Processing of Non-Metals

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Module - 5
Polymer Matrix Composites: Processing
Lecture - 1
Composite Materials

A very warm welcome to all of you, in these series of lectures on processing of non metals as all of you are well aware, We have been discussing various aspects of processing of non metals in the different types of lectures which, we have seen till date. We have already seen different types of non metals like glasses, ceramics etcetera. So, today we are going to start another important module on processing of polymer matrix composites, which is one of the most important categories of composite materials, which are being used today although there are different types of composite materials, which are being used such as the ceramics, composite materials, the metal matrix composites, but, the most applications of polymer matrix composites are found in day to day world. So, before going towards the characteristics and the application areas of the composite materials we need to understand that, what is a composite material, as we have seen different types of monolithic materials or single phased materials till date from now onwards, most of our discussion would be based on the composite materials.

So, we need to first understand that, what is a composite material? So, composites basically are made up of one or two additional phases in the primary phase. So, there will always be two to three phases in the composite material. So, before finally, going towards the composite material first of all we will see that, what are the challenges in the selection of the materials? for example, there would be some specific requirements for which a particular material has to be chosen. So, what are the important properties that have to be taken care of when, we are going to select a material. So, in today's lecture, we will just have an idea about the challenge of that selection that, what is the selection and we will also see that, what are the basic composite materials? So, before starting the section, we will say that, we have two different classes of composite materials, which fall under the category of non metals; we have already seen, what are plastics? So, our focus would be using plastic as a matrix material and reinforcing it with different types of fibers to make a polymer matrix composite similarly, we have already seen, what are

ceramics. So, we would be reinforcing the ceramics with some reinforcements in order to make it a composite. So, our focus would be on two broad categories of composite materials, which are the polymer matrix composites and the ceramic matrix composites. Our focus would not be on the metal matrix composite because the course as the course structure goes. It is on processing of non metals. So, our focus majorly would be on the non metallic aspects of the materials. So, now, we will just go thru the important criteria of selection of materials. So, why these composites are required at the first instance, we would be seeing in a couple of slides that are going to follow.

Now, composite materials already I have told you the brief introduction of the composite materials. So, composites basically are a two or a three phased system just to repeat again, composites are basically made by combining two or three different phases together. Now, these phases can be of different types means, we can have a plastic, we can have a ceramic although, we can also have a metal and these are combined with some other reinforcements, which lead to a development of a material which is far superior than the properties of the individual constituents. So, all these aspects we are going to see, but, first of all we need to understand that why actually advanced materials or these types of materials have been developed because here, we are combining two or three different phases together to make a single phase and the single phase we say is a better representative of certain properties, which are not attainable by the two materials taken independently suppose, I have a material a and I have a material b. So, these are the two materials taken independently and when, I combine the two materials together a plus b gives me some properties, which are better than the individual properties of a and b. So, that is the most important aspects that is why these materials have been developed. So, we will see the different types of composites and how to process these composite materials.

So, first important aspect is the selection of materials, we have to select a particular material for a particular application, we have to see that, what are the important characteristics that should be taken care of for example, we can see in our studio only, I am using a mouse, the material for the mouse is a plastic material. The mouse cam also be made up of a metal, it can also be made up of wax, it can be made up of any other material, but, why it only plastic material has been selected to make this mouse. So, the design of the product dictates that, which material should be chosen similarly, the other

important aspect is the in use means, when I am using this mouse the requirements should be met. So, important most importantly we have to see that, what is the design of the material, what is the design of the product as well as the in service requirements of the products. So, with the on the basis of this only we are going to select the material. There are various properties, various characteristics which should be taken into account, when we select a particular material for a particular application. So, what are these factors? What are these properties? What are these characteristics, which should be taken into account while selecting a material and these properties will lead into further development of new materials such as composite materials.

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So, now we can see the background that is why, the material development is required. So, we have so many diverse applications from biomedical applications to aerospace applications to marine applications and even household applications. So, always we want that, there should be good quality, good performance. So, for good quality, good performance the focus has to be always on materials as well as their processing techniques, although the single phase materials or we can say simple materials or natural materials like glasses and ceramics sometimes natural glasses and natural ceramics. The processing techniques have been developed over a period of time, but, for these advanced materials where, we are blending two or three different materials together, the focus becomes more important on the materials aspect, on the design aspects of these materials as well as the processing aspects of these materials.

So, here we can see the focus on these days is on performance and quality we can call this as a golden triangle of manufacturing engineering, in which we have three important sides. What are the three important sides as is quite clearly mentioned on your screen the design the materials and processing technology. So, in order to catch this particular problem or to just understand the nuances of these problems related to materials related to processing technology related to design aspects. We need to understand courses like this, although in our course our major focus is on the two sides of this triangle, what are the two sides of this triangle which we are focused on the materials and processing technology, we need to understand that, what are the different types of advanced materials and what are the different types of processing technologies, which are used to process these materials or to manufacture these materials or to produce these materials. So, we cannot do away with the materials side as well as the processing side of the important design applications.

We have to, although we are able to generate a very good design, but, we have to focus on the materials, which are going to be used for converting that design into a tangible product and we need to understand the processing technology. The cost effective good quality processing of that material, which will lead into a development of a good products, why some of you may be wondering that, why we are discussing all these things at such a later stage in our course, because for different types of single phase materials again, I am emphasizing there are lot many processes, which have already been developed, but, the role of materials and their processing becomes even more relevant, when we are combining two or three different things together or different phases together or different constituents together in order to make a third material, which is called a composite material. So, when you have a two phase system, the processing also a challenge as well as the design is the challenge more important. The material development itself is a challenge. So, what is the need? So, what are the requirements and why do we need to develop these new materials, we will just quickly go through different aspects of material development, that why do we need to develop different types of materials.

