Introduction to Composites
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Lecture – 07
Different Types of Fiber – Glass Fibers

Hello, welcome to introduction to composites. This is the start of the second week of this course. Last week we had discussed some general attributes of composite materials define the term composite and provided an overview of different types of composites, their classification, their applications, their advantages, their limitations and so on and so forth. What we plan to do this week is we will have a detailed treatment on fibers, which provide in most of the composites, man made composites, strength and stiffness. So, we will discuss different types of fibers, their properties, how these fibers are made and what kind of applications these fibers have as we do that and if we are able to finish fibers within this week. Then we will also move to the next material constituent of composites which is matrices.

So, we will again if we have time go into deep details of different types of matrices their chemical structure, their material properties, applications, limitations, manufacturing processes etcetera, etcetera, but before we start all this discussion. Last week I forgot to mention the books, which you may want to refer in context of this course. So, one book which I will be heavily relying upon is this one.

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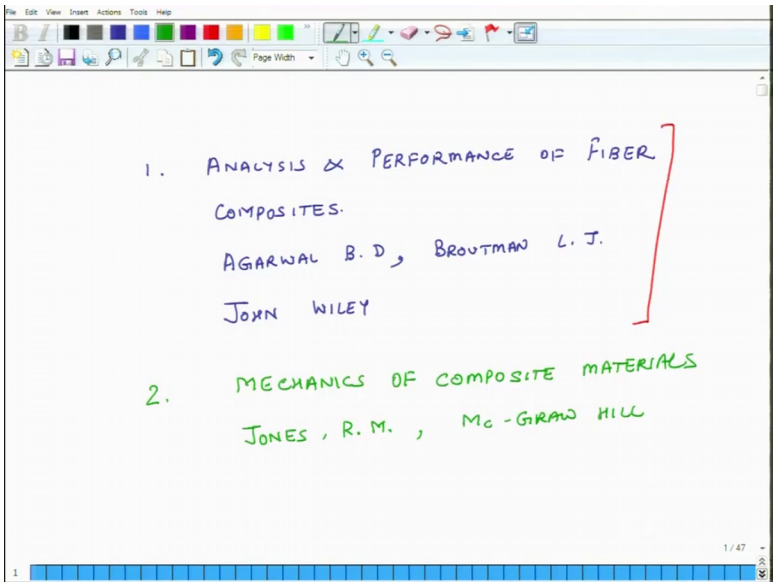

So, the name of this book is analysis and performance of fiber composites. This is written by agarwal Bhagavandas Aggarwal or b d agarwal. And Broutman, Lawrence J Broutman and it is published by John Wiley. Now the good thing about this book is that it has a lot of practical details about different aspects of composites how they are manufactured and things like that. And it is also written in language which is relatively easy to understand.

So, this is the book I will be heavily relying upon. And it will be useful that if you get access to this book if you are able to buy it or take it from your library, and refer it, then it will be useful. Because then you and I will be on the same page. But then there are 2 other books which you may consider referring. So, the other book is about the name is mechanics of composite materials.

And this is a very famous written by very famous of a author rm jones. And it is published by McGraw hill. Now this book is a very good text on mechanics of composite materials, the mathematics underlying it. So, you may consider this also, but the first book which I talked about out by agarwal and broutman. That also deals with mechanics, but it also deals with other topics like different types of fibers composites matrix materials methods of manufacturing and things like that.

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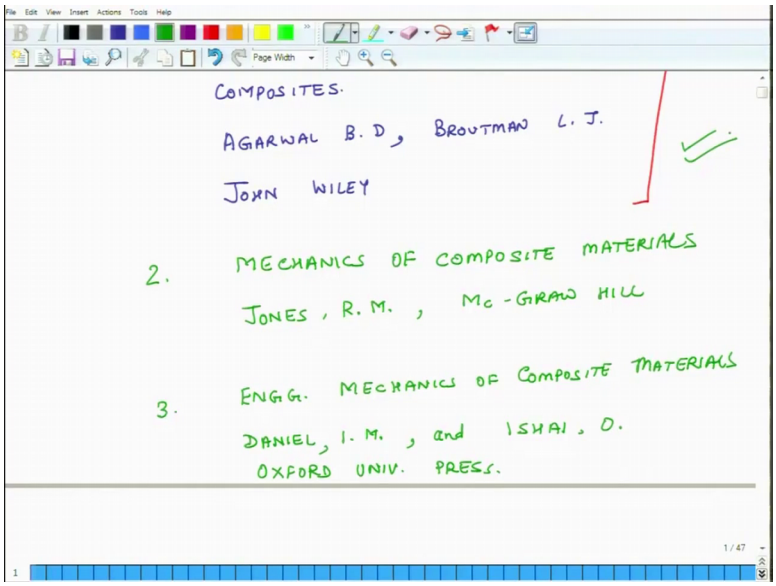

And the third book which I will also refer is engineering mechanics of composite materials. And this is written by daniel let us I M Daniel and who? Ishai and it is printed by oxford university press.

