Processing of non metals

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Module – 1
Engineering Materials and Processing
Lecture - 1
Engineering Materials and Processing Techniques: Introduction

A warm welcome to all in this series of lectures on processing of non-metals. As the title of the course suggests processing of non-metals, there are two important words in this title that is the processing and the non-metals. So, our focus would primarily be on the tools and techniques and the methods which are used for the processing of non-metals. The overall objective of the course is to acquaint the students with the techniques, which are used specifically for the processing of non-metals.

As there is a difference between the properties of the metals and the non-metals that we will see in the series of lecture or in the subsequent lecture. The techniques which are used for processing are also different, because for metals we will have certain techniques and for non-metals we will have some other techniques. So, basically our focus would be on the techniques or the processing techniques for processing of non-metals. The total modules in this particular course are seven. So, we at the end of this particular lecture, I will outline that what are the contents which would be covered in these modules. So, we will be focusing on different types of non-metals, and we will be seeing that which are the techniques which are used.

But, coming on to the contents of today's lecture as on your screen you can see the title of today's course is engineering materials and processing techniques. So, today we are not going to talk about the non-metals, but we are going to talk about that what are the different types of engineering materials which are available with engineers to design and develop new and new products. Then our focus would be on the different types of processing techniques that are available with the engineers to process these materials or these particular innovative materials into tangible products. So, our focus today primarily is engineering materials or the classification of engineering materials, and the classification of different types of processing techniques. Then we will see that what are the broad guidelines which are used to select a particular material from a variety of

materials which are available with the engineers. Also we will see that in processing techniques, there are number of processing techniques which have been developed for processing of metals and non-metals. And we will categorize these techniques and finally, see that what are the factors which we have to keep in mind when we are selecting a particular technique for a particular application.

So, module number one has two lectures; in module in the lecture number one, our focus is on engineering materials and processing techniques, the basic introduction of these two words or these two broad outlines. And in lecture number two, our focus would be primarily on the non-metals that what are the non-metals, and we will compare the properties - physical and chemical properties of the non-metals with the metals. And because of these properties only the processing of metals is different from the processing of non-metals. And the techniques which are used for the metals cannot be blindly applied for non-metals or on the other hand process processing techniques which has been developed for non-metals cannot be blindly applied on the metals. So, our focus would be to differentiate between the properties of the metals and non metals. So, that we understand that which are the materials, which have the properties similar to the non-metals and how these materials can be processed

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So, let us start today's lecture with the very general concept that is the customers require quality and product quality depends upon. So, basic background of studying this

particular course is that the need of ours is to develop good quality, good quality and cost effective manufacturing. So, the manufacturing or the processing technique which is been developed or which is been used to convert a raw material in to a final product should have two basic criteria. First one is that it should generate final product or tangible products of very high quality; second is that the cost effectiveness of the product. Suppose there is a technique which is making a very good quality product, but the cost is also considerably high, the customer may not be ready to buy that product. On the contrary, the cost is very low, the cost of conversion of the raw material into final product or cost of processing raw material into the final product is comparatively low or relatively cheap, but the quality that we are getting is not good then again the customers would not be interested in that particular product.

So, basically the catch words are good quality and cost effectiveness. So, we have to focus on these two points that the processing technique that we develop for converting the raw material into the final product should have these two important criteria. That is the processing technique should be of very high quality, it means it should be able to generate products, which have good quality, which means there should be accurate précised and the cost of processing should also be good. But, these are general concepts in general when the customers demand quality the quality of the product would depend upon on your screen you can see a very simple diagram. The product quality will depend upon the materials, it will depend upon design, and it will depend upon the processing technology.

So, in this triangle if all of the three things are of optimal quality are of optimal have or meeting the optimal optimality guidelines, we would be able to generate a product which is of very good quality and which is having cost effectiveness. So, product quality primarily depends upon the materials that we choose for making the product, the processing technology that we use for developing the product and the design of the product itself.

But, in our course, we have processing of non-metals again coming to the title of the course, there are two important words processing and non-metals. So, non metal may fall under the broad category of the materials that you see on your screen in that triangle, one side is the materials, so non-metals may fall into the materials category and the processing word will fall under the processing technology. So, we are not focusing on

the design of the product, our focus is on the materials aspects and how to process those materials. So, that we are able to generate good quality products which are also cost effective.

So, in our course we will be discussing different types of processes, maybe I can just make a wild guess that may be we may be discussing may be 50 to 75 different processes for the conversion of materials which primarily would be non-metals in our course into the final product. And we will see that what are the different types of products which are made how the processing technology would dictate the properties of the final product that we are making.

So, basically in today's competitive business environment, the customers are the kings or the customers dictates the type of materials and the type of processing which go which goes into the development of the product. So, customers want quality and the quality subsequently depends upon the three parameters that is the design of the product, the materials that are used to make that product, and the processing technology which is used to convert the raw material into the final product. So, this particular point justifies this particular course that is processing of non-metals, because all engineers should have an idea regarding the processing of non-metals.