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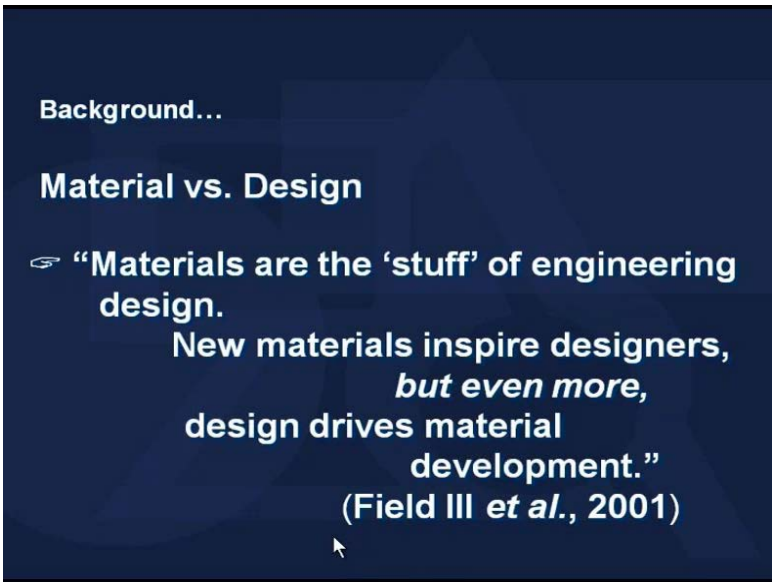

So, material versus design, this is very rightly said materials are the 'stuff' of engineering design, because any design we have a design of a aero plane, it will be made up of materials I have a design of a mouse, I have a material to convert this mouse into a particular product similarly, any different material, any different design I take, It should be converted into a tangible product with the help of materials and processing technology. So, materials are the stuff of engineering design new materials inspire designers, but, mo much more design drives the material development. So, it is a two way traffic as is clear in this statement, you can see new materials inspire design suppose a new composite material is developed, new composite materials means, there is a different type of constituents, which are combining together in order to make a new material. Now, this new material has been developed, it has got some properties and these properties can be harnessed by the designers to develop a new product, which will be made up of these materials.

So, the new materials, which will inspire the designer in order to use that material in some of these designs, but, even more it is the design that derives the material developed which means, the design has already been made a particular shape has been found out or a particular shape has been given to a particular design and now, the material has to be found out that, which material can be molded into that desired shape and then further we have to find out that, which process can be used to convert that design into a tangible product at which process can be used to convert that material into that particular design

for example, suppose I want give a very intricate shape to wood, it cannot be given may be by the conventional processes. I need to have some specific treatment of the wood and some specific modification in the shape of the wood can only be done with some specific processes. So, what I mean to say that, it is a two way traffic either a new material has been developed designer will find the applications and the products that can be made up of that material or a design has been made application has to be found out that, which particular application is best suited for that application. I mean to say the material, that which particular material can be applied in order to convert that design into a tangible product. So, it is two way of traffic alright.

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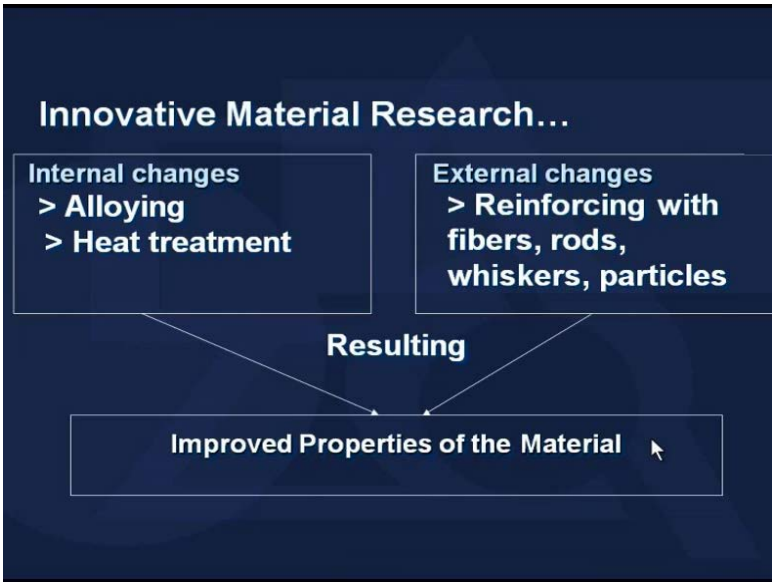

So, now we will go forward to the innovative material research, why there is always the trend towards finding out new and new material, because always there is a need for a specific application. Now, suppose I want to send a particular spacecraft into space, we need to find out that, which materials can sustain the type of conditions that are prevalent in space. So, always if I want I am going to use a particular material for marine application, I have to find out that, what are the specific requirements in the marine applications, which type of composite will be able to sustain the marine environment, which type of composite will be able to sustain or in order to satisfy the design requirements in aerospace applications, which type of material is more suitable for biomedical applications. So, always there is a trend towards innovative material research.

So, as we have been discussing the various aspects of materials developed, we need to understand again, I am emphasizing that, what is the need for developing new materials, what are the requirements of developing new materials as we have been discussing in this course of lectures, that processing of non metals is an important aspect of engineering metals non metals, there are different materials and now we are combining the different materials together to generate a third material. So, what is the requirement of generating this third material, what are the requirements, which this third material has to meet, which are not being met by the materials, which have already been in use or the conventional materials. Now, innovative material research means that always we are focusing on coming up with new and new materials. The physicists the people working in the area of chemistry or in general I can say in basic science, they are always focusing on developing a new material. There are broadly two approaches of developing new materials which would be required to meet the necessities and the requirements of the today's engineering applications.

