Introduction to Composites
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Lecture – 12
Matrix - Properties and Classifications

Hello, welcome to introduction to composites. Today is the last day of the ongoing week. Until so far we have been discussing different types of fibers, which are used in composite materials; and we have come across glass fibers, graphite fibers, metal based fibers, fibers made from high performance polyethylene fibers, ceramic fibers and several metallic fibers. Now, all these fibers are embedded in a matrix material. So, the performance of the overall composite is not only strongly dependent on how real opt and appropriate the fiber is to me in context of our needs, but also how opt appropriate is the matrix in context of our needs. And to explain that we have to think about it a little more carefully. So, we will discuss as to what is the exact roll of matrix material in context of the efficiency of a composite material.

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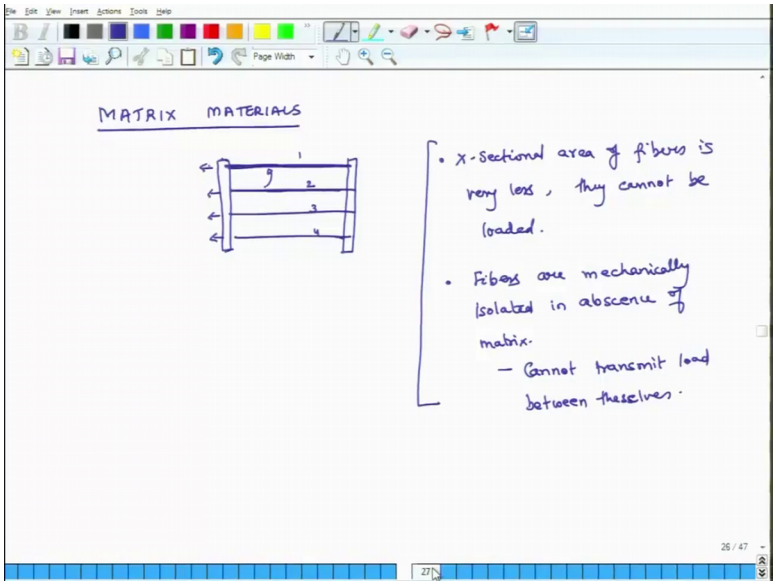

So, let us see what does a matrix material do. So, we will discuss matrix materials. So, what does it do. So, if you have a bunch of fibers, by themselves what can they do, the first thing is each fiber is very thin. So, because the cross sectional area of fibers is very less, you cannot load the fibers by themselves because they are very thin, you cannot grip

them and load them, they cannot be loaded this is a practical problem, you cannot catch them and pull them easily. We need very special complicated devices. So, this is one limitation.

The second thing is fibers without matrix are isolated or mechanically isolated in absence of matrix. So, what does that mean they cannot transmit load between themselves, you cannot transmit load between themselves. So, it could be that so why is that important, why do we want loads to be transferable? Suppose you have just four fibers and each of these guys you are pulling, you are pulling it in such a way that you apply the same force on each fiber. And let us say this is thicker, fiber one is thickest, second one is slightly thin, third one is even thinner, and fourth one is thinnest.

And you are applying same force to all fibers same force to all fibers. Now, because one is thickest, it will tend to extend the least amount; and four is thinnest it will tend to extend the by maximum amount, but because the ends are constraint in like they have to trans you know extend by the same amount. So, what you really have to figure out is how do you transfer extra load from here to this guy. So, that the entire thing has uniform displacement. So, we need for efficient design of structures a mechanism to transfer load between fibers and this transfer cannot happen, if there is no matrix.

So, matrix does these two things at a very fundamental level. It binds all the fibers together, so you have a physical shape of the composite. It helps you grip and apply load because everything is now you are connected; and it helps you transfer loads between different fibers so as to make the overall system much more efficient in terms of load transmission. So, this is what a matrix does.