Processing of metals is covered in much more details in most of the syllabi in all around the world, but there are no dedicated courses dealing with the processing of non-metals. All of our study process is such as costing, such as machining, such as forging such as bending which are primarily used for metals or the tools and the techniques, which have been developed for these particular processes focus on metals as the raw material, because costing we melt a metal pour it into a mold and we get the final product. In case of machining, most of the research work done or most of the literature, which is available in the form of books focus on the metals aspects. They take the metal as the raw material and then apply different type of machining operations, may be they may be doing turning, drilling, milling, shaping, planning, all machining operation have been developed taking into account metal as the raw material.

So, focus is least on the processing aspects of non-metals. So, this particular course has been designed in such a way that we are try to understand that which are the materials which have properties similar to the non-metals which are engineering in nature may be

there are certain engineering materials like plastics, ceramics, which are not falling under the category of metals. So, our focus would primarily be on these types of materials and how these materials can be processed. In context of this particular slide, once again I want to revise that in today's business environment, today's competitive scenario customers want quality, and the quality depends upon the materials processing technology and the design. And in our particular course our focus would be on the processing aspects of non-metals.

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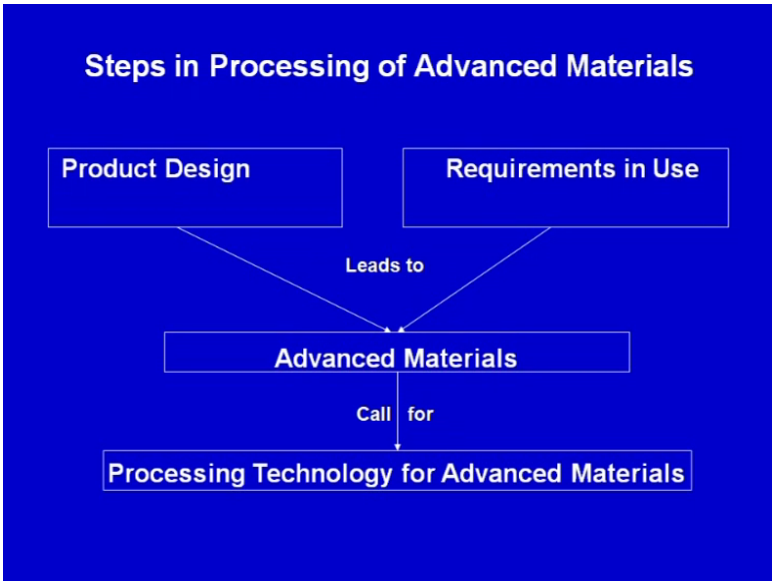

Now, what are the steps in processing of advanced materials or may be certain innovative materials. One of the important aspect is the product design and another is the requirements in the use. So, we have a specific application where a particular design has to be made and then this particular product would be used in certain conditions certain specific conditions, for example, it can be used in under water application where it can be used within our body. So, it has the product has got certain specific requirements, for example, for marine applications and bio medical implants there would be some requirements, when the product would be in use whenever it is inserted inside the body in case of bio medical implants. So, you have requirements in use and you have a product design. Now these requirements and the design guidelines leads to the advanced materials. Most of the time when there are certain specific requirements that have to be made or that have to be met by the product it will go for or it will dictate the development of new and new materials which can satisfy those requirements.

So, advanced materials are coming into picture, because of the requirements in use as well as the innovative product designs that are coming into picture day by day. So, when the advanced materials are developed they call for processing technology for advanced materials or unconventional materials. We may call advanced materials are unconventional, we have conventional engineering materials which are in use for the last 150 or 200 years, but there are few materials for which not much work has been reported or not much literature is available. So, our focus primarily is on these type of materials and our focus with the passage of the modules when we will be discussing the various modules, we will be seeing that we are focusing on certain materials for which not much literature is available.

So, new and new materials are getting developed because of the innovative product designs and the requirement of the products in certain specific application. So, the product design and the requirements in use in service requirement lead to the development of new materials, and when the new materials are been developed, our focus is primarily to find out that how these materials can be processed. So, that they convert the raw material into a good quality product also the focus is on the cost effectiveness of the product.

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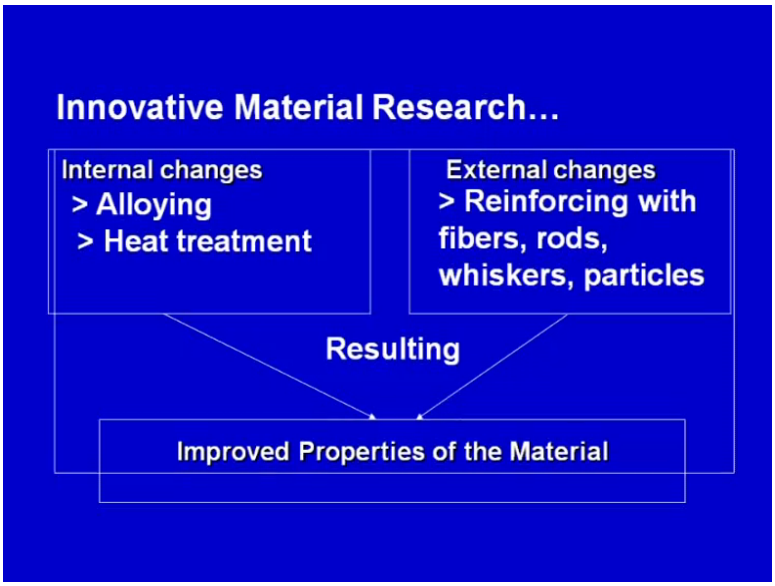