Now, what are these two approaches? The two approaches are the internal changes and the external changes. I have a material suppose material a, I want to make a material c by that material a simplest approach I will do some processing on that material and convert that material into a desired material. Now, how that can be done? That can be done on the left hand side of the figure you can see, it can be done by alloying or heat treatment. So, these are, you can say two broad approaches in which a material can be converted or it can be transformed into a desired material with desired properties. So, broadly there are two categories, one is the internal changes and another one is the external changes, within these two categories, the first one is converting a material into a desired material with these two important process that is by alloying or by heat treatment but, in case of composite materials our focus is not on alloying or heat treatment, our focus is on the second type of material development, that is reinforcing with fibers, rods, whiskers and particles. So, what has to be reinforced, there is a material a, I have a reinforcement in the form of material b. Now, I will combine these two things together material a and material b together and I will have a third material, that is material c.

Now, material c has a innovative edge over the materials a and material b, if I use material a and material b in certain particular application, they may be excellent, but, in some particular applications it will have some limitations material a similarly, material b

will also have some limitations, but, when I combine these two materials together, the combination or the third material which we generally call as a composite material would be having certain properties, which will not be achievable by the two independent materials or the two constituent materials taken along. So, whenever I think of developing a new material for a particular application my focus would always be on these two approaches, that is the doing some internal changes in the material or adding some another phase into the material in order to develop a new material. So, as you can just refer to this figure internal changes and external changes, what these two changes result, these result in a material which has improved properties.

So, the third material or the developed material has got improved properties of the constituents and these are the properties, which are desired, which are really required in the applications. Suppose I have an application in which the material, which I am developing has to be used in aerospace. Now, aerospace has got its own applications or on material requirement for example, the first and foremost requirement is that, the material which we are going to use for making a component which has to be used in aerospace application has to be light in weight. So, that is the first and the foremost requirement for the material which has to be used in the aerospace applications. Now, I would go thru these two approaches and try to come out with materials, which are light in weight, but, certainly they should be able to meet the strength and the other criteria which are require for that particular application. So, here in this particular slide, we are focusing on what is the area of materials research or what how the new materials can be developed. So, these two materials, these are the two approaches of coming up with new and new material just to have a quick revision of what we have seen in this slide.

We have two important aspects of material development, one is the change in the basic nature of the material that is by the alloying or the heat treatment or the external change is by reinforcing the basic material that we call as the matrix by fillers, rods or by certain other types of reinforcements. So, these two things, when we are combining together these will lead to few new materials and these new materials would have certain properties, which would be very superior as compared to the properties which are already attainable with material a or material b taken independently. Now, we need to understand that where does processing fit into all these pictures.

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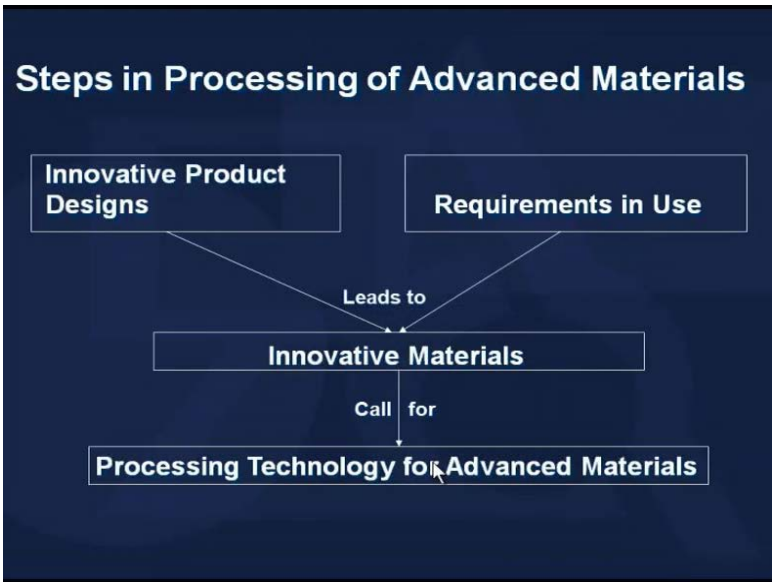

So, that we will see with the help of this particular slide, you can see steps in processing of advanced materials. So, although the focus is on processing that is coming in the end of this particular slide, you can see processing technology for advanced material but, first we need to understand that, how this advanced materials are coming into picture. So, these advanced materials you can see, that innovative product designs. So, basically what I mean to say here is that new and new product designs are coming into picture. Now, these product designs have to be finally, converted into a product.

Now, when we have to convert these are design into a product, there are materials which are required to go into that design. So, that the design can finally, see the day of the light or the light of the day sorry. So, basically this product design requires some materials and sometimes for some particular applications for example, underwater application, a particular component has to be underwater throughout its service life. So, it needs to have certain physical and chemical characteristics, which particular material can offer this characteristic is a material for that particular underwater application. So, we have in service requirements, we have product designs and these designs and requirements focus or leads to the development of new innovative material. So, as is clear from the slide you can see, there are innovative product design, there are requirements in use I have given the application of underwater and these leads to innovative materials. So, the requirements and the needs are there and these needs and requirements have to be met.

Now, these needs and requirements are of the various engineering applications. So, these engineering applications require the development of new and new material.

So, you can see the innovative product designs and the requirements in use they combine together and they leave to the material scientists and engineers and they guide the material scientists and engineers to come up with innovative materials. So, till now we have focused on the materials aspect. Now, we want to focus on the processing aspect. So, till now we have seen that there is a need to come up with innovative materials we need to come up with new and new materials for specific applications. So, once the material has been designed or the material has been found out. This is the two things which can be combined together to give a particular property, which is not achievable with independent material. Now, the further step is to find out the cost effective good quality processing root for that particular developed material suppose, I develop a material a by combining x and y x and y have been combined together and these have been you can say bind it together and I found out that if I blend these two materials together. I should be able to make a material a, which has far superior properties, once this innovation has been done.

Now, how to convert this innovation into a commercial success? I need to understand, I need to develop, and we need to think that how these particular materials can be processed, then finally, towards the end you can see in this particular slide processing technology for advanced materials. So, here in this particular module we will more importantly be focusing on one class of advanced materials which are the polymer matrix composites.