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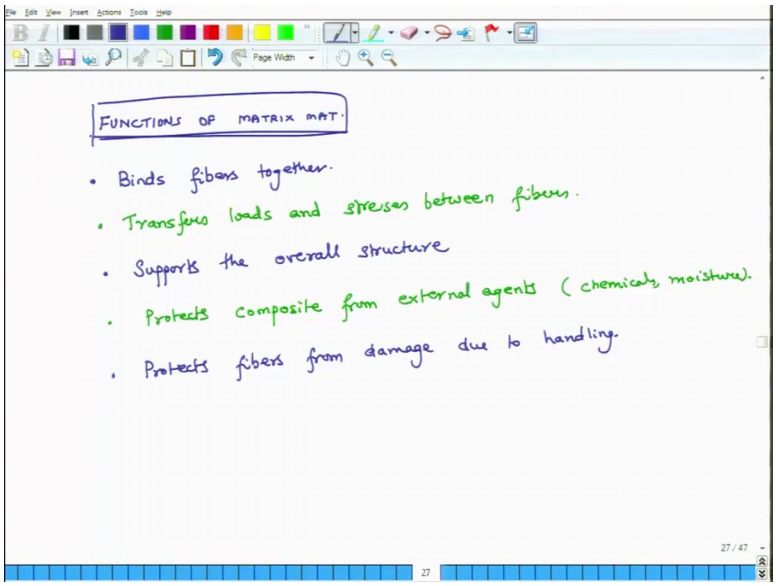

So, let us see again, what are the important functions? Because once we understand this, then, we have to we can start figuring out which particular matrix will be good for us. So, this is important functions of matrix materials functions of matrix materials. First function - it binds the fibers together and that provides the overall composite to come together; otherwise, you have just individual parts. Second - it transfers loads and stresses between fibers, transfers loads and stresses between fibers and between the composite structure.

Third thing it supports the overall structure. So, we cannot think that matrix is less important, these are very important functions, matrix is equally important. Fourth - we know for instance some fibers are very sensitive to moisture, so it protects composite from external agents for instance chemicals, moisture. And so on and so forth. And the last one is it protects fibers from damage due to handling like we saw in case of glass fibers, they can upgrade each other. So, these are very important functions of matrix materials. So, whatever we choose we have to make sure that all these things happen if all these things are not being performed by a matrix efficiently then it is not a good matrix material.

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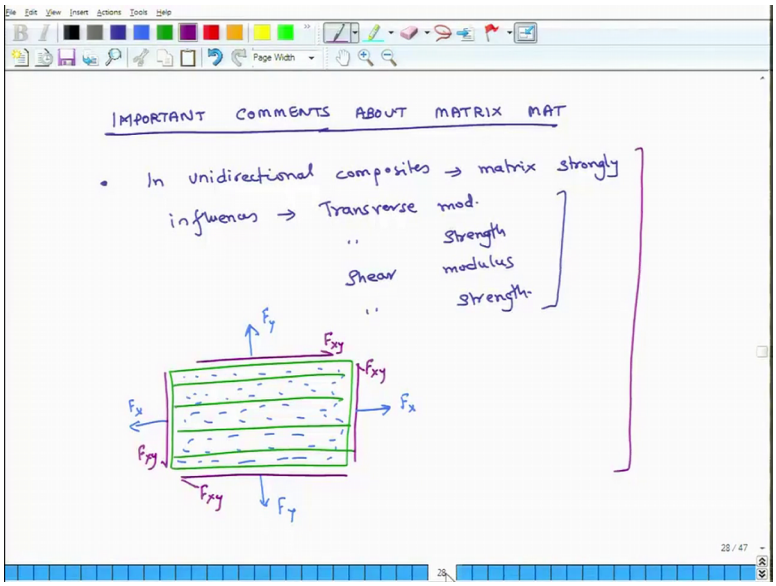

So, some important points, important comments about matrix materials. So, this is from a functional standpoint, but they are some other things which matrix has a very strong influence on. So, what does it influence? In unidirectional composites, matrix strongly influences what, transverse modulus, transverse strength, shear modulus, shear strength. I will explain that there are several other points, but this important to understand. And now we have to over tart getting used to all these terms like transverse modulus, shear and things like that.