So, in innovative material research, how the new materials are developed? New materials are developed there are two approach is there an intrinsic approach and there is a

extrinsic approach. There is a intrinsic modification in the material or there can be additional reinforcement which can be added into the material, so that we get a new material. So, on your screen you can have an idea. A new material is developed primarily why it is developed is to improve the properties of the existing materials. So, whenever we have a material and we want to convert that material into material which have better properties, we will do some internal changes and we will do some external changes. In internal changes we can do alloying, we can do heat treatment; in case of external changes, we can do reinforcing with fibers rods and whiskers particles.

So, this particular aspect that is external changes, we would be considering in one of our modules on processing of metals processing of polymer matrix composite and our focus would be on processing of ceramic matrix composites also. So, there we will see how a metal matrix composite sorry how a polymer matrix composite is made and how a ceramic matrix composite is made. Just to give you an outline, because I just called metal matrix composite, there are three types of composites, polymer matrix composites, metal matrix composites and the ceramic matrix composites. Our focus in this particular course on processing of non-metals would be on processing of polymer matrix composites and on processing of ceramic matrix composites. Because the title is processing of non-metals, we will not be discussing on the processing of metal matrix composites, because in metal matrix composites the bulk is provided by the metal and the most of the properties are dictated by the metal.

In case of polymer matrix composite, the properties are dictated by the polymer and in case of ceramic matrix composites most of the properties are dictated by the properties of the ceramics. So, our focus would be processing of polymer matrix composites and processing of ceramic matrix composites. There on your screen you can see, because these composites are made by the reinforcement of fibers rods or particles. So, our focus would be on these type of advanced materials which are finding huge application in various engineering fields. So, we have a base material the base material can be polymer we are adding certain fibers, fibers can be glass fibers or fiber can be carbon fibers or aramid fibers. So, we have a base material which is a non-metal and then we are adding certain reinforcement into it, and we are developing a material which is better as compared to the conventional material.

And on the other hand, we can do alloying and heat treatment which is very common in case of metals. Metal alloy there are so many metals, which have their alloys and alloys are finding huge application in most of the sophisticated requirement such as aerospace application and marine application. So, an internal changes can be done, we can make alloys we can do heat treatment to change the structure or do the great refinement of the metal, so that the properties are improved.

Why we are doing this? On your screen with all these modifications in the materials, finally leads to the improved properties of the material that is there here you can see the improved properties of the material. So, innovative material research basically means that new and new materials have to be developed every day. So, we have we can do internal changes in the material, we can do external changes in the materials. Why I am focusing on this, because this provides an introduction to what is going to come in the subsequent lecture, because one complete module that is module number five is focused on polymeric matrix composites, in which polymer is reinforced with different types of fibers. And we get a composite material which compose how to process that composite material that we are going to discuss in module number five.

Also we are going to discuss in one particular module, the ceramic matrix composite in which the raw material is ceramic which is reinforced with different types of reinforcement. So, our focus majorly would be on external changes in the material which will result into the improved properties of the material. So, whenever a new material has to be developed, these modifications are possible at the internal level or at the external level. And then these internal and external improvements in the materials improvement lead to the improvement in the mechanical properties of the final product. And why we want to improve the properties of the material, because in the previous slide we have seen that the product quality depends upon the material the processing technique and the design.

So, our focus is not on design, but certainly on materials. So, whatever convention materials are available with us, we would certainly like to do some modification with those materials, so that they are suited to certain specific application. So, I have already given two important applications like bio metrical implants or the marine application which have certain specific requirement which the materials has to meet when the product is made by certain materials. So, when we require new and new materials and

few modification has to be done in the materials to improve their mechanical or physical or chemical properties.

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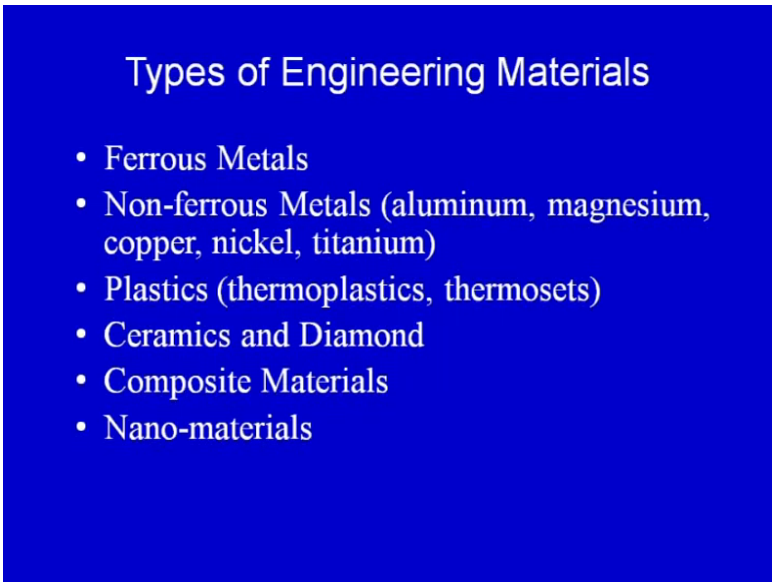

