Introduction to Composites
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Lecture – 05
Advantages and Limitations of Composite Materials

Hello welcome to introduction to composite materials. Today is the second last day of this inaugural week of the course that is the fifth day. And what we plan to do today is again continue the discussion which we initiated yesterday. Because we started talking about different advantages and limitations associated with composite materials. So, yesterday what we had discussed was concepts like specific weight and specific modulus. And what we found was that; if we engineer are composites correctly, then they become really efficient in terms of providing same amount of stiffness, or same amount of strength for the for much lesser mass. So now, we will extend that discussion.

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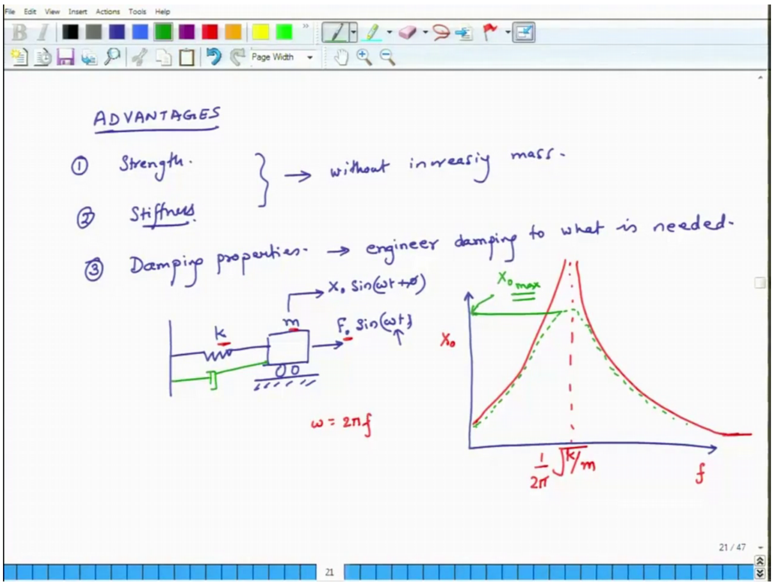

So, first we will look at in a broad and general sense.

Some of the important advantages of composite materials, the first so, there several reasons dozens of reasons. And will look at some of the important reasons. So, first reason why a lot of people use com composites is because they provide more strength for this same amount of mass, for same amount of mass. The same amount of mass, you can improve the strength. And this strength comes from the fact that in a lot of engineered composites. We use fibers and these fibers in general are much stronger than the bulk material. So, for the same amount of material, we can have much higher strength. The second is we have already mentioned is stiffness. So, again yesterday we saw in the table that if we engineer are composites correctly, they can provide a lot of stiffness.

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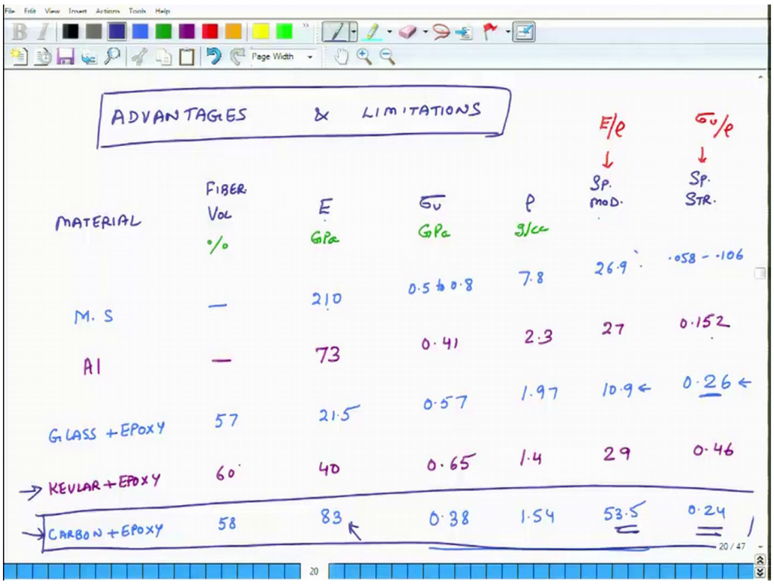

And to increase the to will have that stiffness we do not need to use a lot of mass.