So, these are the text, but you should at least try to get access to the first one if you get access to others great. So, that takes care of the books. So now, what we will start discussing in today's lecture and also the rest of the weak is all about fibers.

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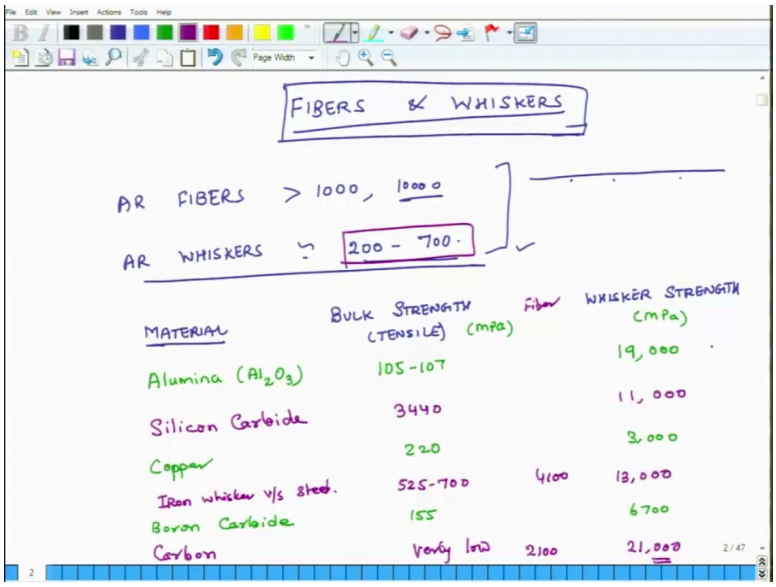

And there are 2 terms, fibers and whiskers. So, at a basic level fibers and whiskers are very similar, but the aspect ratio of fibers is definitely more than thousand, is some actually most of the time it is more than 10 thousand. The aspect ratio of whiskers is about few 100's. 200 to 6 700. So, this is one difference on geometry. But for the reasons which we had discussed earlier, we said that because these fibers are long and they are very thin. The chance of having a flaw in the fiber is very less.

So, they have very almost flawless structures. There not many flaws along the length, but still fibers have some flaws. But whiskers are super pure. Super pure and almost flawless and, but then the other thing is that they are smaller in length smaller in length. So, as a consequence because of their extreme purity and flawlessness, the material properties of whiskers are even higher than that of fibers. So, I will just make a table so that you get a feel of it this is bulk the strength, this is tensile. And the units are in mpa and this is the whisker strength. Now you can make this whiskers from different materials, you can make them from ceramics, you can make them from metals, you can make them from carbides. You can make them from non-metals such as carbon; will list some of these strengths for different materials.

So, the first material we will talk about is alumina. So, what is alumina chemically it is aluminum oxide. Take this aluminum oxide and in bulk form, and you test it intention. It breaks at about 105 to 107 mpa megapascals. So, all this is mpa. This is also mpa. But the whisker strength is 19,000. So, significantly higher about 200 times more than that of the bulk strength. Another material which may we may consider is silicon carbide bulk strength 3.4 giga pascals or 34 40 megapascals whisker strength again very high 11,000 megapascals, to give you perspective steel, bulk steel if you pull it most of the steels they are strength does not exceed 1 gigapascals or thousand megapascals.

So, alumina whisker is 19 times as strong as regular steel. Some other strongest steel not mild steel some other one or some other strongest steel. And silica silicon carbide is about 11 times stronger than some of the strongest steel. Let us look at some whiskers made from metals. So, copper bulk strength is 220, whisker strength 3000. And you consider iron, iron whisker versus steel.

So, steel strength is about in this range typical. So, 525 to 700 megapascals if you have some super speciality steels they need something like one gigapascal or thousand, but if

you just take pure iron and it is whisker. It is strength is about 13000 is very high. 2 more examples, boron carbide. So, again it is a non-metal. It is strength is about 155 megapascals, whisker strength 6700. And then finally, let us look at graphite or carbon. So, carbon it is very low. But whisker strength is 21,000.

If you take a graphite fiber in last class of the class before that we had discussed properties of fibers, what is carbon fiber? So, this is for the whisker. Carbon fiber is somewhere. So, if I make another column fiber carbon fiber is about 2100. So, it is 10 times has strong has a carbon fiber. Steel fiber so, this is steel. This is about 4100, steel fiber. So, this gives you some idea.