Now, we have seen what are the engineering materials, which are used in today's scenario. We have seen the importance of materials; we have seen that the product quality is dependent upon the material and the processing techniques. So, now, we come on to the types of engineering materials, which are been used worldwide these days to convert them into a tangible product, which would which can be further used for certain specific application. So, what are the types of engineering materials. This is just a broad classification, we can have ferrous metals, we can have non-ferrous metals such as aluminum, magnesium, copper, nickel, titanium. We can have plastics thermoplastics and thermosets. We can have ceramics and diamonds, we can have composite materials, we can have nano materials. So, these are the different types of engineering materials which are been used today.

On your screen, our focus would not be on the metals, our focus would be on non-metals. So, there are certain categories of non-metals which are present in this particular slide that we will see in the lecture number two. In which, we will see how we distinguish between a metal and non-metal, but for today's reference, we can just take into account this particular slide, we can try to understand that these are the engineering materials which are available with the engineer, and he has to choose among these materials to

take a decision that which particular material is applicable for which particular application.

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Now, when we talk about the selection, there are large variety of materials, which are already available in the previous slide we have seen. Just to revise we have ferrous metals, we have non-ferrous metals, we have composites, we have polymers, we have ceramics, we have diamond, nano materials, so there is a wide variety of engineering materials which are available. Among these materials the user or the engineer has to choose that which particular material would be suitable for the application for which I am making the product.

On your screen, you can see the challenge of selection is because of the ever increasing variety of the materials, which are now available. Each material has got its own characteristics, its own specific application spectrum, advantages and limitations. So, there are large variety of materials that we have already seen. Again to revise the variety of materials which are available, we have metals or we have ferrous metals, we have non-ferrous metals, we can have plastics, we can have ceramics we can have nano materials. So, there is a large variety of materials which are available with the engineers and designers. And they have to choose them, now the choice would depend upon the characteristics, applications, advantages and limitations, because certain materials may

have certain limitation for some specific application, so that particular material cannot be applied for that application.

Suppose, we have under water application, there me be certain materials or metal, which may corrode when it is in contact with the seawater, which is salty. Sometimes some deicing salts are also put in seawater, so it may produce the corrosive environment and the metal metallic pillar that we are using for the underwater application may not give us a very good service life. So, depending upon the specific requirement, we have to choose that which particular material is good. So, we will definitely like to go for a material which is very good corrosion resistance in under water application. So, there are some materials which will have certain limitations. So, there will be some materials which will be advantageous, for example, the composite materials have high strength to weight ration or high stiffness to weight ratio. So, they can be used for lightweight application. Therefore, for lightweight applications the composite materials has got an advantage.

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So, depending upon the characteristics of the material, depending upon the applications of the material, and the advantages and the limitations associated with the material, the designer or the engineers has to choose the best material for the specific application. So, the catch word is or the catch point is that to select the optimal material according to the design and in-service requirement. So, I have emphasizes in-service requirements, because the material when it is designed, it will go into service, it has to perform the

desired function reliably. If it does not perform the desired function, the function for which the product has been designed then the product would be a failure. So, then again we have to do the failure analysis, and find out that what were the causes of failure. But as a engineer, we have to address the problem before it actually takes place. So, we have a wide variety of material that are available and we have to choose a best material for a specific application.

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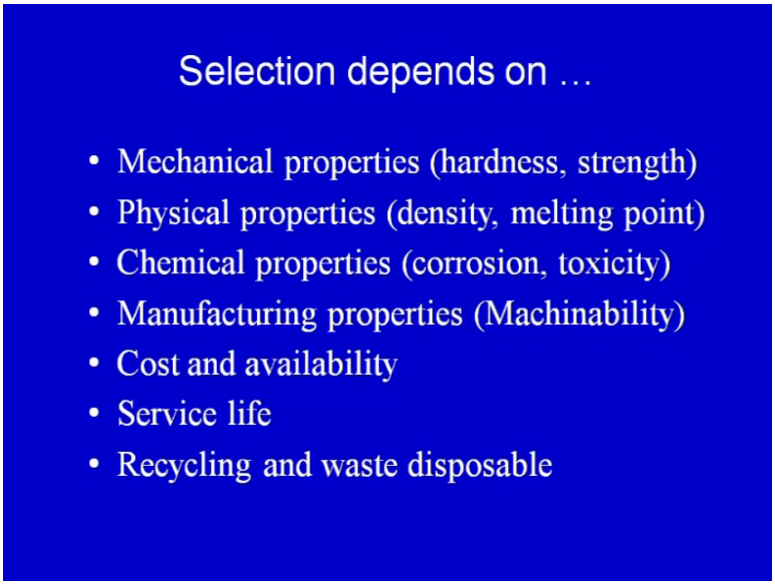

Now, how this selection can be done. Now I have till now what we are discussed we have seen that there is a large variety of materials which are available or we can say there is a large family of material which are available. And we have four broad guidelines that we have to study the characteristics of material, we have to study the applications for which the material has been developed, and what are the advantages associated with those materials, and what are the limitation. But still, there are few criteria which we have to outline when we are selecting a particular material for a specific application.