So, till today till this particular slide we have just seen that what is the importance of materials and how the new and new materials are being developed and what are the needs and the requirements that are leading to the development of new and new innovative materials. Now, finally, suppose we have a plenty of materials at our disposal and I have to design a product, we have to find out that, which particular material would be more suitable for this particular application. Now, we need to understand that, what are the important physical chemical characteristics? That should be taken into account when we select a particular material. So, the next few slides would be focusing on the important factors or the characteristics that should be taken into account while selecting a particular material for a particular application.

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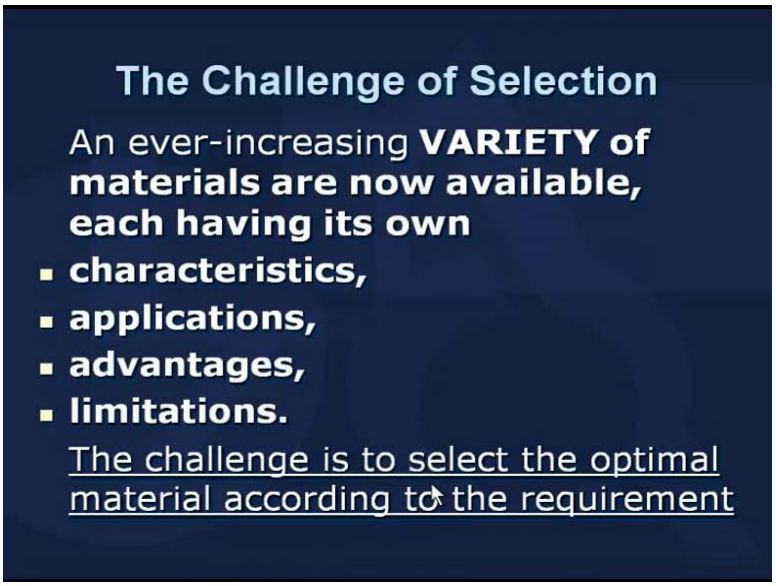

Now, the challenge of selection till now we have seen new and new materials are coming up, there are large varieties of materials which are available with the designers to choose from and now they have to take decision that which particular material is more suitable for particular application. Now, you can see on the slide and an ever increasing variety of materials are available each having it is own you can see each material will have its own characteristics applications advantages and limitations. So, these are the four important points, the four important points just to repeat are the characteristics of the material the applications of the material advantages and the limitations.

Now, the challenge for the designer is to select the optimal material according to the requirement, I have already given one example, of underwater application I have already given an example of aerospace applications there can be so many other applications like the biomedical implants any material, which would be used for biomedical implants for making a biomedical implant has to have certain important characteristics. It has particular material has to be designed in such a way that, it can be used for biomedical implants. So, each and every application will drive the new and new material development. Now, these are the four important characteristics, which have to be considered when we are trying to understand the problem of selection. So, the selection is very important for example, loosely on a very lighter side we can say every morning when, we go and brush our teeth the bristles are made up of a polymeric material, cant we make those bristles of metallic wires, we have wire brush in use, why do not make

the bristles of metallic wires, because the brush has to touch our teeth as well as the gums. So, for a particular application there has to be a particular material depending upon the requirements of that particular application. So, here we can see different types of characteristics that have to be taken care of

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Now, we have in the very first slide, we have seen the very first lecture on this particular course, we have seen that there are variety of engineering materials available these days with the designs. So, what are these varieties of materials out of which we can choose the best material? Now, these variety of materials are the ferrous metals the non ferrous metals like aluminum, magnesium, copper and nickel. Then, we have plastics, we have already seen one module on plastics in which, we have seen different types of thermo sets and thermoplastics, you have also seen different manufacturing techniques or processing techniques for processing the plastics.

Another category another type of material which are available are the ceramics and diamond, we have already seen what are ceramics and what are the various types of ceramics. Then we have composite materials which we are now discussing in this particular module and then, there are some advanced materials like nano materials and shape memory alloys. Now, these are the variety of materials, which are available with the designers and now they have to choose which particular material is best suited for which particular application

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So, first important aspect to understand is the properties of the materials. Now, the important properties of the materials are. So, when selecting a particular material for a particular product we have to see that, what are the important properties of the material within properties? also we have different types of properties like first and the foremost for mechanical engineers are the mechanical properties. Now, what are these mechanical properties? Mechanical properties are such as strength, toughness, ductility, hardness elasticity, fatigue and creep. There can be others also. So, these are some of the properties of materials which have to be taken into account when you are selecting a particular material.

The strength to weight ratios of materials is also important, particularly for aerospace and automotive applications. So, an example has been provided the strength to weight ratio. So, strength to weight ratio is particularly important in case of composite materials then, we will start our discussion on the types of composite materials, we will say this is one of the most important property which has to be taken into account, this is one of the most important mechanical properties which has to be taken into account. When we are selecting a particular composite material for a particular application in totality composites are suitably properly suited for use in light weight applications. So, the first and the foremost property, that we have to take into account while selecting a particular material are the mechanical properties just to revise we have so many different properties here, that we cannot go into detail this particular lecture, but, we need to understand the

various mechanical properties of a particular material, because the mechanical properties of s plastic would be different from the mechanical properties of a metal and from the mechanical properties of a ceramic.

