Manufacturing Guidelines for Product Design

Prof. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology-Roorkee

Lecture-06
Engineering Materials

Namaskar friends, welcome to the second week of discussion in our course on manufacturing guidelines for product design. As you are well aware that in the last week our focus was on the manufacturing processes, we have tried to understand, we have tried to highlight, we have tried to discuss the basic aspects of manufacturing processes. We have tried to classify the manufacturing processes.

We have tried to understand the process capabilities of the most commonly used manufacturing processes and then we have tried to see that what are application areas, what are the typical applications for the various manufacturing process. We have seen that where casting can be used, we have seen where injection molding can be used, we have seen where blow molding can be used.

So it was just to touch the tip of the iceberg because the manufacturing is a very very very very very very diverse field with lot many processes that are used for manufacturing of different types of products. So we have just tried to understand that if we want to understand a manufacturing process what should be our focus. Now the focus can also be different as a manufacturing engineer or as a production engineer or as a mechanical engineer I would like to understand the process in a much that in a much better, in a much deeper, in a much exhaustive manner.

Whereas as the product designer I would like to focus only on the applicability, only on the versatility of the process, I may not be too much interested into the process parameters or the process mechanism or the process mechanics I will be only interested in what this process can do for me as a product designer.

For example suppose I have to make a very bulky product it has to be made in metal, as a product designer I will be interested to find out which process can help me to produce this product and I may zero down on casting, that casting is a process which can give me bulky

large metallic products. Now the further design of the manufacturing process for making this costing which is large in size depends upon the expertise of the manufacturing engineer or the mechanical engineer.

But as the product designer when I designing the product I must have some basic idea about how the product is going to be manufactured. If I have that idea I can definitely liaison with a manufacturing engineer and try to fine tune the designs in consultation with him. So therefore we need to have basic understanding of manufacturing from the product designer point of view and this course is designed for that purpose only.

In the first week we had a discussion on the manufacturing processes, in the current week that is week number 2 our primary focus will be on the engineering materials because as a product designer we must know we must have the basic understanding about the materials which we are going to use for fabricating our product, if we take the examples of this recording studio we can see there are different types of product that we are using in this studio.

And each products is made by materials, so how much importance do we give to materials as engineers or as managers or as professionals, most of the time if we do not give much importance to the engineering materials as well as the manufacturing processes. Let me take an example when we get up early in the morning we go to the washroom and brush our teeth, how many of us will be able to tell that what is the material of a handle of the brush.

Many of us may not be able to answer this question despite of our engineering degrees, despite of our management degrees, many of us who have studied mechanical engineering may not be able to name the process which is used for fixing up the bristles on the handle of the toothbrush. So we do not give much importance to manufacturing, we do not give much importance to the materials which we see all around us.

So as a product designer it becomes important for me to understand that what are the various types of materials, what are the specific advantages applications areas, limitations, exceptions or the engineering materials. And if I know that I will be able to make a judicious choice of material for my product design. Let us take an example of a chair, now we can have a chair which is made by a plastic material.

We can have a chair which is made by wood, we can have a chair which is made by metal. So we have different types of chairs made by different types of engineering materials. Now how this selection of material has taken place. So some thought process must have gone into the selection process that where the wooden chair is better, where the plastic chair is better, where the metallic chair is better.

So 3 different the functional requirements remain the same, function requirement is that we have to provide a seat for a person who wants to use this product, but there are other requirements or secondary requirements or tertiary requirements which will definitely affect the choice of a material. For an example we want to design a chair which we have to move from one place to another place on regular basis.

The most important requirement will be that it must be light in weight because it has to be move from one place to another place on a regular basis, then we have to see that which material we must choose so that we are able to transfer or transport this chair from one place to another place without much effort. On the other hand we may like to fix the chairs at one place only and we do not want to move them.

In that case but we want the long life because it is a permanent structure that were creative or permanent facility that we are creating. So the chair need not be moved in that case we need more strength, more life. So in that case the choice of material will be different. So therefore as a product designer I must have understanding about the various engineering materials, the possibilities that exists.

The classification of the engineering materials certain examples we can take that in these situations these materials are used and certainly when we advise, when we advocate, when we propose that this material can be replaced by a new material we have to justify that how the new material is better than the existing material. So all that kind of understanding a product designer must have in order to propose the use of materials for his or her product.