So, that is another thing. And so, all this discussion in is in context of having without increasing mass. Third reason a lot of people use composites is that they have higher damping properties. In fact, you can engineer the damping of a structure to what you want. So, you can engineer damping to what is needed. I will give you a simple example. So, suppose I have a simple spring and mass system. And let us say this stiffness of this is spring is k, and the mass is m, and I excited by a force F sin omega t. And because I am exciting it this will have a displacement. And let us say that displacement is x naught sign omega t plus c.

So, k is fixed m is fixed. And so, is F naught. Now I can do an experiment. And what do I do in experiment? What I do is that I change my omega. So, what are the fixed things in my experiment? K remains fixed and remains fixed and F remains fixed. And omega is changing. And as so, first I exited at one hertz. In the second experiment I excited 2 hertz. And each time my excite I measure how much it moves by, what is the amplitude of the deflection. So, what I will plot here is on the in the graph x naught no, on the x axis I will plot omega, or I can even plot frequency. So, omega equals 2 pi F. And on the y axis, I plot how much the spring this mass moves by, amplitude of the motion. And what you will find is that the system behave something like this. Initially as I increase my omega, x approaches infinity, x approaches infinity at some frequency, which is known as the resonance frequency, whose value is k over m times 1 over to 2 pi.

Now, if it was a real structure, we do not wanted to have infinite displacement. Otherwise it will break. So, and luckily in real structures, it is not having only a spring and a dash part. But there is also some damping. So, there may be some damping also. And when damping is present, the system behaves something like this. And this displacement so, let us call this x 0 max, it depends on how much is the damping present in the system.

If damping is extremely small, the value of x 0 max will be very high. If damping is very large it will be less. Now it just happens that most of the materials metallic materials they have very low damping the damping you can express it in different units one way to express damping is on percent. So, the damping in metallic metals is somewhere between point one percent to 0.01 percent, extremely small.

So, if it this if this spring was made purely from you know metal thing, then these displacements at resonance frequency could be very large. But if you have a composite in general composites have much higher damping. And based on how much fiber you put in the system and how much matrix you can put, you can actually figure out how much damping you need and you can actually introduce that much damping into the system. So, that is why this is another advantage which we get from composite materials. A 4th advantage we get and I had briefly explain this earlier is resistance to wear.

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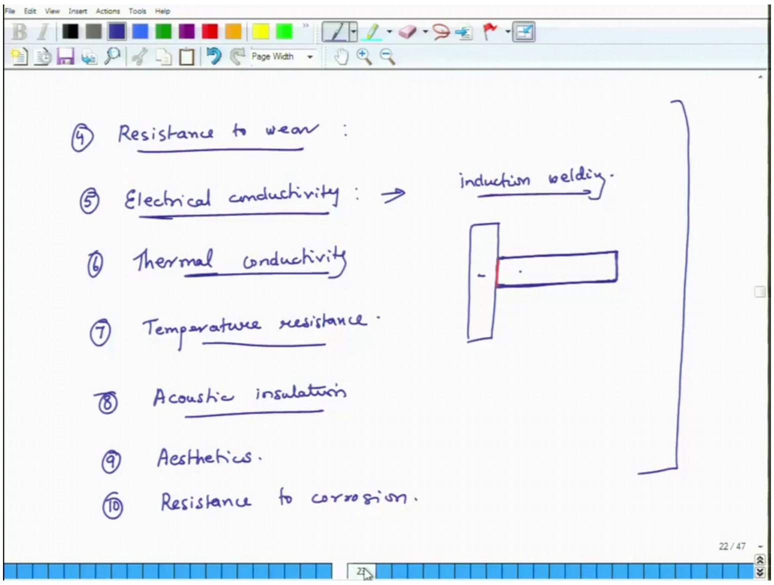

So, again we can mix different constituents and the composite material and bind them using some composite. And make sure that the product does not wear very soon. For instance, in brake shoe pads where we pads which are used to break tires wheels which are running at high rpm.