So, we need to understand that, what are the requirements of this particular application for example, if I want to put a particular material inside the body or I want to use a particular material as a biomedical implant, it should have good toughness. So, that. it does not fail on a very small loading environment or very small load is acting and if the biomedical implant fails you can think of the patient, who is having the biomedical implant inside his body. So, the important point is we need to understand the mechanical properties of a particular material before advocating its use for a particular application. So, we have seen some of the mechanical properties in this particular slide you can see again just for the revision point of view, what are the mechanical properties that are to be taken care of these are the strength, toughness, ductility, hardness, elasticity, fatigue and creep as I have already mentioned there another properties also which can be taken into account under the broad umbrella of mechanical properties

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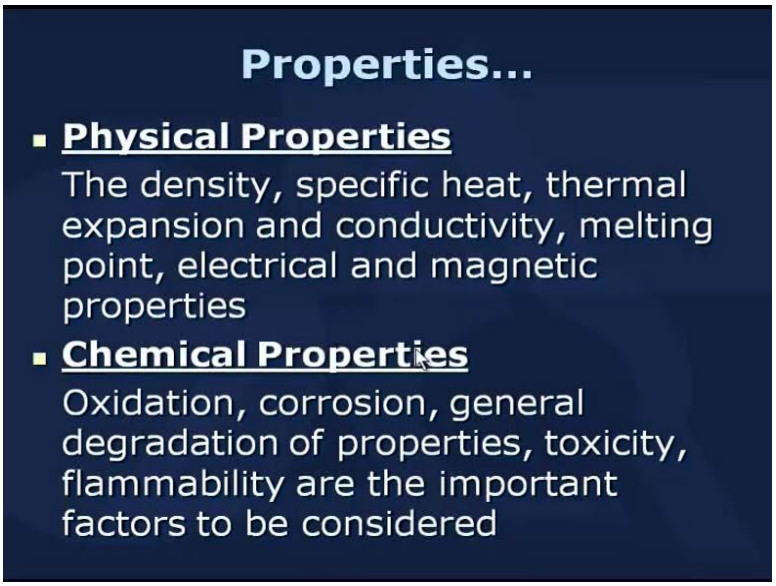

Now, coming on to the next, the physical properties are like the density specific heat thermal expansion and conductivity melting point electrical and magnetic properties. So, these are the physical properties, that have to be taken into account while selecting a particular material then, we have chemical properties like oxidation, corrosion general

degradation properties toxicity flammability these are important factors, that have to be taken into account when we select a particular material. So, till now we have seen three important properties, which have to be taken into account these are the mechanical properties, the physical properties as well as the chemical properties specifically like we can take an example of corrosion, when we are taking a composite material, we have to see that, how it will react when it is undergoing or when it is being used in a particular application, where corrosive environments are in use.

So, if a particular composite material will degrade on corrosion, we can avoid that particular material for that particular application. So, we have to see, suppose another property toxicity, we have to see that a if any material has to be chosen for a particular store for storing the food we have to see that, the material should have, should not be toxic in nature or it should not produce toxicity reacting with some of the food ingredients. So, that type of decisions have to be taken depending upon the chemical properties for example, the physical properties, we can see density specific heat, thermal expansion, melting point is an important property, suppose a material has to be chosen for a handle in a utensil, it should not only have a very low melting point, suppose you are heating a particular food ingredient in the utensil and the temperature rises to a particular level, the material that is used for making the handle should be able to bear the temperature. So, that is a physical property that should be taken into account.

So, when we have a particular application depending upon the application, we have to think, we have to take a decision an engineering decision, that what are the properties, this particular material has and whether these are in line with the property or the requirements or the of the particular application. So, we need to understand the mechanical properties, we need to understand the physical properties, we need to understand the chemical properties.

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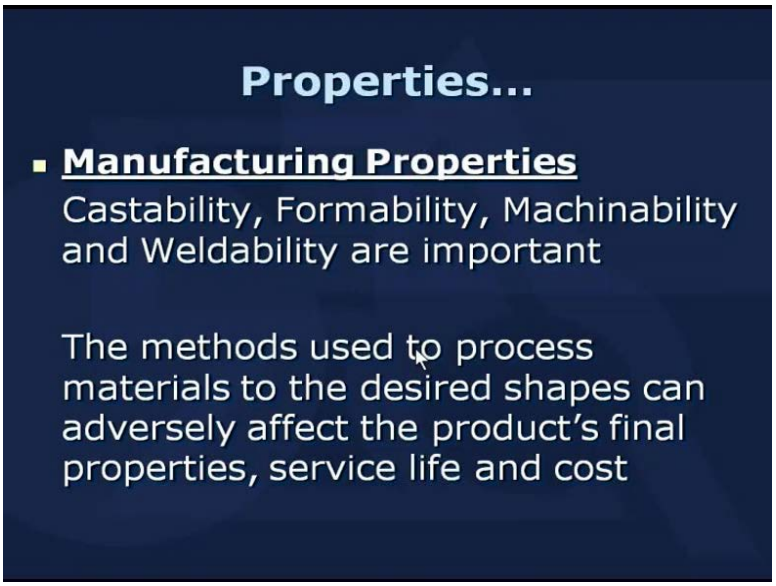

As well as, we need to understand the manufacturing properties of the materials. Now, what are the manufacturing properties of the materials manufacturing properties are like cast ability, formability, and machinability and weld ability. Now, suppose we have taken a particular material we need to understand that whether this product can be cast into a important engineering component or not what are the problem areas associated with casting similarly, whether this can be machined or not whether this material can be welded into different shapes or not. So, if you have a very huge product you need to develop that into four or five different individual components and then, these components have to be joined together to make up the component.

So, your welding becomes a very important manufacturing process in the development of that particular product. So, we need to understand whether it can be welded or not whether it can be machined or not. So, basically we can see, we have seen four important properties of the materials. which have to be taken into account when we are doing a judicious decision of selection of a particular material for a particular application. Now, what are the four properties that we have seen till now? Mechanical properties, physical properties, chemical properties and the manufacturing properties. Now, suppose I have a particular material suppose material a with me and I have a particular applications suppose the application is z or suppose, I take z under water application any material I have to choose which will be used to convert into a particular product and the product will be used for underwater application. I need to first understand the requirements of

underwater application and then I will try to match the material and when I am selecting a particular material.