So whenever the product design is being finalized as a necessary requirement we have to specify that his product will be made by which material and what are the various types of engineering materials that we are going to study, that we are going to discuss in today's

session with certain examples. So let us now start our discussion, the title for today is engineering materials.

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Now on your screen you can see different classes or different types of engineering materials, the first category that we have highlighted here are the metals or the alloys, you can see it is clearly written the names are given metal or alloys. So you can see here aluminium, brass, cast iron, copper, steel, bronze, metal sludge. So all these fall under the category of metals or alloys.

All these are the polymer pellets and also we can call them in the general name as the plastics, these are some of the plastic products which are shown here which are made by these colored pellets, then this is another category of engineering materials that we call as the ceramics. So we have plastics or polymers, we have ceramics, we have metals or alloys and then we can have a category of materials which we call as the composites specifically used for specific requirements, lightweight requirement, high temperature requirement.

Depending upon the type of a composite material we can have different types of application areas. So here we can see 4 broad classes, 4 broad families of engineering material. So if you talk of metals we can discuss metal in a 20 our session, there are different types of courses regarding the metallurgical aspects of metals or joining aspects of metals which are already available on NPTEL.

But from product design point of view once we have to choose a material we need to understand the basic characteristics of that material that we will try to address maybe in a subsequent sections in this week. So but today our target is to classify the engineering materials. So engineering materials broadly we can see there are 4 families here, metals or alloys, polymers, ceramics and composites.

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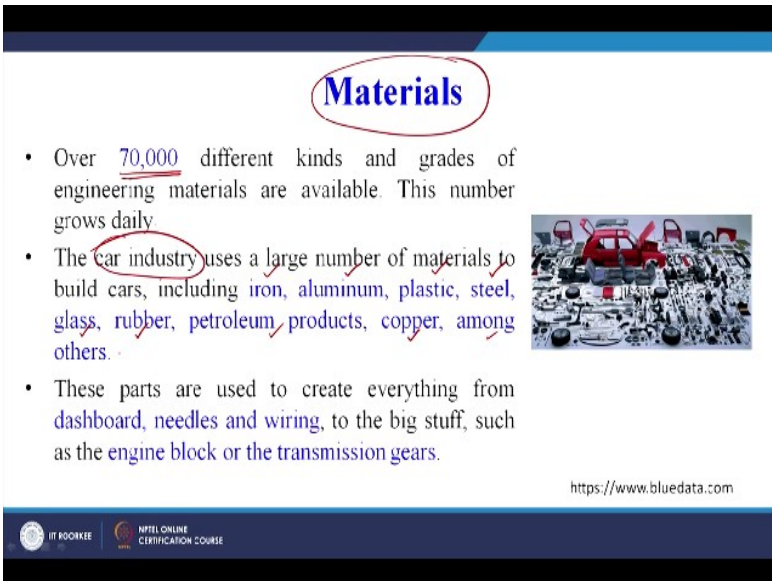

So let us now see how we can classify them. So we will come to the classification but let us have a brief introduction about the importance of materials. So what is we can say the depth and breadth or we can say the length and breadth of the field of materials, science and engineering. We can see from here over 70,000 different kinds and grades of engineering materials available.

And this number grows daily and if you refer back to our first week of discussion I think in the second session we have seen that why do we need to develop new and new manufacturing processes because the new and new materials are being developed every day may be every week and every year. Depending upon the specific applications every day there is a discovery, scientific discovery or invention.

Whereas a new material or a combination of materials is being developed to address a specific application, just few days back the environment day has passed and we have seen there was lot of focus about the use of plastic materials. So within this field which is one specific family of the overall family of engineering materials within plastics there is lot of

focus on developing new and new types of polymers which are biodegradable in nature which are environment friendly in nature.

May be everyday researchers are putting efforts and trying to develop material which do not harm our environment which are friendly to the environment in which the philosophy can be that we derives certain raw material from our environment only and then make it a engineering material, make a product out of it and finally once the product has lived its life the material can be pushed back into the environment without causing any harm to the environment.

So that kind of philosophy is developing in which we are trying to harness the potential which is available in the materials which we see around us in the environment in our ecosystem. So we try to derive the raw materials from our ecosystem and then try to develop them into engineering products and finally dispose them of into the environment in a much cleaner way. So new and new materials are being developed every day.