So, consider a composite which is made up of fibers, and it is embedded in a sea of matrix. Now, typically the young's modulus of fibers is very large compared to that of matrix and also the strength of fibers the tensile strength of fibers typically is very large compared to that of matrix. So, if I pull this composite in this direction, let us say it is apply F x then it will be the fibers which will decide how much extension the composite is going to experience, because the fibers are much more stronger and much more stiffer than matrix. So, fibers are going to decide what is going to be the overall extension and whatever is going to be the overall strength.

So, in the direction of fibers if I pull it, I will get an idea what is the longitudinal strength and longitudinal modulus of the composite and that is being predominantly going to be decided by fibers, especially there are very large number of fibers. But the same is not true if I pull it like this. If I pull it in the y direction, the fibers do not have a tendency to

stretch, it will be the matrix which will decide what is going to be the transfers modulus and transfers stress of the system just based on this physical understanding the mathematics and all that we will discuss later. So, if we want the material to be stiff and strong in y direction, it will be predominantly decided by the matrix. So, we have to choose matrix correctly.

Similarly, if we have a composite the same composite, if we wanted to be strong in the shear sense in the shear direction. So, this one is I will say F x y the shear modulus and the shear strength also of the system will be predominantly influenced by matrix. So, this is important. So, matrix for structural reasons also is very important it is job is not only to do all this good stuff, binding the fibers, transferring load supporting the structure, but it also for unidirectional composites. It has a strong role in influencing transfers modulus, transfers strength, shear modulus, shear strength. Let us see what other things it is very important for.

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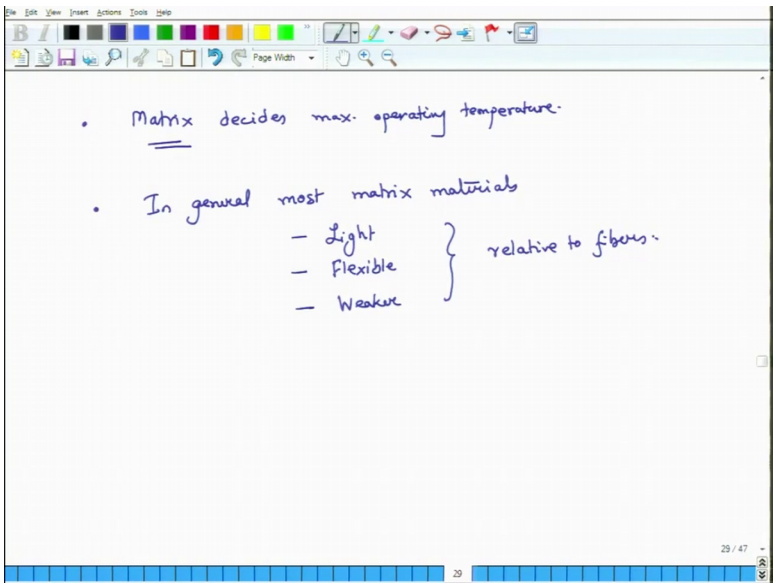

Matrix decides maximum operating temperature, because in most of the in a lot of cases the fibers can take a lot of temperature glass fiber can take a lot of temperature, graphite fiber can take a lot of temperature, boron fibers can take a lot of temperature ceramic fibers, they can take a lot of weight. HPPE may not be at the appropriate, but most of the fibers can take a lot of high temperatures. But if the matrix is some plastic which starts

beginning soft at 150, 160 degree centigrade, the overall composites operating temperature limit is going to be decided by the matrix. So, this is another thing.