I will see that, what are the mechanical properties of that particular material? What are the physical properties of that particular material rather it can sustain underwater application or not or underwater environment or not then, I will see the chemical properties because sometimes there will be some salts in water. So, this particular material will always be in contact with that type of water which is salty. So, I have to just check that, what is the material is whether it will be able to sustain that particular type of corrosive environment or not and finally, I have to see the manufacturing properties, how this particular material can be manufacture.

So, I have a list of materials suppose, I we have seen the variety of materials which are available, there are three or four types of materials sorry, not three or four there are six to seven families of materials which are available and out of these six or seven families of materials we have to choose. Now, I can use any method of finding out, that which particular material is best suited for a particular application suppose I take three materials material a, material b and material c as the candidates for a particular application and I have suppose four different specific requirements of that product.

Now, these four requirements and three materials, it becomes you can say selection problem in which I will see that, which particular material suits all the four requirements of this particular application. So, out of these 3, I will be choosing one and the first and the foremost thing that. I will be keeping in mind are the 4 important properties which will go into the application. These 4 properties are the mechanical properties. The physical properties, the chemical properties and the manufacturing properties, they apart from all these properties, there a number of other properties or other characteristics that have to be taken into account. So, very quickly we will go through these four characteristics. Once, we have already found out the technical aspects of the materials for example, the mechanical physical and the chemical properties then, there are other things that have to take into account

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Now, the first and the foremost thing is the cost and the availability of the economic aspect of material selection is as important as technological considerations that, we have already seen of properties and characteristics of materials. So, we have to see, we may be finding a particular material, which is most suited for most desirable for a particular engineering application, but, if it is very costly we may think of avoiding that material and look for substitutes, which can provide us s little less performance, but, at a relatively lower cost. So, vast availability is equally important. So, if a raw or processed material are not available in the desired shape dimension and quantity quantities then, what can be done first and foremast technological consideration already we have seen, we have highlighted or found out that these are the two material, suppose which can suit our application. Now, out of the two, I have to select my first and foremost intuitive appeal would be to go for the cheapest one.

Now, suppose I choose the cheapest material after choosing the cheapest out of the two, which are satisfying the technological considerations. It is not that material is not satisfying the technological considerations first and the foremost point you can see in your slide, again I want to emphasize the economic aspects of material selection are as important as technological considerations. So, we have already taken the technological considerations into mind we had suppose a list of five materials out of that, we have chosen the two best materials, which are satisfying the technological considerations.

Now, out of these two we want to select the cheapest one. Now, the cheapest one is the cheapest material or the way we can say.

Is the one which is suiting our requirement? So, the cheapest material is, if it is not available in the raw or the processed form then, what we need to do the second point I am highlighting. Now, raw or processed material is not available in the desired shape dimension and quantity, what we need to do out of five in the basis of technological considerations. I have come to two on the basis of economic considerations I have come to one I have chosen the cheapest one out of the two.

Now, if the desired shapes and quantities are not available, what is the approach that I am going to follow? The simplest approach is to do the design modifications. So that, we can the design can be modified in such a way it can be redesigned. So, that whatever is available we can use that particular shape or size in order to make the tangible product or what we can do is, we can think of designing a particular material or we can change the shapes and sizes of the material that is available at our end although it would be done at economic. You can say justification, we have to somehow improve the cost would certainly increase in this particular case where, we are modifying the shape and size of the material to fit to our particular design.

So, there two approaches either to change the design or to change the material. So, the first and the simplest approach is to change the design according to the materials that are available or you can keep the design constant, you can change the material or change the not the material, but, shape and size of the material bring it to the desired design, but, it will add cost to the overall product development process.

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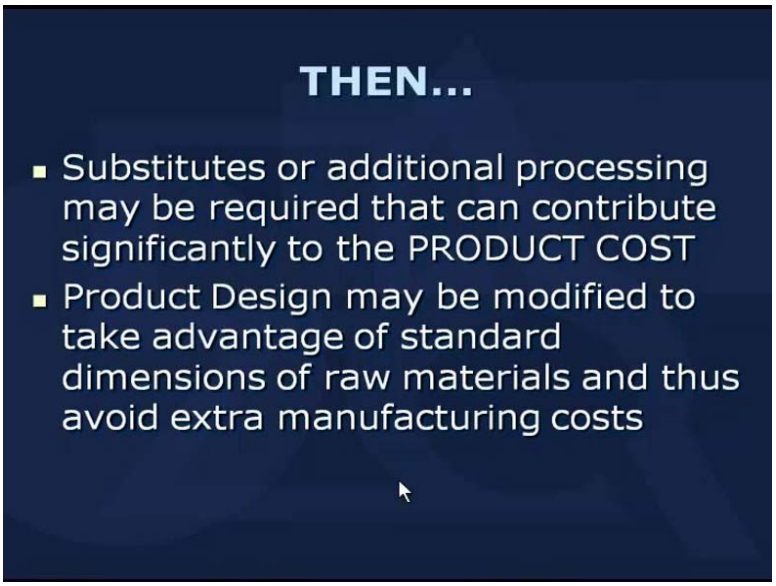

The other aspects as we have already seen substitute or additional processing may be required, that can contribute significantly to the product cost. So, the point that I was highlighting in the previous slide that, if the material is not available in the raw or the processed form the desired shapes or quantities. What are the approaches that are there with us? So, the two approaches, which are quite rightly, point out in this particular slide you can see. So, we can find look for the substitute or additional processing may be required that can significantly add to the product cost or the second approach can be product design can be modified to take advantage of the standard dimensions of raw material and thus avoid extra manufacturing costs.