We need those things to be highly wear resistant. So, in application such as those. A lot of times composites are used, another example where a lot of wear resistance is required are in cutting tools. Because the tool experience is high amount of shear forces anyone that tool to last long. So, there also we can use composites. Let us look at some of the other areas. Electrical conductivity; now they may be certain applications, where you want electrical conductivity to be very high, or of a medium level of a low level.

Again, based on the composite, I mean if you have to increase the conductivity one way to do it is put more graphite into it into the system. And graphite is a good conductor of electricity. So, the more graphite you put the better connections will be between all the parts of the body and it will it is conductivity will improve. So, in this way you can have you can modulate conductivity of the system.

Another example is thermal conductivity. So, before we talk about thermal conductivity one place yeah, one example where you want some electrical conductivity in a piece of plastic is, where you have to do induction welding. So, this is an example. I will explain that. So, what happens in induction welding is, that suppose you want to join these 2 pieces. Now earlier induction welding we used to happen between metallic parts. So, what would happen is that somehow induction current would be introduced at the interface of these 2 parts. Induction current will be introduced here, and here and as the current flows between the 2 parts. Because the contact between these 2 parts is not perfect, there is a lot of resistance and as current flows through the resistance I square r loss becomes high especially at the interface.

So, here lot of heat get generated at the interface. And when heat gets generated these 2 parts melt and you can well these 2 parts together. Through inductive welding process, now this was possible in metals earlier, because metals are conductors of electricity, but people also wanted to have induction welding for plastic parts. To the way you can do it is you can inject in those plastic some graphite particles, or some other metallic particles which conduct electricity. So, then you can make them conductors of electricity. And then again using the same process you can have induction welding in plastic parts. So, this is one example, where you can you want to engineer the electrical conductivity to meet your functional goals.

Another example another reason why people uses for thermal conductivity so, for instance plastics in general are very poor conductors of heat a very poor conductors of heat, but there may be several applications, where you want heat to be transferred from one part of the system, where let us say lot of heat has been generated there may be in I see where lot of current is going. So, it generating heat anyone to remove heat and transport it to some other part. And you do not want to use metals because they are heavy.

Maybe you can engineer a piece of plastic, which is having a lot of graphite content or graphite fibers. So, they can transfer heat from one part to other and using this because they have better thermal conductivity. Another reason why we use composites is temperature resistance. So, we can engineer specific composites. So, that they can take a lot of high temperatures for instance earlier in this course I had explained; that there are several applications where when the missile enters into the atmosphere. It experiences temperature has high as 4 to 5 thousand degrees Fahrenheit. And you want that temperature to be registered otherwise the whole thing would be the milk or break.

So, special composites are designed graphite composites. And then they are coated with anti-oxidation layers so that, because and things become very hot graphite can take a lot of temperature, but then it can burn. So, if you coated with some antioxidation agent. And they can take a lot of high temperatures, and without breaking or without getting oxidized. Another example is acoustic insulation. You can engineered composites, to absorbs specific sounds or to reflect certain sounds based on their material properties. So, that is why I talked about acoustic is insulation. And then a lot of times composites are used for aesthetic reasons. For aesthetics, and then for resistance to corrosion, and then of course, they are several other advantages, but I can keep on going, but these are some of the important advantages which people have used.

So, to the point is that there is not one single composite material. There you can have millions of different types of composites. What you have to do is that you have to look at what are your needs, and based on that you actually design a composite material which meets your needs. Now having said that, composites have problems also it is not that they are the perfect most perfect materials.