And therefore we need to understand as a product designer this advancement show that we propose the use of the materials which are friendly to the environment. So 70,000 is not exhausting number, so every day we may be finding that there is some new development in the field of material science and engineering. So just to take one case the car industry we have taken the car industry uses a large number of materials.

Now what type of material we see in the car most of us may have used car or maybe driving in in a automobile if we see around so many materials are there, that they seat that we are using on which we sit, you see there is foam which is a kind of a engineering material, the handle that we hold may be a metallic handle in the car or in the bus. So any automobile you take so many engineering materials use see around.

Even if you are driving in a air, if you are travelling by air in an aircraft so many engineering materials using around you, if you are driving, if you are traveling in a train again you will see so many engineering materials around you. So in car also it use the large number of materials which are used to build the cars. Now what can be these materials, let us see iron, aluminium, plastic, steel, glass, rubber, petroleum products, different polymers, copper and among others.

So we can see just a spectrum of materials which are used for making the car. Now when we are designing a product we have to see that which material we must choose and large variety of materials are available with us. So these parts are used to create everything from dashboard, needles and wiring which are may be our domestic applications to the big stuff such as engine block or the transmission gear which are engineering products.

So we can see from a simple part I started the today's session with a very simple example of a tooth brush, a handle of a tooth brush, and bristle that are fixed on the handle to make it a usable product. So from simplest product to the most sophisticated product for example for aircraft applications or spacecraft applications engineering materials find their applications everywhere and therefore as a designer I must have basic understanding about the different types of materials that are available to be chosen or from which we can choose what type of material is applicable for our product.

Another example that I have taken today is of a chair, so we have seen that 3 different metallic chair, plastic chair, wooden chair. So depending up on the application we will chose the material. Now what is the list that is available with us, so different types of engineering materials are available already we have seen the examples. So now let us further classify them, we can have ferrous metals like cast iron or steel.

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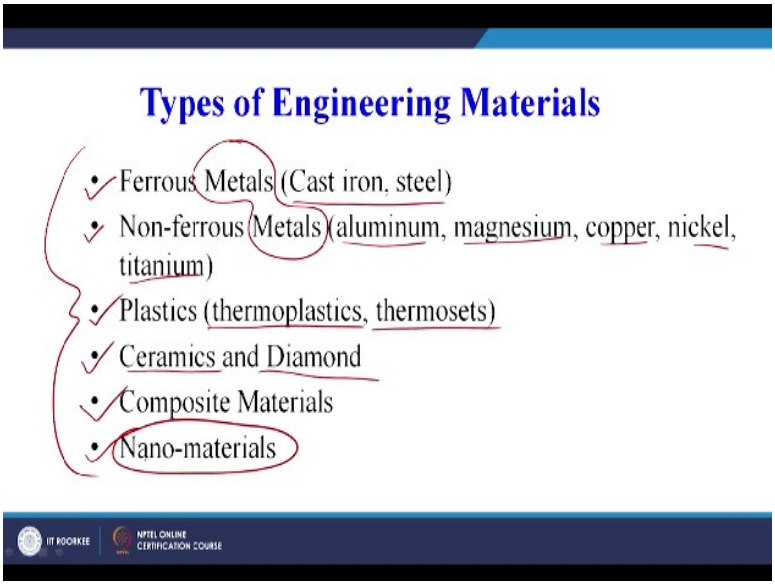

We can have non-ferrous metals, so both are in the metals category only, but 1 category can be ferrous family, another can be non-ferrous family. So we can have aluminium, magnesium,

copper, nickel, titanium. So we can have non-ferrous metals then we can have plastics, thermoplastics and thermosets. Then we can have ceramics 1 category can further be diamond, then we can have a composite materials.

So one categories can be nanomaterials, so we can have nanomaterials coming out from any of the categories which are already mentioned. So major classification for engineering materials has been explained here, Now within this you can write some places. some examples are already given for examples ferrous metals examples are given, non-ferrous metals examples are given.

Plastics you can have different types of plastics, plastics is itself a very large family, 1 classification is already given a thermoplastic and thermosets, then within thermoplastic also you can have different types of example like polypropylene, polyethylene, for thermoset also you can have different examples like epoxy, so you can have different examples you can make a table, you can see what are the thermoplastic.

