Introduction to Composites
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Lecture – 08
Production Process and Types of Glass Fiber

Hello, welcome to introduction to composites. Today is the second day of the second week of this course. And what we plan to do today is extend our discussion which we initiated yesterday, that is about glass fibers. A specifically will start discussing the production process associated with glass fibers.

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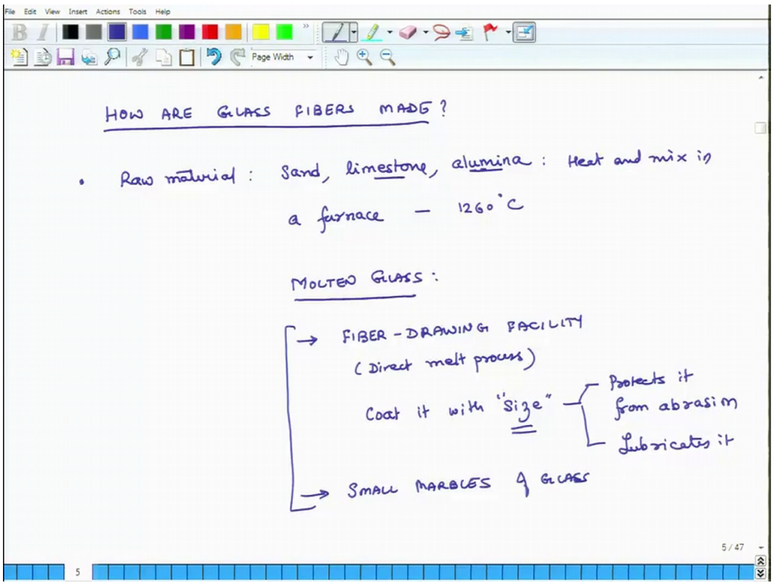

So, how are glass fibers made? How are they made? So, this method, I am not going to provide a lot of details about this method, but general idea we should have. So, and this method is used to produce both, continuous fibers as well as staple fibers, or short fibers. So, the raw material used is sand, limestone and alumina. So, alumina is aluminum oxide, sand is silicon oxide and limestone. And you mix all these things. And you heat them in the furnace,mix them melt them, heat them in a furnace. So, a lot of impurities because of this it comes out.

So, you heat, and mix in a furnace. And you have to heat it till about 1260 degrees centigrade. So, as a consequence a lot of impurities because of presence of limestone and alumina they float out. And pure silicon dioxide is left at the bottom. So, that is how you produce molten glass because sand has a lot of impurities. So, the aim is to get rid of these impurities from the sand, now this molten glass it is in molten state, fluid state.

So, either you make directly fibers from them, fiber drawing facility. This is known as direct melt process and especially if you are trying to make continuous fibers. So, we have a pool of molten fiber and it is being pushed through small holes. And so, it comes out and it starts freezing as it comes out and it is gribbed then you slowly pull it out. So, you get an a continuous fiber out of that and as it is coming out you also spray some light water.

So, that it becomes solid and it quenches, it gets quenched. And then after it has become cold at that stage you again, you spray it, or coat it mean size coat it with size. So, what does this do? It protects it from aberration and it also lubricates it. So, this is very important otherwise if you shift a lot of continuous fiber and after 2000 kilometers several days it would be broken into small, small pieces.

So, this is important. So, this is through a direct process. So, either you draw this directly, but there may be some factories where you they do not have the facility to produce the fiber, but they know how to produce pure glass. So, in those places what they do is they make small marbles of glass and these small marbles are shift to another place where there again molted you know melted and fiber is drawn.

So, in this way you make continuous long fibers. If you have to make staple fibers what happens is; so, suppose there is, this is a die and fiber is coming out of from here you know.

