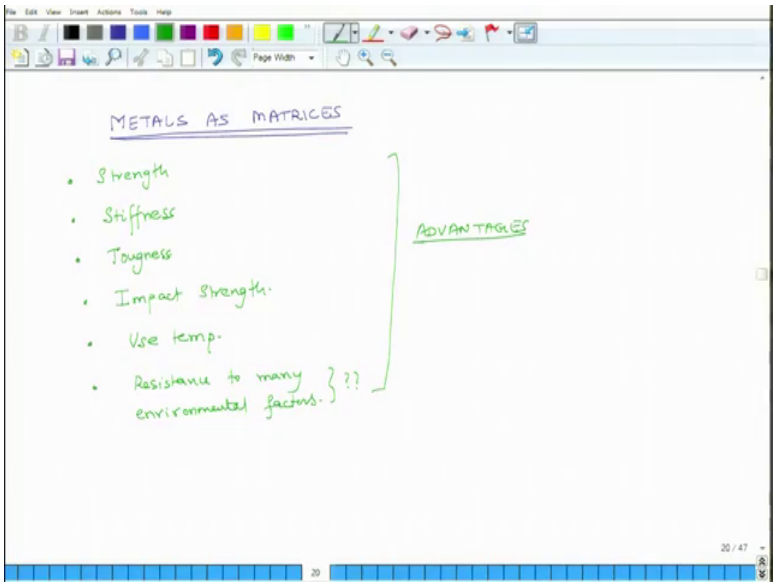

So, metals as matrices. Here we will not worry too much about point properties. Because, we have an idea that when we look at metals they are several orders of magnitude stronger, stiffer than these plastics. Why do we want to use metals as matrices? Let us look at some of the important reasons strength. If we want to make things much more strong plastics, they cannot provide a lot of strength by themselves. We have to only rely on fibers, but metals as matrixes they can provide a lot of strength.

Stiffness same thing we use metals. They also provide lot of stiffness. Toughness; what is toughness? Is the ability of a material to absorb a lot of;

Student: Energy.

Energy. So, these matrix materials which are plastic based they cannot absorb a lot of energy unlike metals. Impact strength, a lot of these materials are ductile. When something hits at high speed, they deform and once they deform in plastic they can take a lot of energy because they are tough. So, they have a lot of impact strength, but a lot of these plastics when you hit them first thing they are not strong and then they crack. They do not take a lot of energy, absorb a lot of energy.

So, I will say use temperature. They have high use temperature which can be several 100 degree centigrade and some case it can go up to 1000 and resistance to many environmental factors, for instance UV radiation. You do not have to worry about if they

are metals. But, the plastics you have to worry about it. But then there are other things. Some metals react with oxygen. They react with air, they react with humidity. So, we have to look at it. This is we have to look at it carefully. It is not a 100 percent true statement that they are resistant to. It varies from metal to metal.

So, these are the advantages, but still because of all these advantages they are still not very popular. Why? Let us look at some limitations look at the limitations.

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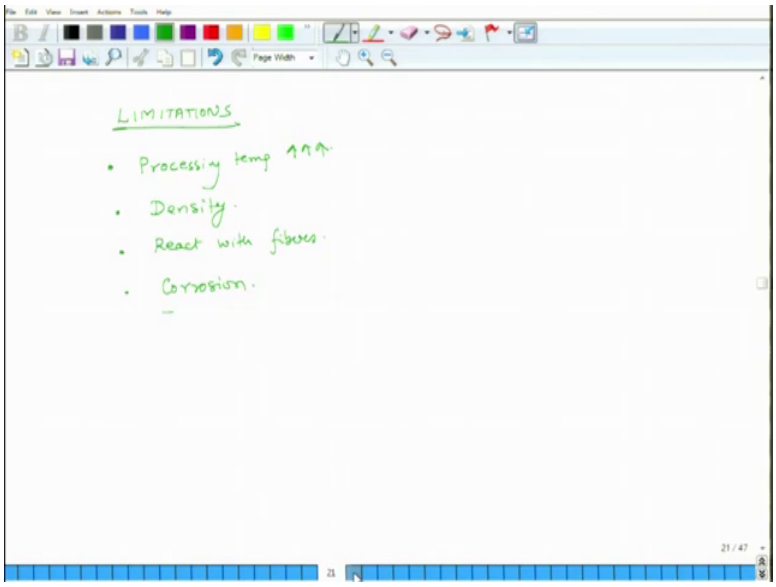

One is processing temperature is very high because if you want to make a matrix out of material, you have to melt it somehow. So, the temperature has to be very high and now at that high temperature suppose do you want to mix it with graphite fiber, you have to make it inert because at that high temperature if you mix it with graphite, graphite will also become hot and it will burn.

So, the atmosphere has to be inert. Processing temperature is high as. That is why the overall manufacturing of these types of materials is expensive. Density is high. So, we will lose on the specific stiffness and specific strength. A lot of metals they react with fibers. For instance they may react with graphite and things like that. We do not want that and then we have corrosion. These are the limitations.

Now, let us look at some examples for next 5-10 minutes. So, we will look at some examples.