What are thermosets, what are the specific applications areas for thermoplastic, but a specific application areas for the thermosets, so that kind of understanding further we can develop, but initial stage of product design out of this family or for out of this classification we can choose that yes this particular part has to bear lot of temperature, the temperature may go up to 600 degree centigrade.

So automatically one thought must cross here mind that polymers may not be suitable for this application because it is a high temperature applications. So let us propose the use of a metal for this application and in some particular application or a product the weight of the product may be very very important. So we will see that polymers are best suited but then we will again refer to whether the temperature is going to affect in any role or is going to affect and the importance of this product we see that no temperature is not an important parameter for this product.

So then we will propose that ok lightweight is the main criteria let us go for the plastics for making this product. So that way we have to do analysis may be we have to give weights for the various parameters and then find out that which is the best applicable material for this particular product. So this classification is important and each and every product designer

must know that what are the various choices or what are the various parameters that are going to help him to design the product or what are the various we can say importance class of material out of which he or she can choose in order to fabricate the product.

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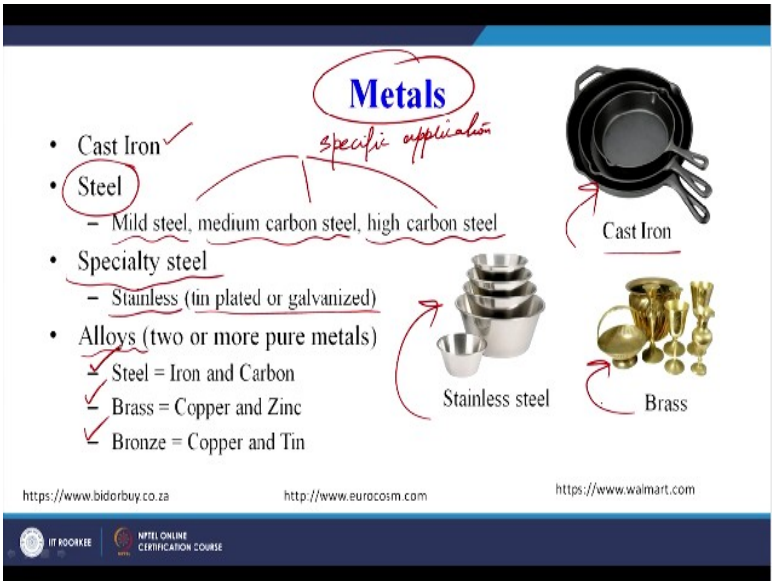

Now we will take each one of these very quickly with examples so metals we can see we can have cast iron very commonly used material, all of us use steel utensils or may have used steel utensils at any given time of our lives may be in hostels usually we have steel plates for having our meals, then within steel also we can have mild steel, we can have medium carbon steel.

We can have high carbon steel and each one of these will have their specific application areas specific application so we can tailor the, steel for a specific requirement, for those of you who have a mechanical engineering background there is another type of steel which we call as the high speed steel which is used as a cutting tool material. So similarly depending upon the requirement of the application will see which type of steel we want to use or which type of we can say combination of the alloying elements we have to use for a specific application.

One example I have already taken as high speed steel, tool similarly for high speed steel also you can further go into 18-4-1 and see what are the various constituents of the alloying elements that make up the high speed steel. So the knowledge is endless you can go to the any depth of understanding for any particular topic. So here we are just classifying now the engineering material.

So if you select one particular material for example steel within steel also you can get hand books on steel, there are complete volume has been written on steel only and the various classification of steels based on the different types of the alloying element as well as the application areas from the microstructural point of view from the metallurgical point of view from the application point of view.

From the processing point of view we can only spend maybe 20 hours or 40 hours of discussion only on steel, but at the product designer I may not be required to understand too much into steel because once we purpose the use of steel we can refer an expert who knows everything about steel as engineering material and take his or her inputs when we are fabricating the product.

But when I am designing my focus has primarily to be understanding or to have an understanding of steel as an engineering material. So we have steel then there are speciality steels one of these is stainless steel which is used for making household utensils which can be tin plated or galvanized. Then we can have alloys within metals we have another example of a metal can be I am using this “Kada”.

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This is a metallic products so different types of metals you cannot use pure metals you have to make them into alloy form for satisfying the specific engineering requirements or for specifying the manufacturing requirements, pure metals may not be that deformable so for

making them deformable you have to alloy them. So you can have different types of alloys one of the alloys example given is steel, brass, Bronze.