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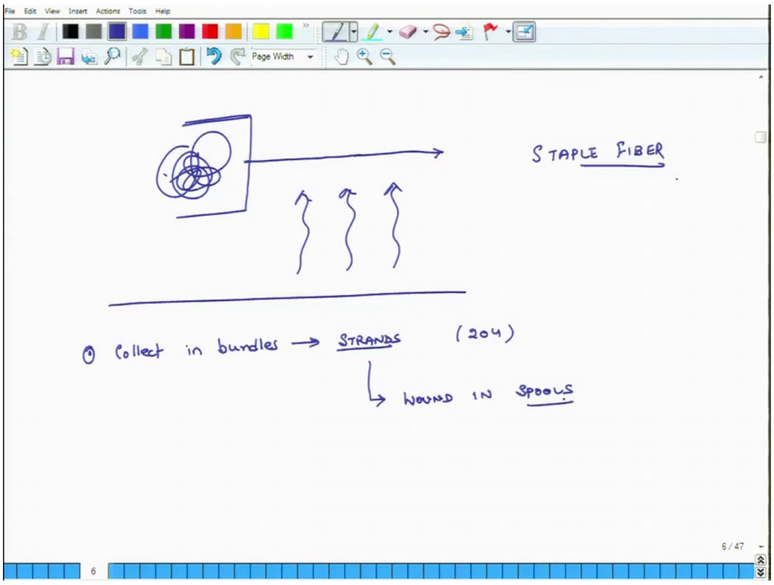

So, fiber is so, on this side you have this molten glass and through a small extruding hole fiber is coming out, to make staple fiber. You blow high pressure air in this direction. So, as it comes out because fiber is brittle, it breaks in roughly equal sizes, and that is how you generate staple fibers. So, anyway, so, once these individual fibers come out.

The first thing is they have to be sized, you have to be coated with size and then you collect them because you do not wind individual fibers in a spool. You take several fibers and collect them, and collect in bundles. And these bundles are called strands. So, typically each stand may have something like 204 fibers individual fibers, thin fibers you collect them in bundles, but these strands will start cutting into each other unless they are all the fibers are sized properly. And then these strands are then bound in spools are reels.

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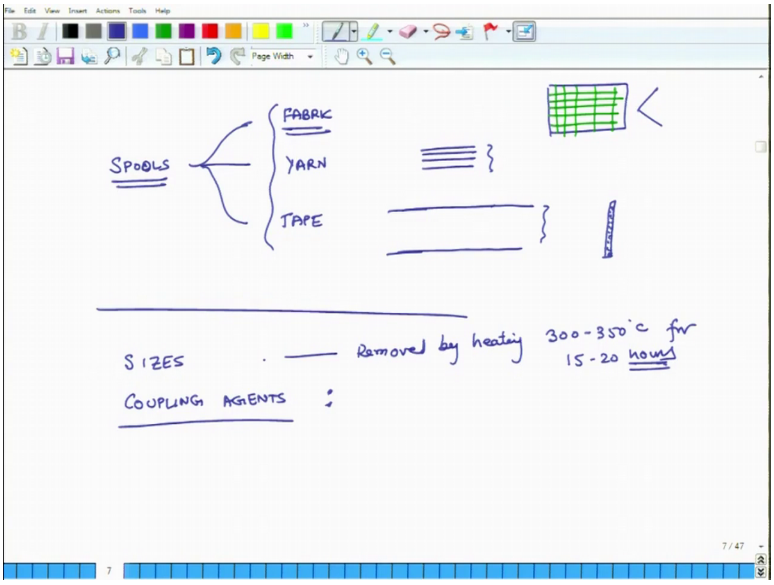

Now, what you do with these spools? So, you can use these spools, which have a strands. To make several types of materials. So, one thing could be to make fabric, piece of cloth. So, in the fabric you will have a stands like this, and stands like that. So, we can make a fabric or you can make a yarn. So, yarn is bundle all of spools, bundle of spools, or you can make up tape. So, the in a tape this will be a little wider.

So, bundle of yarn is the overall thickness of this yarn is not whole lot, but this tape maybe in 10 centimeter millimeter 15 millimeters wide 5 millimeters to 10 millimeters wide. So, if you look at from the cross section this may be very thin, but it will have a lot of a stands in it. So, these tapes can also be used to make unidirectional composites, yarn can be made used to make unidirectional composites.

Fabric can also be made used to make composites, it may or may not be unidirectional when I say unidirectional is there are a lot of fibers in one direction, but very few fibers in the other direction then it is more or less unidirectional. So, or is the number of fibers is almost equal in both the directions, then they will not be unidirectional layers. So, that is so, this is what you do with spools.

And so, that is there we have already talked about sizes. And we have also talked about coupling agents. So, ones the fiber comes to the place where it is being used to make a composite, you have to remove the size. For instance, if you starch, which is covering the fiber a starch by itself can absorb a lot of moisture. So, that will make things bad. So, you have to first is you have to remove the size a lot of times, that is done by heating the fiber heating the fiber and these sizing agents degrade at few 100-degree centigrade.