So, till now we have covered four or five important aspects of the challenge of selection first is the technological consideration in terms of the mechanical properties, physical, chemical and the manufacturing properties of the material second one is a cost and the availability aspects. So, if the cost, if there are two materials, we will choose the cheapest one and finally, if it is not available in the desired shapes and sizes we will change the product design or we will have to process it further to bring it according to the design requirements

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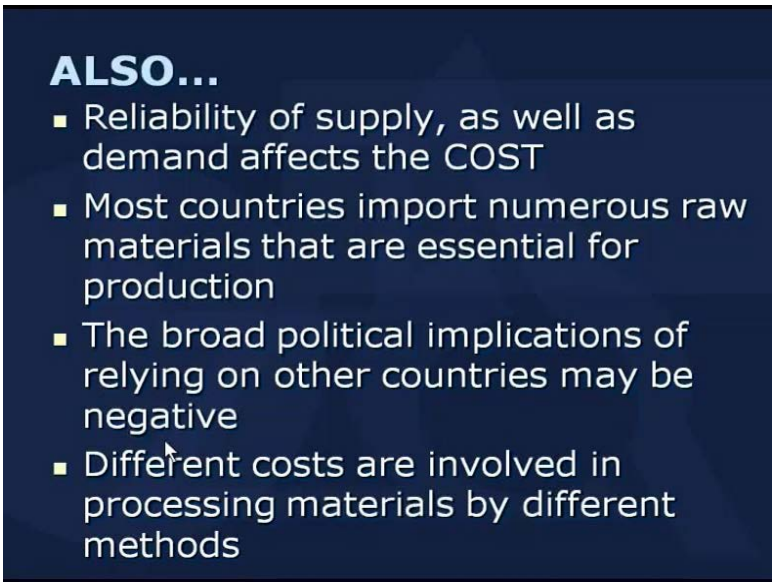

Now, what are the other aspects, that have to be taken into account, we have to see the reliability of the supply as well as the demand affects the cost. So, if the demand of the product is more and the supply is less although it will have the nearing on the cost and the reliability of the supply is also equally important, when we have to select a particular material for a particular application, suppose I select a material for which, the supply is very limited and I have to make a product out of it. So, the supply is limited the receipt of the material will also be limited and it would be dictated by the vendor who is supplying the material to or company.

So, when we are selecting a material for a particular application, we should also focus on the reliability of the supply. Now, most countries import numerous raw materials that are essential for production. So, this import, export business sometimes also dictates the selection for the engineering material for a particular application. So, we have to see the broad political implications of the relying on the other countries and sometimes these implications may be negative also these, we see because of the political compulsions so many you can say restrictions are put on a export and import of certain by certain important commodities and then these political implications force, the designers and the engineers to select the materials accordingly.

So, cost and availability is also equally important select a particular materials for a particular application different costs are involved in processing materials by different

methods, that also has to be taken into account, because if there are three materials. When we have to process it into a particular product, processing material a would incur a different type of cost, different cost structure processing material b would have different cost structure processing material c will have different cost structure. So, the processing will have nearing on the cost structure of the final product.

So, therefore, we have to see that, which particular material has to be selected although this comes under the broad umbrella of the cost justification suppose there are two materials, we will choose the cheapest material, which would be finally, converted into the final product here, in this particular aspect we have focused on the cost and the availability issues of the material. Now, cost is very important availability on the contrary is also very important. So, we have to see that what are the these two important aspects, when we are selecting a material

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There are other aspects as well like the appearance these days we see there. So, many good quality products are in market. So, quality is a very important aspect of the product in which, the very beginning of this particular lecture. We have seen a triangle in which the product quality was being dictated by the materials, the design as well as the processing technology. So, when we have to certain a quality we have to see and we have to appropriately choose the materials. So, the materials which will give good appearance would have you can say a better appeal in the market and would result into

higher revenues. So, appearance, the appearance of the materials after they have been manufactured into product influences their appeal to the customer.

So, it is a very important business decision that to select a material, which will give good appearance after processing similarly, color feel and surface texture are characteristics that are considered before making a decision about purchasing the product. So, these customers take into account all these things like color fill or the surface texture of a particular product.

So, we have to see the appearance of the material should also be good, we cannot choose a material for a particular application, which would not good look for the eyes of the customer or to the eyes of the customer, the customer should feel very happy, he should feel that, if he owns this particular product he would be have a certain type of a esteem value associated. So, these are few important aspects, which have to be taken into account. These are the cost and availability, the appearance and further we will see there are few other aspects which have to be taken into account when we select the particular material for a particular application.

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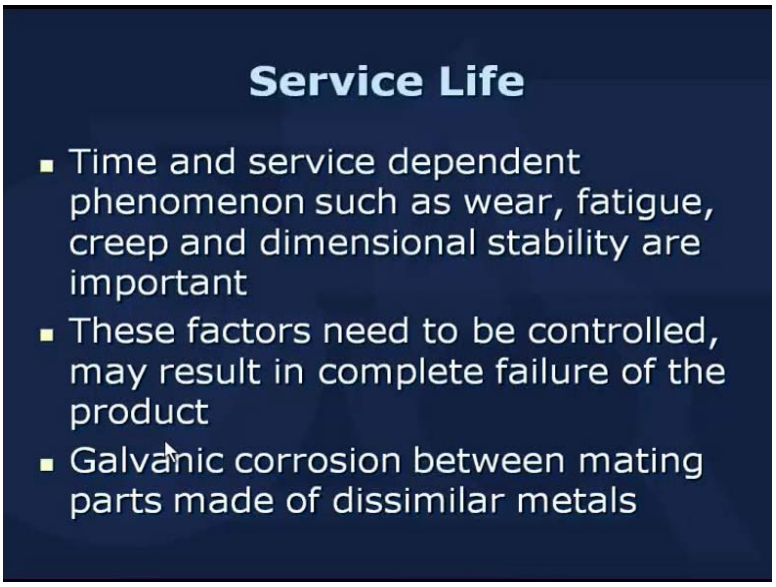

Service life of the material time and service dependant phenomenon such as, wear fatigue creep and dimensional stability are also equally important. So, we have to take into account all these four aspects wear fatigue creep and dimensional stability is important. Now, suppose I take a particular material for a particular amp application and

suppose after two months of use, it was designed for a service life of suppose one year only after using it for two months, the dimensions got changed, because of some atmospheric conditions and because of any other reasons.