So you can have different types of alloys, so whenever we propose the use of metals within metals also as a product designer I may like to choose from a ferrous alloy or a nonferrous alloys is by electricity has to be conducted, I will try to see which is the best conductor of electricity which metal has to be chosen, if the strength is a requirement I will see that which metal will be able to provide me the adequate strength.

If toughness is a requirement we will see that which metal can provide us toughness. So depending upon the requirements of a product we can choose that which metal will satisfy our requirements. So metals is a very big family we will try to see if possible during our discussion and in the time permits that what are the specific application areas for the metals some of them definitely are mentioned here and what are the specific properties for which the metals can be used or what are the specific requirements of the product for which the use of metals can be proposed.

Some of them you can see here cast iron, then stainless steel utensils, brass utensils are shown here, then for other application different metals are used. For example the engine block is also made up of a metals, so because the temperature is higher there so polymers cannot sustain that. So we propose the use of a metal there. So there are number of engineering applications like connecting rod since I am mechanical engineer.

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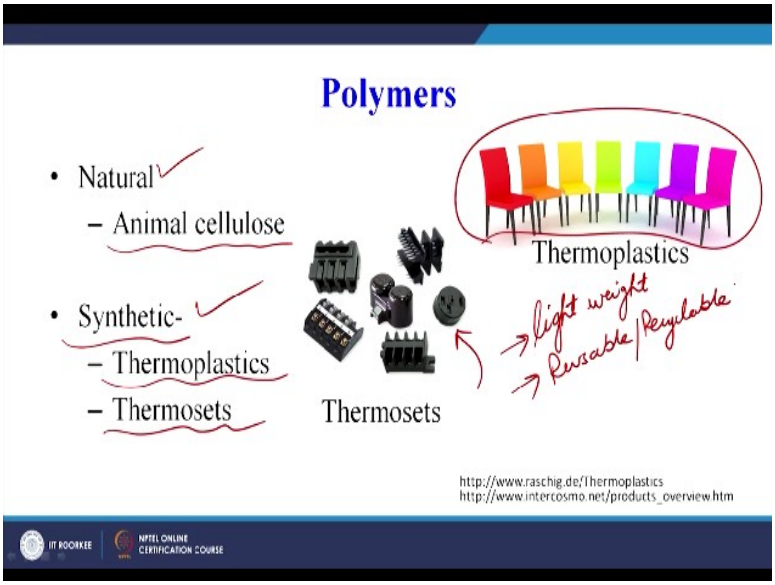

So my examples are also related to mechanical engineering field only. So there are many applications where metals are finding use, coming onto the polymers there can be natural polymers like the animal cellulose, then there can be synthetic polymers which we have already seen thermoplastics and thermosets. So of these applications are thermoset application, these are the thermoplastic applications.

Now what are what is the difference between thermosets and thermoplastic that we will cover maybe in the subsequent sessions but polymer is a large family it is also very very exhausted family if you tell to name it may be 5 types of thermoplastics and 5 types of thermoset, it those can easily be named why because the family is very very large. Now if you see the types of polymer applications we can see the applications are basically light weight applications for polymer as well as we will see that for polymers we can make them many product can be reusable or recyclable also.

So we can have the we can propose the use of plastics where we want light weight, where we want that product after its life can be recycled and a new product can be developed from the used products. So those are the application areas. We will come to the detailing in the subsequent session. Then next category ceramics used for basically you will find their application for high temperatures.

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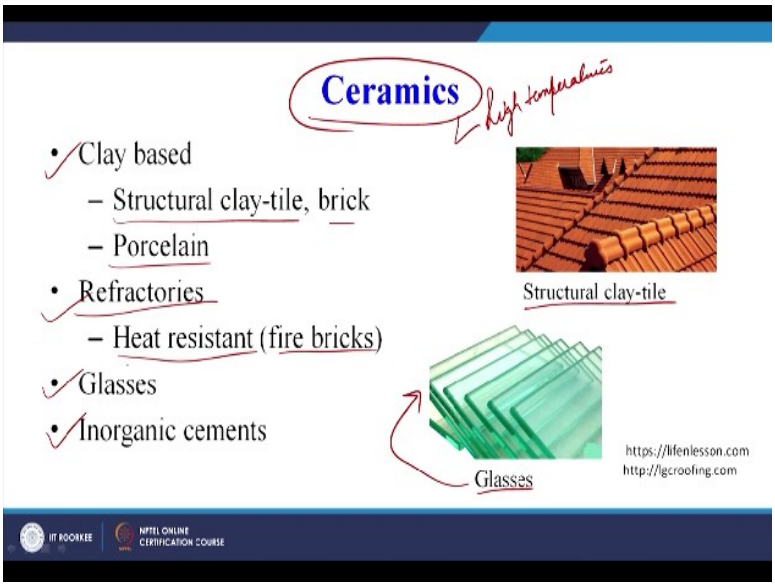

