Introduction to Composites
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Lecture – 16
Production Methods

Hello, welcome to introduction to composites course. Today is the fourth day of the ongoing week. Yesterday we had just started discussing poly ester resins and how they are produced and we will continue this discussion on polyesters today as well. So, one thing I wanted to mention is that we had explained earlier that to produce polyester you require a resin.

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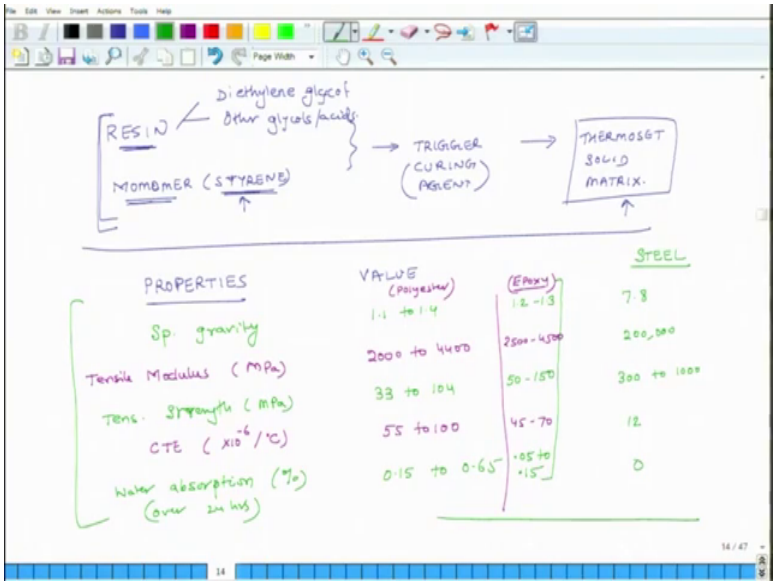

You require a monomer and typically it is styrene and these 2 when you mix and you want to initiate the reaction of cross length in between different chains, you add a trigger or a curing agent and. So, you add a trigger or a curing agent and once this thing is over then that is when you get your final thermoset solid matrix material. This is how you get the process.

Now, based on what type of resin you pick and what type of monomer. So, here I have said that you can use this monomer as a styrene, but based on which resin you pick and which monomer you pick, you can change the material properties of the final product which is the thermoset solid. So, typically you use this resin as diethylene glycol. It all

again depends on what constituents you are using. This is the raw material, but you can use other alternatives could be other glycols or acids.

Similarly, instead of styrene this is the monomer you can use some other materials and you can get different properties of the final product. So, this is the over of overview. Now finally, in context of polyester resin, let us look at some of it is properties. So, properties and here we have value. The first one is a specific gravity and this value can move anywhere from 1.1 to 1.4.

Next value is Tensile Modulus and this is in MPa. This is anywhere between 2000 to 4400. Tensile strength this is again MPa. So, the strength is it can depend 33 to 104 coefficient of thermal expansion. What is coefficient thermal expansion? Units are into 10 to the power of minus 6 per degree centigrade. This is 55 to 100 and the last one is water absorption percent and water absorption over 24 hours. So, you put a something for 24 hours in water and see how much water is absorbed.

So, it will absorb anywhere between 0.15 percent to 0.65 percent. Now compare these with steel. Steel is the most common (Refer Time 05:09) material used in the world. What is the density is about 7.8 for steel. Tensile Modulus it will be 200,000.

So, roughly the Tensile Modulus of this matrix material is 100 times less than that of steel. Let us look at the strength. Strength typically of steel would be may be anywhere from 300 MPa to if you really go to great type of steels super strong steels it could be 300 to 1000. So, then point is that you should have a prospective. This is steel. This is where plastics. This is where are fibre is.

Coefficient of thermal expansion. Coefficient of thermal expansion is about 12. It depends on the steel and of course, water absorption is 0. So, this gives you an overview of thermoset resin known as polyester. Roughly speaking 100 times weaker than steel, 10 times weaker than 100 times less stiff than steel, 10 to may be 30 times weaker than steel and it expands much more 4-5 times more than steel. So, this is all about polyester resin.