So, whiskers are super, super strong compare to bulk materials. And they have even more strong then fibers. But they are not use the whole lot, because they are not typically very long because if you make them long some flaws come into the system. But if you have a very small component and if you want to increase it is strength significantly maybe you can add consider putting fiscus in it. And it can become significantly strong without addition of a lot of material.

So, this is something I wanted to explain. Next what we will start doing is we will start looking at different types of fibers. Will look at all different categories of fibers, and we will explain about their properties their typical characteristics. How they are fabricated, where they are used what are the advantages and limitations of using these different types of fibers.

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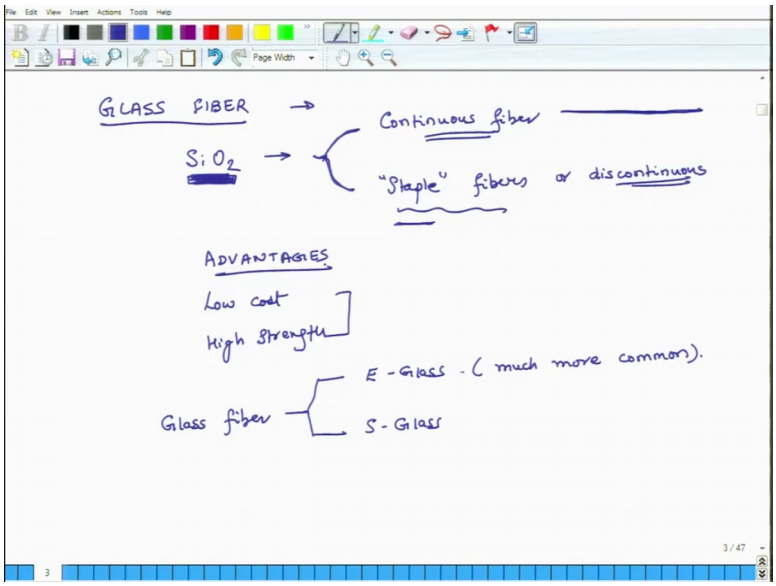

So, the first fiber we will look at is glass fiber. Now what is glass? Chemically if you take what is glass it is basically silicon dioxide or sand, pure sand is silicon dioxide. If you melt it and if you make sure that it is gotten rid of all the impurities it becomes glass silicon dioxide and it is transparent. So, that is there. And it is used in a lot of places in nowadays. We also use it in buildings, making walls and big structures. But we can make it is fibers and they become very strong, and it is glass fiber is perhaps the most popular of all the fibers. Amongst to all the composite materials which are used, because glass fiber is the least expensive one.

Now, these glass fibers come in 2 categories. One is continuous fibers, and the other one is staple fibers, or discontinuous. This discontinuous term is not that much popular. Staple fibers, you may go to market and you say I want staple fibers. What does that mean? That the fibers you may get may not be very long. They may somewhat shorter in length.

And we use these staple fibers for instance I have to make fiberglass or fiber, you know polyester reason if I want suppose I want to make some chair made up of fiberglass. So, I take polyester and I add these staple fibers to it and do a molding of that, and I get a fiberglass chair. So, we have continuous fibers, what is they have in continuous fibers? The fibers are very long. And you may get these fibers in a reel or in a piece of as a piece of cloth and things like that the staple fibers are shot in length.

So, again 2 advantages low cost and high strength. Now these are the 2 categories which come in terms of in terms of length, but you can also have 2 different categories of sio 2 fibers. So, one way to look at them is whether the fibers are long or whether they are short. Another way to look at is the type of glass, because this glass comes in different varieties.

So, one is so, glass fiber in terms of varieties 2 broadly speaking 2 categories there are other categories also, but one is the E glass and the other one is S class there are other categories also C glass and D glass. But they are not that much used, but these are 2 very popular varieties. And amongst these 2 E glass is much more common. It is produced in much larger volume, and it is much more common.

These are the advantages low cost high strength. Now let us look at some limitations of glass fiber.