So, there are few points on your screen, you can see that whenever we have to make a decision among the various materials which are available with us, the first important point to look for is the mechanical properties of the material. Now what are these mechanical properties, just few examples are there on your screen such as hardness, strength, we can go for toughness, there can be other properties like ductility. So, we

have to see the mechanical properties of the particular material, when we are selecting it for a particular application.

Why? Because once we select a particular material, and it has got certain mechanical properties, these mechanical properties would further dictate the processing technique which would be used to convert this raw material into the final product. So, when we are selecting a material for specific application, we have to be very cautious and we have to judiciously select that which particular property should be there which particular mechanical property should be there in that material which we are choosing for specific application. So, mechanical property is the first criteria when we have to select a material for specific application. Within mechanical properties, there are two examples already on your screen, you can see hardness and strength, but there can be other properties also such as toughness.

Then we go for the physical properties; in physical properties, there are two examples density and melting point. So, will come to this when we discuss the various types of manufacturing processes or various types of processing techniques which are used to convert the raw materials into the final product. But for now, we can see the physical properties such as density and melting points also influence our decision, when we select a material. Similarly, the chemical properties such as corrosion and toxicity also influence the decision of selection of a material for a particular application. For example, if a material has to be chosen for making the toys which children are going to use, because sometimes it is seen that children have the tendency to put the toy in their mouth. So, in those scenario, in those cases, the material that we choose for making the toys should not be toxic in nature; suppose it is toxic, then it can have many adverse effects. So, whenever a product is there, and there is a variety of materials available we have to do a judicious selection. So, the chemical properties that has to be taken care of during the selection process or the corrosion and the toxicity, there can be other properties as well.

Then we have to see the manufacturing properties as I have already told in point number one, that whenever we select the material with a specific mechanical properties, these properties are going to have a bearing on the manufacturability of that material. So, the manufacturing properties such as machinability, there can be other properties also like formability, weldability, which have to be studied. And it has to be seen whether the

material can be easily converted into the final product or not or whether the material can be easily processed into the final product or not. So, this emphasizing our lecture that we are focusing on the engineering materials and then we will come on to the metals and non-metals and finally, we will carry forward our discussions on various processing techniques of the non-metals. So, first of all we need to understand that what are the properties which are there in the materials and how this property would affect the manufacturing properties

When we are selecting the particular material, these are the four important technical points, which have to be taken into account. Now what are the four important technical points? On your screen, you can see you have the mechanical properties physical properties chemical properties and manufacturing properties. So, these so these four properties of all the materials have to be listed and then only the final selection can be done for a particular application and finally, there are other important points which have to be taken into account that is the cost and availability the service life of the material recycling and waste disposal.

So, recycling and waste disposal has become very very important in today's environment conscious in world every in each and every country there is a focus on the environment these days. So, there is a there is a catch word called green environment. So, whatever material is selected for a particular application we have to see that how much environment friendly that material is. So, if we have a wide variety of materials and we have a specific application if it can be met with fully bio degradable environment friendly material we should always go for that particular material which has very less effect on the environment. So, we have to see some other aspects such as cost and availability service life recycling and waste disposal also.

So, to summaries the selection problem, in case of materials again within three or four sentences, we can have an idea that what is the overall problem like, there is a wide variety of materials which are available, there are large number of families within materials, which are available. And each material has got its own characteristics, it has got a specific application spectrum each material will have certain advantages and limitations. So, when we have a large variety of materials available with us, out of which, we have to choose a specific material for our requirement. We have to take into account certain important facts, so, these important points that has to be taken into

account are the mechanical properties, the physical properties, the chemical properties, the manufacturing properties, cost and availability, service life and the recycling and the waste disposal. And if still, we have four or five different materials available then certainly we will go for the cost effectiveness of material.