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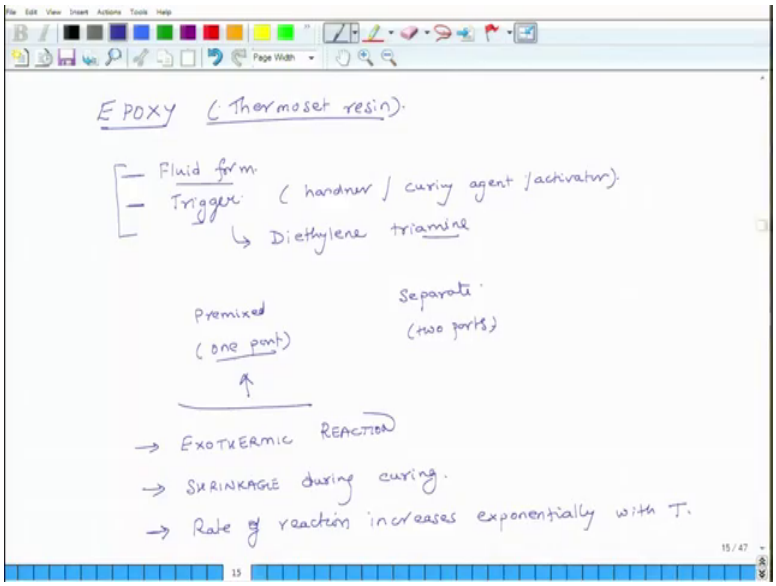

Next, let us look at Epoxy. So, this is also a thermoset resin. How do you get it in market? Like polyester if you want to go to market, what you do? You buy some resin. You buy a monomer. You mix them in some proportion and you add some trigger or in some cases you may get a mixture of both these together and then you add trigger to it and then it just starts curing.

Similarly, if you go to market, you will get it in 2 parts. So, either you may get as a single part, some fluid or you may get as a 2 party epoxy. So, you get it in fluid form and then you again have a trigger. This is also called as hardener or curing agent or activator. One example of this trigger is Diethylene triamine.

So, you take this main material. Mix it with trigger and you get the curing going. Now, as I said in some cases these epoxies come as already in a pre mixed state. You may have premixed or separate. This is in premixed. It is one part and if there in separate, you have 2 parts. In premixed you do not have to worry about mixing in the right proportion already mixed. You have to do is you have to just apply heat; you have to save it or store it at low temperatures. Then the reaction does not proceed in separate. You do not have to worry about solidification. You can store them at room temperature, but then you have to mix them in right proportion and then get the reaction going.

Like polyesters, Epoxies also when they cure they generate heat. So, it is an exothermic reaction. The second thing is like polyesters they also undergo shrinkage during curing

and as in the case of polyesters I forget to mention this earlier when we were discussing polyesters. The rate of reaction it increases exponentially with temperature.

So, a lot of times the way what people do is if they want to generate, they increase the temperature. They makes and this curing happens at an elevated temperature and it also generates it is own heat. They have to make sure that they maintain the temperature at certain point and that is how the thing is cured, but if you raise the temperature very high then the curing will be fast, but the quality of the curing will not be great.

So, there are some standard guides as to what kind of temperature should be maintained to make sure that curing is of a good quality. This is about Epoxies. Now, look at the properties of polyester. This is polyester and what we will do is we will add the values of epoxies also here. So that you can have a comparison. The first thing we discussed was density. Density does not change much between polyesters and epoxies 1.2, 1.3. Polyester is in general slightly lighter, 10 percent lighter.

Tensile Modulus, it is appreciably stiffer 2500 to 4500, 20 percent stiffer. Strength is where you get more benefits. So, it is a much stronger material 50 to 150 CTE not a whole lot different. 45 to 70 and the other significant advantage you get is that epoxies absorb much less moisture. So, they absorb something like 0.05 percent to 0.15.

So, if you have a situation where this lot of moisture and you do not want to have these kinds of moisture absorption related problems. Then it is really good to have epoxy. The other thing is that the glass translation temperature of epoxies is significantly higher compared to those of polyesters. So, they can take a lot of temperature relative to polyesters. So, in a lot of high end applications where we need strength even at some elevated temperatures, we do not go for polyesters but, rather we out for epoxies as the matrix material but cost wise epoxies are much more expensive compared to polyesters.

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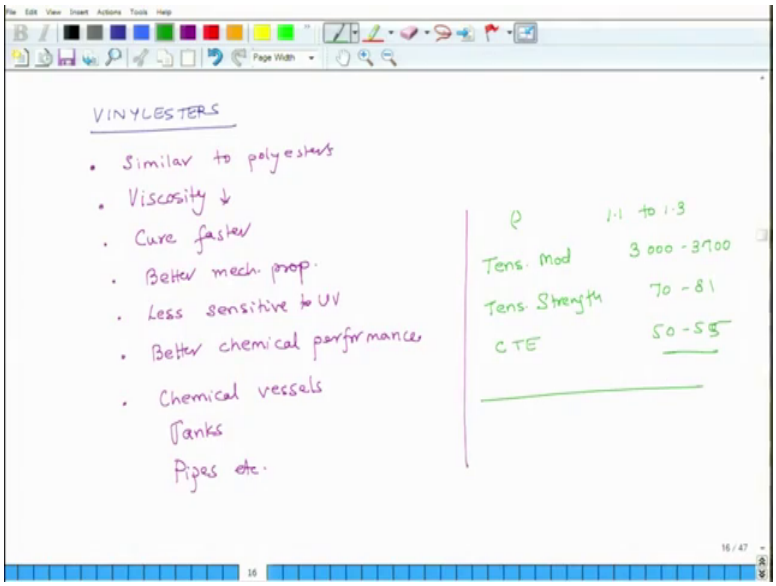