So, they get degraded and then you provide a coating on these fibers using silent these coupling agents, and a class of or a category of these coupling agents are something like silent agents. So, sizing is removed by heating maybe between 300 to 350 degree centigrade for 50 to 20 hours.

So, if you have some starch sitting on it, it will just degrade and de composite and little just go away oxidize and it will go away, you do not worry about any resolution and all that. And then you put coupling agents, on them to ensure a good bond between the fiber and the matrix, and also these coupling agents ensure that the fiber does not attract a lot of moisture. So, it also protects them from moisture. So, this is all about glass fibers. Lastly, I wanted to give you some details on properties of glass fibers.

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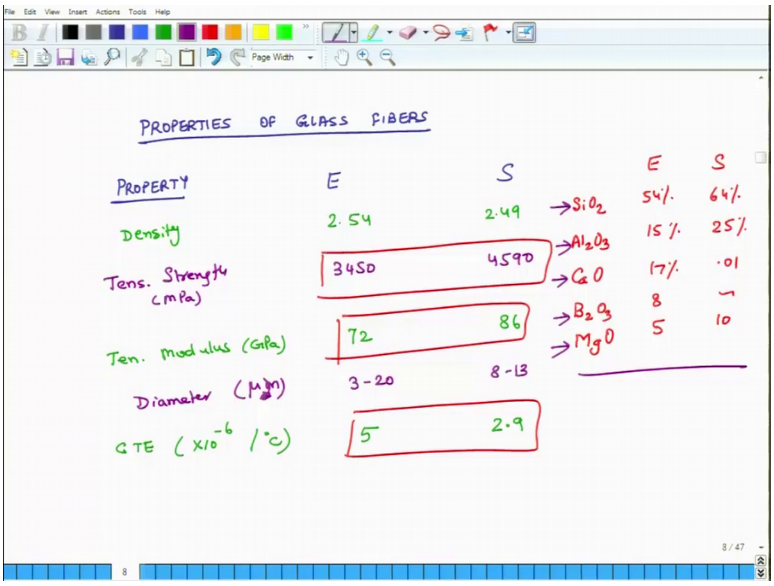

So, let us look at property. And we had said, that there are 2 broad categories of glass fibers. So, the first one is E glass, and the second one is S class. So, let us look at density. So, density is about same is a little heavier 2.54, this is 2.49. Strength tensile strength and this is in mpa. So, this is 3450 and this is stronger significantly stronger 4590 megapascal modulus tensile modulus. This is in GPa. So, this is 72 and this is 86 diameters typically, when it is being produced and this in microns, micrometers or microns. So, there is a lot of variation 3 to 20 microns and this is 8 to 13 microns, and the last thing is coefficient of thermal expansion. And this is into 10 to the power of minus 6 per degrees centigrade.

So, E glass expands more significantly compared to S class. So, you would wonder what is the difference between E and S because especially these properties.

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Strength, CTE even modulus they are significantly different. So, the main thing is in their chemical constitution. So, if you look at E glass, and if you look at S glass, these glasses are made from different types of oxides of metals and silicon. So, let us look at so, one component is silicon dioxide. So, this is about 54 percent, but this is more 64 percent. Aluminum oxide this is about 15 percent.

So, I am just rounding these numbers, and this is about 25 percent. Calcium oxide this is about 17 percent. And this is negligible 0.01. Then it has boron oxide. 8 this is again very less. Magnesium oxide, this about 4.7 or I will round it 5. And this is actually large 10 percent. And then there are several other oxides of different materials of sodium, and barium, and iron and so on and so forth. But primarily the differentiators are silicon dioxide, aluminum oxide, calcium oxide, boron and magnesium oxides of these metals. And this is why, because they have different compositions they have different properties.

So, this is all about glass fibers, which I wanted to share with you. And next, what we will do is, we will start discussing graphite fibers or carbon fibers. So, in the remaining part of this class, and also in the next class we will discuss graphite fibers.