So, a material that is used to make the product was to last for one year has only decayed or dimensionally become unstable only after two months. So, we have to avoid those materials, which do not offer us that kind of dimensional stability, which is desired suppose, that product was designed for two months only and after two months, it has got dimensionally unstable then, there is not an issue but, the important point to note is when selecting a important material, we have to see whether it will bear under specific conditions or not what is the service life in terms of the fatigue cycle. It can take or whether it will have pre phenomenon at elevated temperature or whether it will have an important dimension stability property at a particular degree of usage or not. So, we have to take into account all these points when we are specifying the service life and if the service life has already been designed by the designer that, this particular product will be used for a minimum of three years by the customer.

So, when we are selecting a particular material, we need to understand that, this particular material has to bear in the service requirements for the next three years. So, we have to select a material which can bear those requirements for at least five to seven years taking into account. The factor of safety or the type of use the customer is going to put to this particular material instead of use. I can also use the word abuse sometimes some customers will abuse the product like anything till in those type of conditions. The product should not fail, it should work satisfactorily for a desired or for the not the desired, I should say that designed life of that particular product. So, material selection is equally important, when the service life of the product is to be specified. So, these factor needs to be controlled they result in complete failure of the product. So, if we have not taken into account all these properties. The product may fail prematurely suppose the product was designed for one year; it fails after two months only. So, one of the examples is given like galvanic corrosion between mating parts made up of dissimilar metals. So, this type of environment is accounted by the particular material, it may fail. So, when we are selecting a material we have to see that, the service life of the product will be made out of that particular material.

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This important aspect on your side recycling aspect, which is very important in today's scenario. We have to see we have to select those materials which are easily recyclable. So, recycling and proper disposal of materials at the end of designed life has become increasingly important in today's scenario, each and every company is focusing on using materials which are light in weight, which are easily recyclable. So, the focus is on recycling if the recycling complete recycling is not possible at least there should be means and methods of disposing the material. So, emphasis is on conserving recourses and ascertaining a clean and green environment.

So, green environment is a catch word in today's business environment norms and regulations have been formed in order to achieve these objectives. So, basically in this particular slide, the focus is on selecting a particular material which is easily recyclable, if not easily recyclable it should be disposed of easily, because there are very stringent guidelines, there are very stringent legislations leading to recycling and the biodegradability of the materials

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So, the final criteria for selection. So, before we go to the final criteria for selection. Let me just emphasize on the properties, that we have seen or the characteristics. That we have seen while selecting a material, we have seen that there are few technological considerations. Now, what are these technological considerations? Those are the mechanical properties of the material, the physical properties of the material the chemical properties of the material and finally, the properties of the material. So, these are the four important you can say properties, which have to be taken into account while we are formulating a material selection problem apart from these technological considerations, we have to see the cost and availability of the material, we have to see the recycling aspects of the material and we have to see the service life of the product, it is designed for.

So, once all these important points have been taken into account then, we are encountered with the criteria for selection that what final criteria should be chosen for selecting a particular material for the designed application. Now, you can on your screen, you can see materials are primarily selected for their mechanical, physical and chemical properties to ensure proper functioning. So, first and foremost we have to see we have to select a particular material which has specific physical chemical and mechanical properties, which do not lead it to failure in the service requirement as soon as the product is put to use it should be able to sustain the loads or the you can say service requirements that are the product has to face therefore, it should have sufficient

mechanical. I should not sufficient, we should say adequate their mechanical, physical and chemical properties. So, that is the first and the foremost requirement or criteria for selecting a particular material, the second point on your screen, when several materials are suitable means, there are number of materials, which specify all the their mechanical, physical and chemical properties of as require by the application then and no other requirements has to be met the cheapest material is usually selected. So, now from the technological considerations, we are coming to the secondary considerations like cost and availability recycling service life primarily, we have to look at the material from the technological considerations point of view, that is the physical chemical and mechanical properties and then we will come to the subsidiary or secondary criteria that are the cost and availability.

So, if the primary requirements are being met by different materials four, five materials are there with us then, we will see which one is the cheapest and when all other requirements are met we will loosely chose the cheapest material which is going to satisfy the design requirements. So, till now we have seen our course is on processing of non metals but, till in today's lecture, we have seen different approaches of developing new and new materials and we have seen that when we have to see a particular material for a particular application. What are the criteria? We should follow or at least what are the factors that, we have to take into account while we are selecting a particular material. We have given no emphasis on the manufacturing aspects. So, ever last point no consideration to manufacturing techniques.

So, the last point the need of d f m need of d f m means that, when we are designing a particular material or a particular product, we have to focus on the manufacturing aspects also d f m means design for manufacturing. So, the designer will specify that, this particular material would be used to make this product. So, once that material has been finalized, we have to understand that how this material would be processed into a product, because when the product is being made. It has to be cost effective, it has to be good quality only then, the customers are going to buy that particular product. So, what is the major emphasis here, is the design should focus on the manufacturing aspect also and the materials we are selecting should also be focusing on that hoe these materials would be finally, transformed using some of the other processes to the final product. So,

finally, we can see that due consideration should be given to the manufacturing properties also.

So, in today's lecture just to summarize what we have seen, we have seen that, there is a need to develop new and new materials that is the first important point then, there are different approaches which lead to the development of new materials and finally, we have seen that, there are different types of you can say properties, that have been taken into account for selecting a particular material for a particular application. So, now, we have seen the importance of materials and their development in the subsequent lectures. We would be focusing on the processing techniques of different types of composite materials. We would be covering two types only polymer matrix composite and ceramic matrix composites.

Thank you.