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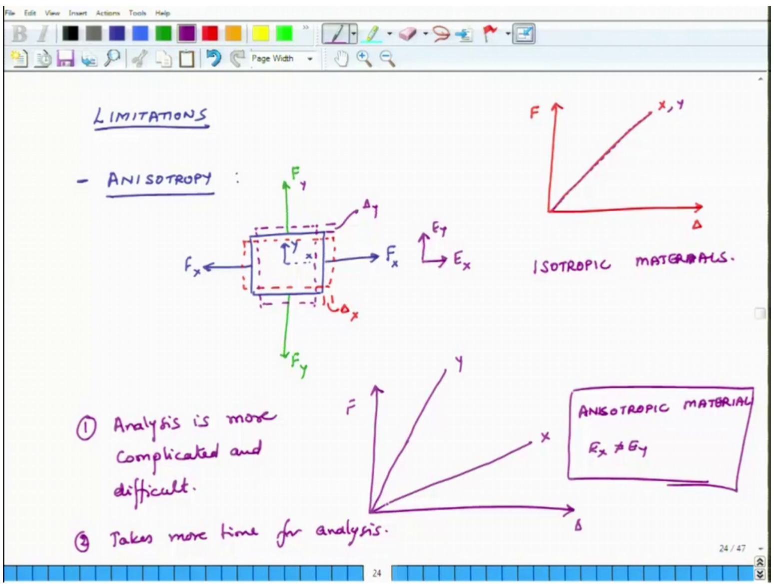

So, let us look at some of the problems or limitations. And it is important to understand those when we are talking about composites. So, the first thing is an isotropy. A lot of composite materials are anisotropic. What does that mean? So, let us try to understand that. Now suppose I have a piece of metal. Let us say it is a square piece of metal. So, and in I do a 2 experiments on it.

In the first experiment, let us say this is x axis and this is y axis. So, in the first experiment I apply force in the x direction, and I pull it and as it expands. So, when I pull it will become something like this. So, it will have some extension in the length delta. And if I plot delta versus F, it will be some straight line. And this is the line for x direction. In the second experiment I remove fx, but I apply force in the y direction.

And when I apply force in the y direction, this material and remember I am saying that this is a square piece it is not a rectangular piece. So, this is how it deforms as a purple thing. And so, first deflection was delta x, and another case this is delta y. And now if I plot delta against delta y against F y, I will get another plot. And because this is metal, the plot for x direction and the plot for y direction will be identical. Because the material property, the young's modulus in x direction and the young’s modulus in y direction E and E y they are identical.

So, from materials which have same properties in all the directions. They are called isotropic materials. Here isotropic materials. So, what is an isotropic material a material which has same properties in all the directions, I can pull it in x direction, I can pull it in y or in z, it is young's modulus it is conductivity everything will be same. So, these types of materials are isotropic materials, most of the materials which we use in our daily lives. For instance, metals, glass, regular plastics, they are isotropic in nature.

They isotropic in nature and anisotropic material has different properties in different directions. So, if I did the same experiment using an anisotropic material, my 2 graphs which I plotted here will not be the same. So, maybe one curve will look something like this. And another curve is look something like this. Because this is a, because so, this this will be for anisotropic material. And that is because in at least in our experiment E x is not equal to E y young's modulus in both the directions is not same.

So, this is about isotropic materials anisotropic materials. Most of the a large number of composite materials which we use are anisotropic in nature. They are not isotropic. And the problem with anisotropic materials is that the 2 important problems. One the mathematics required to understand these materials and predict their behavior is more complicated. So, analysis is more complicated and difficult. So, if you have hard time understanding them, then it is not a good thing. The second problem with anisotropic materials is that to and to analyze them to understand it takes more time. So, you can analyze metallic bridge using computer code finite element code. Maybe in 2 days, but if you try to analyze the it not only is more complicated and difficult, but it also takes much amount of much more time for analysis and that actually means money. Because if I have to analyze a bridge made up of purely metallic materials.

Maybe it will take that analysis x number of hours. And if something is made of composites the same type of structure because the analysis is more complicated takes much larger time. Maybe it may takes 2 3 4 times as much of time. So, it requires more time and when things take more time it always translates to more money. So, this is one very significant limitation of composite materials.

They are several other limitations also. And we will continue the discussion on the limitations tomorrow, but for starters one significant limitation of composite materials is that they are harder to understand and it takes more time for them to analyze and predict their failures and systems because they are anisotropic. So, we will continue this discussion tomorrow. Until then have a great day, goodnight.