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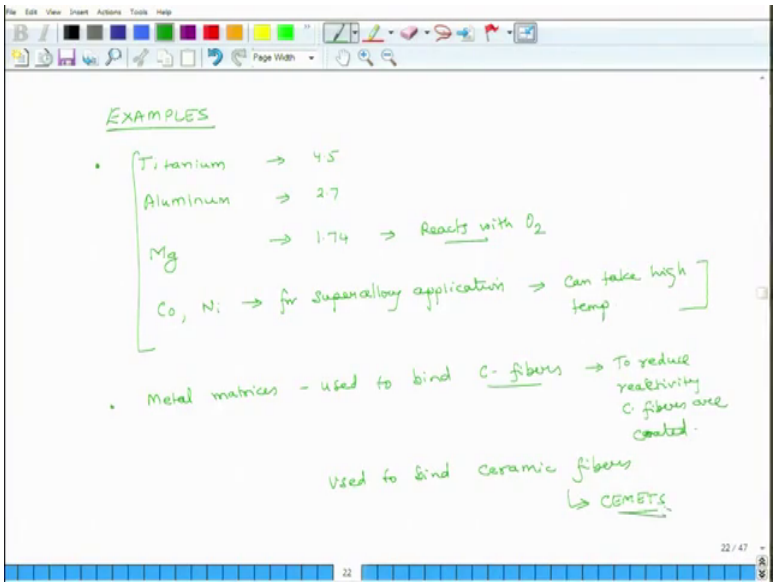

So, some of the most common materials which we use as matrices are based on Titanium or they are based on Aluminum. Density of Titanium 4.5, density of Aluminum 2.7. You do not want to use steel as the matrix material because it has very high density.

So, these are some of the lighter materials. We also have Magnesium and the density of Magnesium is actually pretty low 1.74. But, then it has a problem. It reacts with oxygen. Especially it burns very fast even if you heat it a little bit, it burns very fast and the whole structure can start burning very fast. So, this is a limitation of that. Then there are some super alloys. And there you use metals such as cobalt, nickel for super alloy application. Where would you use them? Where you need strength as well as high temperature application as in aircraft gas turbines, where temperatures are very high.

So, can take high temperatures. This is there and then these are some of the examples. Now these metal matrices used to bind graphite. We do not use these for glass is a low end fiber to bind either carbon fibers, but then we have to make sure that a lot of these metal matrices they react with carbon. So, if you bind them with carbon fibers they react. For in that case what they do is they coat the carbon with something else like tungsten or something.

So, here to reduce the reactivity carbon fibers are coated with something which does not do that and then they are also used to bind ceramic fibers. Example is cements. We have discussed this earlier and then we have some.

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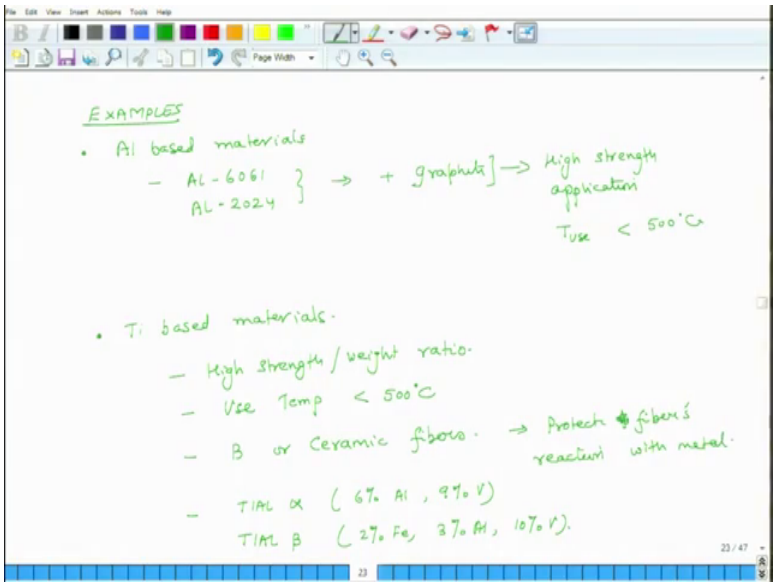

More examples; so, you have Aluminum based materials. For example, there are 2 Alloys. AL-6061 and AL-2024. These materials are used for high strength applications especially in aircraft applications. Where you want high strength, you put graphite fibers and you use this. So, here you add plus graphite fibers and you get real high strength and the temperature use could be as high as 500 degrees centigrade.

But then again this graphite reacts with Aluminum. So, you have to coat it with some protective layer and then we have Titanium based materials. Again high strength to weight ratio. Because Titanium strength is almost as high as that of steel, but it is density is roughly half of steel. So, you really get a lot of strength. Use Temperature can be as high as 500 degrees centigrade. A lot of times you use these Titanium based materials with Boron or Ceramic fibers.

But again Boron interacts or silicon carbide fibers. But, you to have protection against reaction. Protect fibers reaction with metal. This is important and 2 examples of these Titanium based materials. So, these are you do not use pure Titanium or pure Aluminum you use some alloy. One is known as tial alpha and the other one is known as tial beta. So, what do you have in tial alpha? You have of course, Titanium is there, but you have 6 percent Aluminum and 9 percent Vanadium and in tial beta, you have 2 percent Iron and you have 3 percent Aluminum and 10 percent Vanadium.

So, this is what you have. This is all about metal matrices and tomorrow we will close this discussion on matrices by discussing 2 more types of matrices. One is ceramic based matrices and actually yes. Then the carbon based matrices and then we will also have a small discussion on some additive materials. So, a lot of these composites they are not just made up of matrix plus fibers, but we also add some extra stuff. We will talk about those things under the category of additives. That concludes our discussion and we will meet once again tomorrow to have a closer on the discussion on matrices and additives. With that have a great night and I look forward to seeing you tomorrow.

Thank you.