Then another important thing to note is that in general most matrix materials most matrix, so I have we have not talking about some special matrix material such as metal matrix systems as a CEMETS. Most of the times metal matrices are made from polymers like epoxies, polyesters, peak and things like that. So, in general most matrix materials are light, flexible, weaker relative to fibers. So, we have to bear this man mind when we are designing the overall system. So, this is very important.

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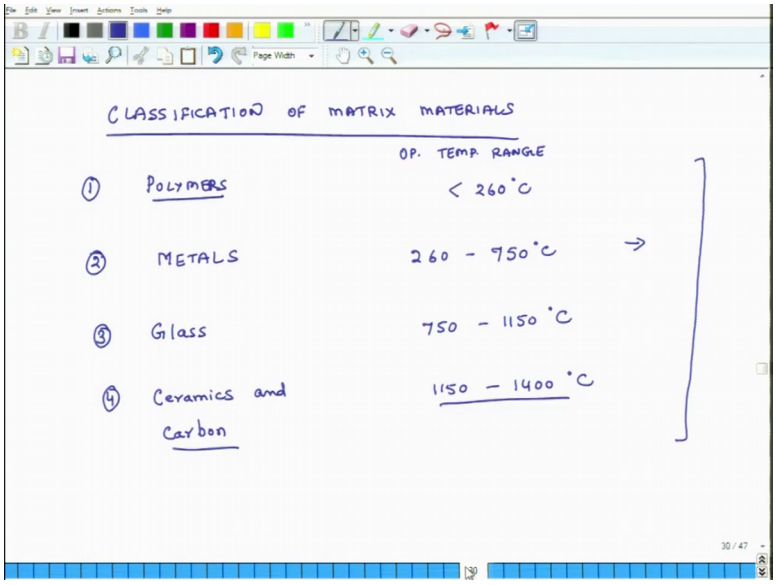

Classification, classification of matrix materials. So, broadly speaking there are four classes of matrix materials. So, the first class is polymers. Polymers, they are organic compounds, long chains and matrices, which are based on polymers; they rarely perform above 200 degrees centigrade. So, operating temperature range, so they rarely, so it is usually less than 260 degrees centigrade. So, if your application ranges room temperature or you know general up to 100, 120 or if it is you really use a really fancy matrix polymer matrix maybe you can go up to 250, 260 degrees integrate, but not more than that then you can use polymers. So, if the temperature which is a very strong influencer as to what type of matrix you should use.

Second one then you can use metals as matrix has materials has matrix materials. So, if you want to increase your operating temperature limit the next choices metals. Here the

ranges from 260 to 750 degrees centigrade, good example of a metal matrix example would be aluminum I mean in some ceramic metal composites sometimes aluminium is used as the matrix because it is light. So, this is there.

If you have to go even higher than 750 degree centigrade think about it what materials do not break above 750, so that could be glass. So, glass allows you to go up to from 750 to 1150 degrees centigrade the good thing about metals is that they are not brittle in general, they are ductile, but if used glass as a matrix material then you have to make sure that you do not apply you know in applications where you it can become brittle. So, if you have high impacts and things like that then this can crack. So, you do not want that so, but then glass can get you up to 1150 degrees centigrade or so.

And then finally, you have ceramics and carbon. So, this can go from 1150 to 1400 degree centigrade. So, these are different classes of matrices and we have classifies based on here operating temperature range. When you are planning to use carbon as the matrix, it is very important to remember that at higher temperatures, if you have a piece of carbon and you have oxygen it will burn. So, you have to make sure that if carbon is the matrix material and temperatures are pretty high, then you have to somehow protected from oxidation. So, you have to put it in something which is still stable temperature wise and it does not react with carbon, and it protects it correctly. So, this is very important thing to consider.