So, third category is Vinylesters. Some broad comments about it. They are similar to polyesters in terms of their materials properties, behaviour. Viscosity is low. So, what does that mean? That if I want to impregnate this matrix in a fibres system, all this matrix as to flow between all the fibres. If it is viscosity is very high, it will not flow easily, but because in Vinylesters viscosity is less. So, it flows in easily.

So, actually this should be viscosity and they also cure faster, better mechanical properties. One thing we had mentioned or were that polyesters are susceptible to ultra violet radiation. So, less sensitive to UV, better chemical performance and where do we use them? We can use them for chemical vessels, tanks, pipes etcetera. Very quickly their properties.

So, the density or specific gravity is anywhere between 1.1 to 1.3. Tensile Modulus in MPa that can actually range from 3 GPa to 3.7 Gpa. The Tensile Strength is actually measurably higher. This is 33 to 104. So, these guys Vinylesters are somewhere in between 70 to 81 and CTE is again not a big difference 50 to 55.

So, broadly speaking you have polyesters at the low end. Epoxies at somewhat higher end and Vinylesters are somewhere in between that is where they are. Let us look at one more material system.

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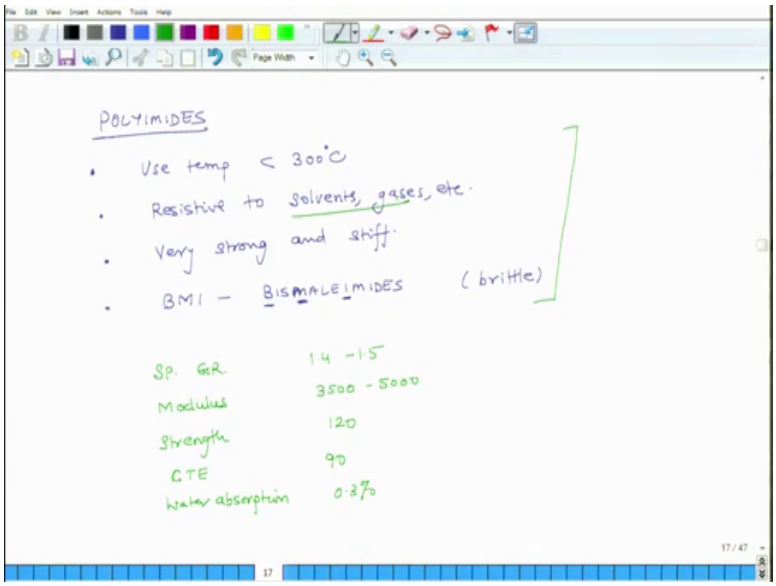

So, these are Polyimides. The good thing about them is that you can use them at higher temperatures. Use temperature can be as high as 300 degrees centigrade.

They are very inert materials. You know very less reactive materials. So, resistive to solvents, gases etcetera. Very strong and stiff. One example of polyimide is known as BMI. It is a short form and it is BisMaleImides. But, these guys are also brittle. We have to think about it quickly some of their properties is specific gravity.

So, this is a little high 1.4 to 1.5. Modulus it is starts from 3500 and it goes to 5000. Compare it with those of epoxies. It starts somewhere from the midpoint of epoxy and exceeds that modulus. The strength is 120. So, much higher than those of epoxies and this thing it absorbs a lot of moisture or CTE is high and water absorption is also high 0.3 percent.

So, these are some of the important thermoset resins and because these guys Polyimides are resistive to solvents and gases and they can be used up to as high as 300 degree centigrade. They are used quite frequently in chemical plants. Especially where operating temperatures are less than 300 degree centigrade. Because, they are very resistive and stable materials.

So, this concludes our discussion on thermosets and starting tomorrow we will discuss other matrix materials. Metal based matrix materials, ceramic based matrix materials and

we will also discuss some of the thermo plastics which are popular in the world. So, with that we conclude our discussion and I look forward to see all of you tomorrow.

Thank you.