And examples you can see structural clay tile glasses different types of glasses are there and in one of our course which is already available online processing of non-metals we have already discussed the processing techniques for glass. So we can see here of flat glass which

can be taken as an application of the ceramics. So clay based ceramics you can see structural clay tiles, bricks, porcelain.

Refractories is another category which are heat resistant, fire bricks, glasses another category inorganic cements. So we have a large variety of application for the ceramics also but one of the key words that I have already mentioned here they are used for high temperature applications. So if you are designing a product where the temperature is going to be very very high, so in that case we want a material which will not deform under high temperature.

And there we may purpose the use of certain ceramics or certain glass of ceramic material and if one example we take which is our day to day examples the crucibles that we use in the lab experiments of sometimes some ceramic products we use in our home for serving food and other items also which are temperature resistant. So wherever the high temperature are used temperature resistant materials have to be proposed there.

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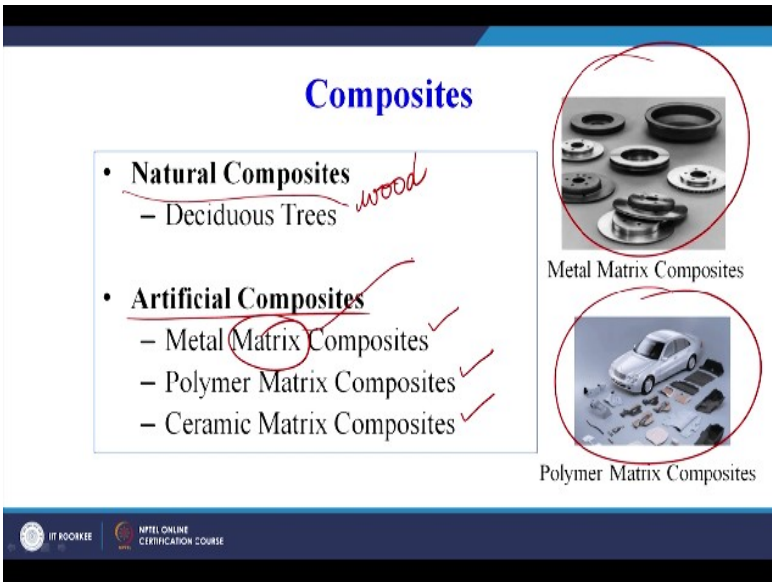

We can purpose the use of the ceramics, then finally we come to another category that is composite, now composites can be natural composities, one of the natural composite that is wood, then there are man made of synthetic composite, such synthetic composites are 3 types, metal matrix composites, polymer matrix composites and ceramic matrix composites. Few examples are given for metal matrix composites.

These are the examples from polymer matrix composites in which the parts that are used in making of automobile are shown here. Now some of you may be new to this topic of metal

matrix or polymer matrix composite, so there is an important term that is coming here that is matrix. So if we talk of a composite materials there is a continuous phase and there is reinforcing phase.

So the continuous phase is called the matrix and the reinforcing phase is called the reinforcements. So there are 2 broad we can say constituent any composite materials one is the matrix, another one is a reinforcement. So from the matrix point of view which is a continuous phase of a composite material, we can have 3 broad categories, we can other polymer as a matrix and then we can put make a polymer matrix composites.

We can have a metal such as aluminium as a matrix and then we can put maybe some additives or some reinforcing agent for example silicon carbide or aluminium oxide into the matrix and then make it a composite material. Similarly we can take some ceramic and then put a reinforcement into it and make a composite. So based on the matrix we can have a polymer matrix.