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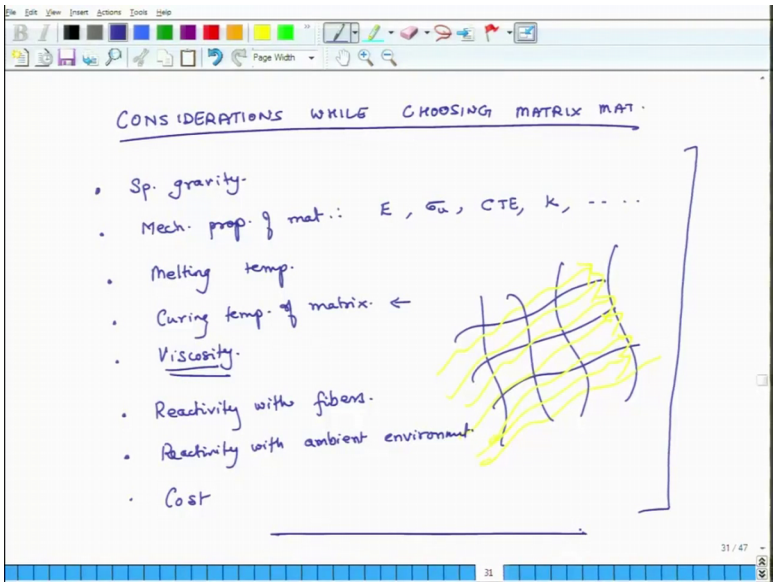

So, with the all this information finally, we will look at some of the important considerations which are required while we are choosing the matrix material. So, considerations while choosing matrix material. So, they are several considerations, they are not in any particular order, but these are some of the important considerations. First one is a specific gravity. Do you want your material to be light or weight is not going to be a bit consideration, so a specific gravity. So, for that reason if I have to have a very super light application maybe I do not want to consider metals as the matrix material because even aluminium which is one of the lightest metals, it has a density of about 2.8 compare to polymers where the densities about 1 or 1.2.

Second thing is we have to look at the mechanical properties of material. So, what does it mean in mechanical properties young's modulus, ultimate tensile strength, CTE, thermal conductivity and so on and so forth. Now, the third one is very important melting temperature. Now, some matrix materials do not have a melting temperature first thing some thermo set polymers they do not. So, you heat them and after a certain point, they will just decompose. So, either you can consider melting temperature or the decomposition temperature of the material, so that is there.

But the another thing is curing temperature of matrix, because a lot of polymers when they are in initial state they are in fluid state liquid state and then you mix them with some compounds, you raise the temperature and then at an elevated temperature, they solidify. And at that elevated temperature because they solidify thermal stresses get logged into those types of things. So, curing temperature has a strong relationship with the thermal stresses which are logged in the composite and also in the matrix material, so that is why this is important.

The next one is viscosity because. So, why is viscosity important? Suppose, you have fibers and then you want this matrix material, you want matrix material to flow like this. Material, which is extremely viscous, will not flow between the fibers very easily. And as a consequence, fibers will be at some places they will be wet, but at other places they will remain dry and where they remain dry they will remain unconnected with the overall system. So, they will be internal cracks. So, for processing related reasons, viscosity is a very important parameter. So, we have to make sure that whatever is the viscosity, it does not create problems like this.

Then you have reactivity with fibers you really do not want your metrics to react with fibers they should be mutually inert with respect to each other. Then reactivity with ambient environment, so it could be that you have going to use your composite in sea water, we have to make sure that we have matrix does not react with sea water or in air or a nitrogen whatever. And then of course, the last thing and very important thing is cost. So, these are some of the very important considerations when we are discussing about matrix materials. And this I hope it gives you a overview of what the whole world of matrix material looks like.

Starting next week we will discuss different matrix materials in terms of their physical properties, and what are some of the specific applications of these different materials? And once we are done with matrix materials, then we will move into the next phase as to how composites are fabricated. So, matrix materials fabrication of composites that is something those are some of the two topics we plan to touch upon next week. So, till then have a great time and I look forward to seeing you on Monday which will be the week three of this course.

Thank you.