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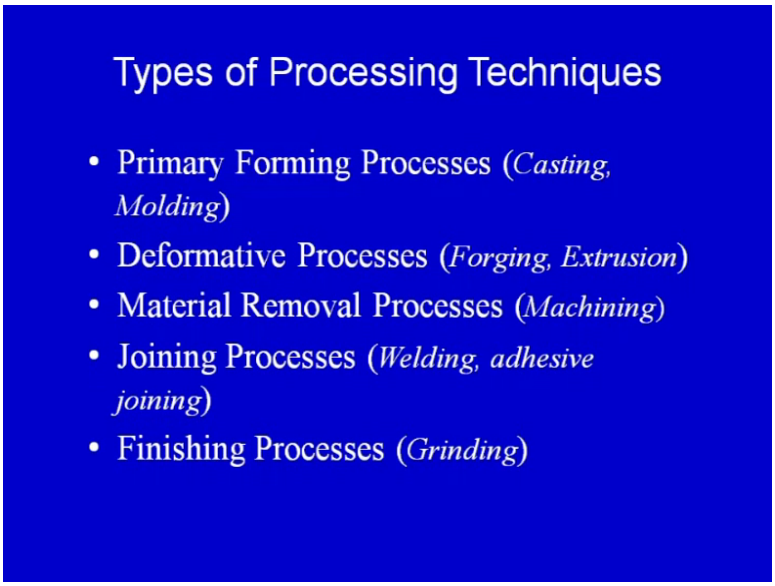

Now, coming on to the types of processing techniques, which are very widely used for the conversion of the raw materials into the final product. There can be a large variety of other processing techniques also which can be used, but this is the brief summary of certain techniques, which are used to convert the raw materials into the final products. We have till now understood the various types of materials which are available. Now we are focusing on the various types of processing techniques which are available and the materials we need to understand the various properties because these properties would finally, dictate their manufacturability or their processibility. If a material is easily processable, it means, it has got certain material properties, which makes it easily processable. And if there is a material which is difficult to process then also it is very obvious that there are some properties of the material which makes it difficult to process.

So, let us first start our discussion with the different types of processing techniques, which are available with the engineers. On your screen, you can see that we have a primary forming processes there are few examples of the primary forming processes that is costing molding. So, these processes fall under the primary forming then we have

deformative processes such as forging, extrusion, there can be other processes also which fall under the category of deformative. There are just two broad examples like forging and extrusion. You can have wire drawing, you can have tube drawing. So, all this processes fall under the deformative processes.

Then we have material removal processes a broad term is given that is machining. Machining can be of different types; it can be drilling, it can be milling, it can be turning. So, we can have different types of machining operation in which the material is getting removed from the raw material and it is getting the final shape in which it is required and then we have joining processes. In joining processes, we have welding, we can have adhesive joining, we can have brazing, soldering. There can be permanent joining processes, there can be temporary joining processes. And finally, we go for the finishing processes; in finishing, we can have grinding, and there can be other processes like honing, lapping, which depends upon the specific requirement. So, what are the types of processing techniques again we want to revise that there are different types of processing techniques such as primary forming processes deformative processes, material removal processes, joining processes and finishing processes.

Now, how do we relate these processes with the materials which we have already seen. Each material has got its own specific properties, each material has got certain mechanical properties, certain physical properties, certain chemical properties, certain manufacturability and requirement certain manufacturing properties. So, all these properties will dictate that which particular process would be chosen for which particular application.

So, we have to see, suppose let us take an example a material is having a moderate melting point, which is one of the properties of the material which we have seen melting point falls under the physical properties of the material. So, there is a material which has moderate melting point, which is not very high or not very low. So, what we can think that if that is the temperature is within the range for which the furnaces are available and we require a huge quantity of the products the production volume is very high. So, what we can do, we can very easily choose the primary forming process, we can use sand casting or any other type of casting process to convert that material which can be easily melted into the final product. And their also we have large volume of product requirement, but if the product volume required is less then we may go for some other

process, because the production volume is also an important parameter while we select a process.

So, the properties will dictate for which process would be suitable for which application. For example, if the material is very, very hard, we may not be able to machine it using the conventional process or the conventional material removal processes. Then we may require to go for unconventional material removal processes. So, hardness, melting point all these are properties of the materials, which will dictate their processability. So, our focus is on the series or the types of processes which are already available with the engineer and then now we will see that what are the various types of selection guidelines or what are the various types of factors that we have to consider when we are going to select a particular technique for a particular material. So, when we have specific materials their properties would dictate that which processing technique can be used cost effective good quality processing of those materials.

So, we need to understand first the materials what are the properties of those materials and how to select the best material for a specific application and then becomes the next stage of the conversion of those materials into the final product using wide variety of processing techniques which are available with the engineers. But when wide variety is available again the problem of selection comes. So, we have seen that there are five to six categories of processes which are available and within these categories there are sub categories and within that sub category we have another category. So, there are huge you can say family of manufacturing processes or processing techniques available with the engineer then they have to select the best particular process. So, that a good quality and cost-effective product is made which we have already emphasized in the beginning in today's lecture.

So, now, we want to see that the selection among the various processes will depend on which important factors. So, on your screen you can see the selection of the particular process will depends upon the properties of the raw materials that is hardness melting point which I have already emphasized in the previous slide. So, each raw material will have certain set of properties which we have already seen in the slide on ever increasing variety of engineering materials we have seen what are the types of engineering materials available and what are the important properties to be taken care of when we are selecting a particular material for a particular application. So, there are large variety of materials

which are there with the large variety of properties. So, the properties which are important are mechanical properties physical properties chemical properties manufacturing properties. So, these properties would dictate their processing later on. So, once some material has been selected which satisfy all these properties then it will dictate that how long that can be processed when we have processing techniques we have to choose that which processing technique would be suitable for which particular application.