We can have a metal matrix, we can have a ceramic matrix composite some of you may wondering when already we have a matrix which is also engineering material the reinforcement also the engineering materials why do we need to combine these 2 things together. Now we need to combine these 2 things together to attain the properties which are not possible with the individual constituencies.

So these 2 constituents may not be able to provide me the desired properties for a specific application and therefore we need to combine the 2 constituents together to make a third material which will be able to satisfy our requirements. So that is the basic need and necessity and requirement for developing the composite materials. For example we can say that if we want to improve the fracture toughness of a ceramic then we can add certain reinforcing agents in the ceramic.

And certainly it has been proved that they improve the fracture toughness of the ceramic material. Similarly for polymer also we improve its strength to improve it console and compressive strength if we add the fibrous reinforcement into the polymer. The polymer matrix composites gives us better properties as compared to the neat polymeric product. So therefore there are advantages of combining the 2 constituents together.

And as a product design I must know that yes instead of using the neat polymer if I propose the use of a polymer matrix composites the strength the other requirements can be extended or we can have a better product if we chose the polymer composite as compared to a polymer or a neat polymer only. This is another class of materials which is fast gaining applications or fast gaining importance in the engineering fraternity.

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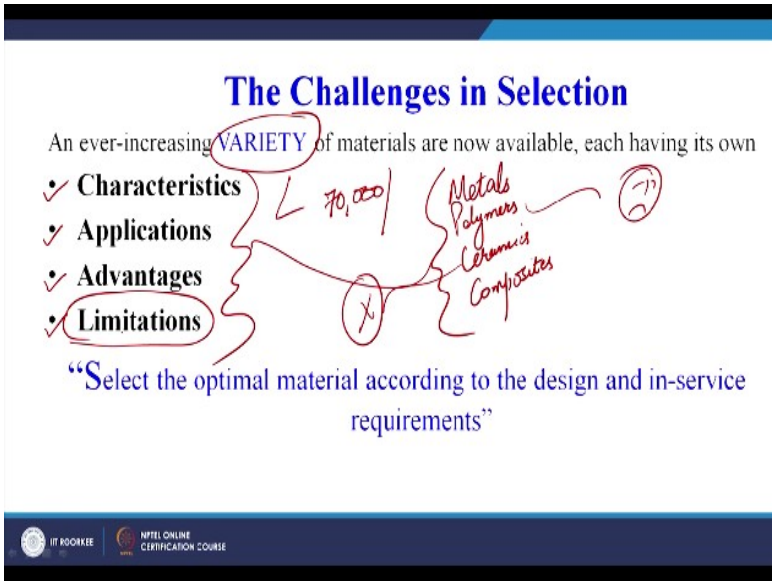

So what are the challenges in selection, so the challenge in selection I will just quickly conclude here and ever increasing variety of materials we have seen this variety is very very important already in the slide we have seen 70,000 types of materials are existing and new materials are being developed every now and then. So if we have large variety of materials as we have seen today also not else which are ferrous, non-ferrous then alloys.

We have polymers, we have ceramics, we have composites, we have so how to choose that which material I must propose for my product. So for that we need to look at the characteristics of the material, we need to look at the application which is already prevalent in the market which are already used for various application or for various usages. Then we can look at the advantages of that class of materials and limitations of that class of materials.

So classes of materials already we have seen just to have a brief summary we can have metals, we can have polymers, we can have ceramics, we can have composites, so how to choose out of these in order to choose we need to look at these important parameter, the

characteristics of the materials, the applications, the advantages and the limitations. For examples ceramics may have got their own limitations.

Similarly polymers may have their own sad point, so the polymers may not be cure for all types of application we cannot propose the use of polymers for each and every application. So we have to see their limitations also. So these limitations then become a guiding force that yes in this application this material cannot be used. So select the optimal material according to the design and in service requirements.

So we have to see our product design that how my product is going to look like, what are the various features, what are the various shape requirements, what are the various size requirements. So that product design specifications we need to understand and based on that we need to select our engineering material, also the in-serve requirements as I have already discussed when we talk of ceramic they are goof for high temperature applications.

So if in in-service requirement high temperature is going to be encountered by the product we can propose the use of ceramics as the engineering material. So with this we conclude the today's session, the introductory session for week 2 on engineering materials, in the next session we will carry forward our discussion related to the choice of the engineering materials that how we can decide what are the parameters governing the choice of a particular engineering material for a particular type of product design as well as the in service requirements, thank you.