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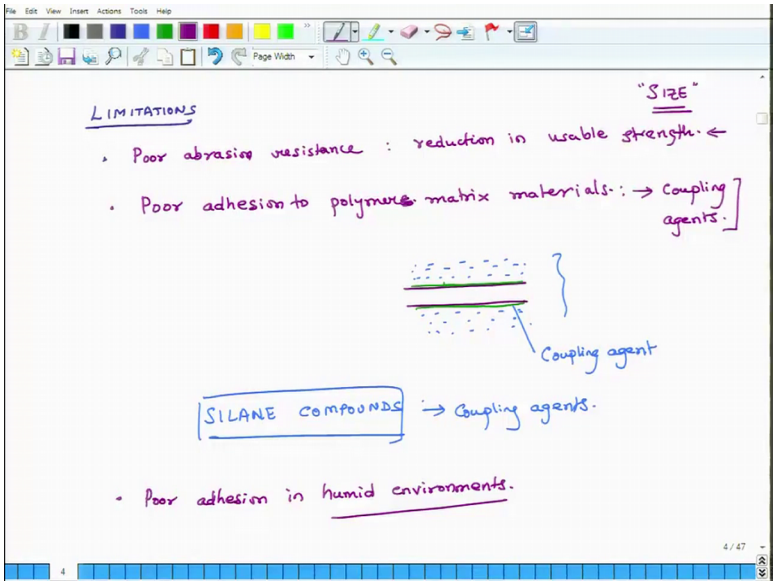

So, the first limitation is and this is very important to understand. First limitation is that if you take 2 2 pieces of 2 glass fibers, and you rub them against each other. They abrade is each other, because their texture is rough. So, they abrade each other and they cause abrasion and breakage of between themselves. So, this very important. So, poor abrasion resistance, what does that mean? That unless we know how to solve this problem if you take a lot of glass fiber if you should take a spool or reel of glass fibers and you open it

by the while you are opening it the fibers maybe abrading each other. And till now you have the open them up, by that time there has strength has gone down significantly.

So, what that means, is this causes reduction, in usable strength. This is one thing. And there are ways to solve this problem, but if you take a regular glass fiber without any coating or things like that then you have this problem. The second problem with these fibers is poor adhesion polymer matrix materials poor adhesion to polymer matrix materials.

So, we will talk about this, but I will go back for a minute on abrasion. So, the way this problem the first problem is solved is; that whenever a glass fiber is produced. While it is being produced it is also quoted by some other material that material is known as size. So, this is the name of a material, it is called size. Different types of sizings are used. An example of one size is starch.

So, it is coated in starch and they say that oh this fiber has been sized, which means it has been quoted by starch or some other materials. Now what these materials do is, then once the fiber has been quoted with the sizing material then when they rub against each other, during transportation or regular usage, then they do not abrade each other that much. So, that is called sizing. The other problem is that if you put a fiber in a polymer matrix. It does not stick to the polymer matrix easily, does not stick to polymer matrix easy.

So, then it is difficult to make good composites out of them, because they do the matrix does not hold them in tight hold them tightly. So, to solve that problem, what happens is we will discuss that maybe later also; that when the fiber is being manufactured in the factory. There it is produced and during the production process it is it is quoted by this size. And then you make them in reels or in fabric or walls whatever shape you want, and from the factory it is shipped to the market.

And from market it goes to places where it is used. The place where it is used it is at that place you want that it has to be bound to or it has to bind to the matrix material. So, in those places people apply people somehow reduce the size, and then they apply another material known as coupling agents. And there are different a types of coupling agents. So, these coupling agents help develop a good bond between the fiber and the matrix.

So, typically what happens is you have a fiber, and I am just going to magnify it. And then there is a coupling agent a coating of coupling agent is on top of the fiber, and then you have this is the matrix material. And the chemistry of these coupling agents is such that on one end it is it sticks very tightly to the to glass. And on it is other end of the molecule it does a very good job in sticking to the polymer, because it has one end which is hydrophilic, and another one which is hydrophobic and because of that kind of a chemistry. So, these coupling agents help develop good bonds between polymer matrix and the fiber. So, this is coupling agent.

A very popular class of coupling agents are silane in compounds, there different types of coupling agents, but silane silane compounds. So, this is a class of chemicals category of chemicals, and these are very popular coupling agents. So, this is so, these this is how you handle the first and the second limitation. And a third limitation of glass fibers is that poor adhesion in humid environments. So, there is moisture in the air and you are trying to make some glass fiber composite you are spraying glass ah let us say polyester matrix over glass fiber. And if there is a lot of humidity there are chances. That the matrix may not stick very tightly to these glass fibers.

So, you have to ensure that whatever whenever manufacturing of these glass fiber-based composites is happening. The environment should be dry. So, this is another important limitation. So, this is about advantages and limitations of glass fiber will continue this discussion on glass fiber tomorrow as well. And we will learn how these glass fibers are made what are their typical properties what are their applications. And after that we will move onto another category of fibers, which are graphite fibers. So, with that we conclude our discussion for today. And I look forward to seeing all of you tomorrow. Till then have a great night, bye.