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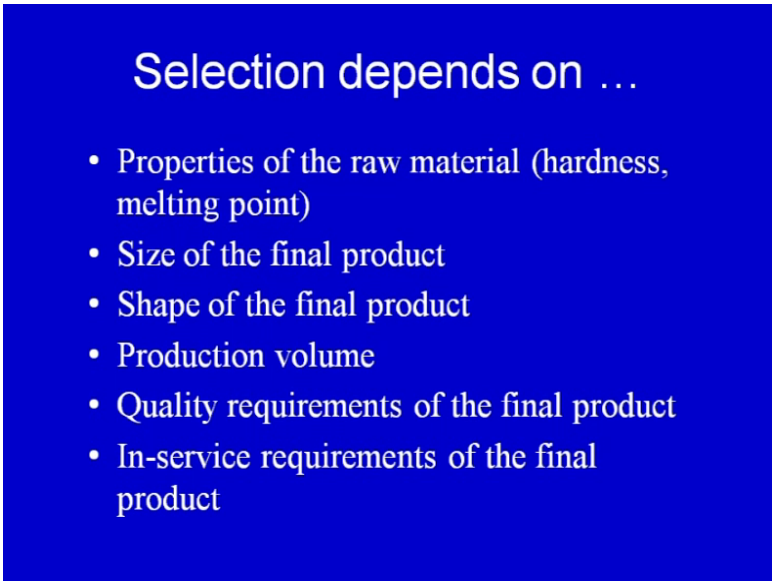

So, let us take an example of the very first point that is the properties of the raw materials. If a material has got a very high melting point, extremely high melting point, can we cast that material? It would be difficult to cast. Why? Because we may not be able to easily or cast effectively melt that material because the melting point is very, very, very, very, very, very high. So, then we cannot use the casting process for that particular application.

Next example, hardness. If the material is very, very hard extremely hard, for example, hardest substance - diamond. Can we use the conventional machining processes or the material removal processes to machine the very, very hard material? It is not possible. So, we cannot use the material removal processes to machine or to remove the material from very hard very hard materials. Similarly, we cannot use the costing process for those materials which have very high melting point again I am repeating, if a material

has the very high melting point the use of costing is not suitable for a high melting point material.

Similarly, if the material is very, very hard material removal process is not suitable for very hard materials material removal I am talking about the conventional process, because the unconventional process have been developed which can focus on very hard material and they can use a softer tool to remove material. But our focus primarily is on the primary processing techniques or the conventional processing techniques which are available with the engineers. So, hardness and melting point are the two properties of the materials and these properties are finally, coming into picture when we are doing the processing of the materials.

Again just to emphasize, on this point, if the material is very hard, difficult to machine. if a material is very high melting point, it is difficult to cast. Similarly, the second point, the size of the final product. If the size of the final product is huge, there may be some processes which may not be suitable for that particular product and if the size is very, very small, there also there would be some processing techniques which cannot be used for that particular product or processing of that particular material. So, we have to take into account, the properties of the raw material, we have to take into account the size of the final product, we have to take into account of the shape of the final product.

If the material is very very complex then there would be some processes, which cannot be used. For example, if the we are doing sand casting, we can have certain degree of intricacy, but within costing if we are going for die casting we can have certain degree of intricacy. So, the intricacy will also or the complex geometry of the part would also dictate that which type of process should be chosen within the same family as we have seen family of casting within casting we can have sand costing within costing we can have die casting. So, sand costing certain degree of intricacy within die casting certain degree of intricacy depending upon the shape of the product, depending upon the complexity of the product. We will see that the processes have to be selected accordingly.

Coming on to the production volume, now the number of products to be processed will also depend will also dictates that which particular process should be selected. If the number of products to be made or the production volume is small, there may be some

type of processes which are rendering themselves cost effective and high quality. For example, material removal processes. If the production volume is not too high, it is moderate or low, we may advocate the use of the material removal processes in such application. But if the amount of material or the production volume that we have to achieve is very, very high, then we may advocate the use of continuous processes or sometimes deformative processes can also be used because most of the processes can be fully automated in case of deformative processes. So, production volume is another criteria which has to be taken into account while we are selecting a manufacturing process or a processing techniques for making certain specific products.

Then the quality requirements of the final product are also very, very important. So, depending upon the quality required or the quality of the surface required or the performance of the product required, we will choose the specific process which is able to meet those quality requirements which is able to meet those specifications. And finally, the in-service requirements of the final product, because the processing will also induce certain properties in the product. A material is having certain properties, which is rendering it to be able to processed into a complete product or a final product and processing will alter or it will add or delete certain properties of the material during the stage or stages of processing and this modification during processing may affect the in-service performance of the product. So, we have to assure that the in-service performance should be highly durable reliable and the material which has been converted into the final product and the product is in now in use should not fail.