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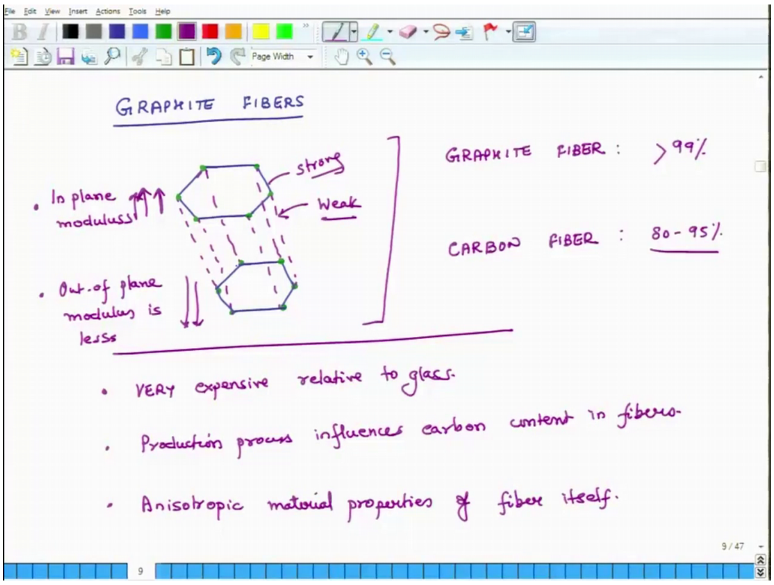

Graphite fibers, if you look at graphite, pure graphite for instance, you take that piece of led in your pencil that is graphite, and if it is super pure then it is pure graphite. What is the structure like? So, if you look at the graphite structure it is made up of carbon atoms. And graphite has a layered structure. It has a layered structure. So, I will try to make, that kind of a structure. So, let us say these are the 2 layers, and each of these, the graphite molecules for atoms, carbon atoms and carbon has a valency of 4. So, this is connected to this. So, it is like this, and then there maybe another ring of carbon atoms in a hexagon on top of it and also in the bottom of it.

So, the point what I am trying to make is, that these bonds are weak. These areweak, but these the bonds are very strong. The bonds within a layer between carbon atoms are strong, but between the layers they are weak bonds. And so, that is why, graphite x has also a very good lubricant, because these rings each layer of graphite can slide over another very easily, because these purple bonds which are between different layers there weak. So, it slides and it does not take a lot of force to break them and again get them established again. So, it acts as a very good lubricant.

So, if you take a piece of lead and if you try to bend it, it very easily breaks, it does not take a lot of strength. So, in graphite fibers we do not worry about all these weak bonds because everything is aligned in one single layer. So, that is how you increase the strength of graphite fibers. And people use different types of terms, sometimes people use the term graphite fiber. And other times they use the term carbon fiber.

Now, if you are careful. This distinction has a meaning. In a graphite fiber the percentage of carbon is more than 99 percent. So, it is almost 100 percent carbon. In carbon fiber this percentage of carbon is not that high, it may be anywhere between 80 to 95 percent. You may use them interchangeably, but that may not be accurate. So, if you think that and the fiber you are dealing with carbon for the percentage is 80 to 95 the name for it should be carbon fiber. If it super pure carbon then it is known as graphite fiber greater than.

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I am sorry. So, this should be greater than these fibers so, several points about these fibers. So, they are much more expensive, very expensive relative to glass. Now whether you get 99 percent carbon, or whether you get 85 percent carbon in a fiber, it depends on the production process, influences carbon content. And as I said because of this kind of a structure, the modulus, in plane modulus is very high, because I have to, if I have to bend this ring it will take me a lot of force, but if I have to bend if I have to makes layer slide over each other it does not take a lot of effort. So, in plane modulus, which means in the plane of these rings the modulus of the material and also their strength is very high. But out of plane modulus is less.

So, it is not significant, what does that mean? Glass fibers, if you take a maybe small piece of glass fiber and when you pull it like that or like that it will have more or less the same modulus, but these guys have different material properties in different directions, in plane very high out of plane.

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So, it means that graphite fibers, and their structure itself they are anisotropic. So, not only the composite is an isotropic the fiber itself is an isotropic. So, the fiber itself is an isotropic. So, this is something we have to remember. So, this is a very brief introduction of graphite fibers, we will continue this discussion tomorrow as well, and we learn how these fibers are produced, different ways of producing these fibers, different raw materials are used to make these fibers, and what kind of material properties we have associated with these fibers. So, that concludes our discussion for today, and I look forward to seeing all of you tomorrow.

Thank you.