So, just to summarize the selection, the various parameters that are used for selecting among the various manufacturing processes or what are the factors that are taken into account while we are selecting a manufacturing or a processing technique for a specific material when the material has to be converted into the final product. On your screen, the factors are the processing the properties of raw material such as hardness and melting point, the size of the final product, the shape of the final product, the production volume, the quality requirements of the final product and the in-service requirement of the final product.

So, just to summarize what we have covered, we have covered today, the basic aspect and the quality aspect in today’s business environment. We have seen that the product quality depends upon the materials, it depends upon the processing technology, and it

depends upon the design. As the title of our course goes our course is focused on processing of non-metals. So, we are basically focused on two aspects that is materials aspect as well as the processing aspects. We have seen them that there is a large variety of materials which are available with the engineers, and among them the engineer has to choose the best material.

Now how to choose the optimal material, there are few guideline, because the materials has to be compared for their mechanical property, for their physical, chemical and manufacturing properties. Also we have to take into account certain important points such as the cost and availability of the material, we have to see the service life the material can offer, as well as we have to see in today's business aspect sorry environmental conscious world, we have to see whether the materials are environmental friendly or not. We have to see how the materials can be disposed off and what are the waste disposal strategy for those materials. So, when we take into the account all these aspects we are able to come up with two or three different materials, which are meeting the design requirements and which can be used to convert into the final product.

So, then we finally choose the cheapest materials, out of these three materials which are satisfying all the other technical requirements. Then coming on to the processing, now the material has been selected which has to be converted into the final product then we take into account what are the various types of processing techniques or manufacturing techniques which are available with the engineers. We have tried to understand, these techniques with the help of some examples. You have seen the classification of the processing techniques and then we have seen that once the material has been selected, the processing technique has to be selected. So we have the best combination of the material and the processing technique, so that finally, we will get the product which is of very high quality and it is also cost effective.

Then we have seen certain points, which have to be taken into account, while we are selecting a manufacturing process for a specific product application. Now what are the parameters that have to be taken into account, what are the factors which have to be taken into account, while selecting the manufacturing process that are there on your screen. Once again to finalize the properties of the raw materials, size of the final product, shape, production volume, quality requirements and in-service requirements are the important factor to be taken into account.

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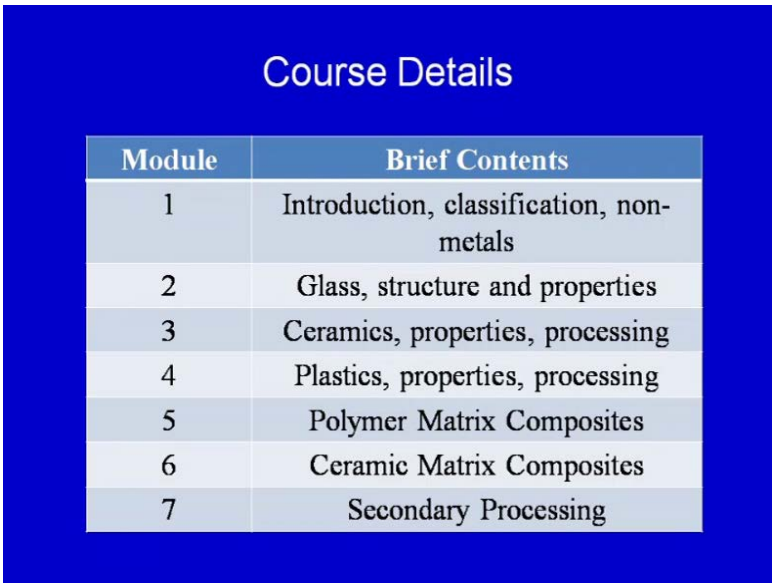

Now, I want to just outline the course that how the course would be run just a brief outline that what we are going to cover, so today we are having the first lecture of module one. In lecture two, we will try to distinguish between the metals and the non-metals based on the properties of the metals and the non-metals. And then we will jump to the module number two, in which we will see glass structure and properties, we will see the melting of glass and how the glass products are made the processing of glass products.

In module number three, our focus would be on ceramics, their properties and processing of ceramics into ceramic products. In module number four, our focus would be on plastics, different types of plastics, thermostats and thermoplastics. And finally, we will focus on the processing aspects like injection molding and compression molding of plastics. In module number five, we would be covering polymeric matrix composites, we would see what are polymer matrix composites, what is the need of polymer matrix composites and how do they compare with the other engineering materials, and what are the specific techniques which are used for processing the polymer matrix composites. Such as we will see (( )) techniques (( )) techniques (( )) and other techniques which are used for processing of polymeric matrix composites.

And we will see in module number six, the ceramic matrix composites, their properties and various processing techniques for ceramic matrix composites. And the last module

will focus on the secondary processing that is the machining aspects or the joining aspects of these materials. So, in these modules, we will try to address the various points which are related to the processing of non-metals. So, with this we come to the end of lecture number one of module one, and will lecture two our focus would be on the various properties of the metal and the non-metals

Thank you.