Manufacturing Guidelines for Product Design

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Lecture-10
Application of Engineering Materials

Namaskar friends, welcome to 10th session that is the last session for week 2 of our discussion on the topic manufacturing guidelines for product design. So just we have a brief review of what we have covered in the very first we cover focus was primarily on manufacturing processes. We have tried to understand the process capabilities of the manufacturing processes.

Although there is a long list or a big family of manufacturing processes what we try to classify the manufacturing processes in 2 important categories and then we try to understand that what are the process capabilities of some of the selected processes which are most commonly used for making the engineering products. So if you remember we have seen the processes like casting.

We have seen the processes like forging, injection moulding, compression molding which are most commonly used for processing of metals and polymers or we can say plastics, in our 2nd week of our focus was primarily on the materials because every product that you see around us is usually made up of engineering materials, we have tried to classify the engineering materials, we have seen what are the various categories of engineering materials.

And accordingly we have seen that how to select the best material for a particular application, that may depend upon the function, that may depend upon the dimensional tolerance, that is possible with the particular family of material, that may also depend upon the cost, that may depend upon the availability, that may further depend upon in-service requirements for example the product has to be used for aircraft applications or aerospace application we need to have a high strength to weight ratio.

In that case we need to make it lightweight, therefore the selection of material will be governed by a lot of factors which we have already covered in our session number 8 and session number 9 in which the title was selection of material I and selection of materials II, today we are going to see that what type of engineering materials are used for which type of applications because of the product designer we must have broad database in our mind where

we have this understanding that the this particular type of material will be used for this particular type of application.

So if we have the broad idea that for these type of application these are the materials, then it makes our choice slightly easier. So that is the target with which we are starting a today's session. So let us try to see now the different types of engineering materials, their specific properties as well as their specific application spectrum or application areas. I believe that going through today's discussion a broad picture will emerge in the minds of learners that which type of material can be used or used for which specific area of applications.

For example we can take the crucibles or the products which are to be subjected to high temperature mostly we will use the ceramics. Wherever lightweight is an issue we will broadly go for polymers. So therefore this discussion will help you to broadly categorise the materials based on the applications. So these are the type of application, this is a specific material which must be used.

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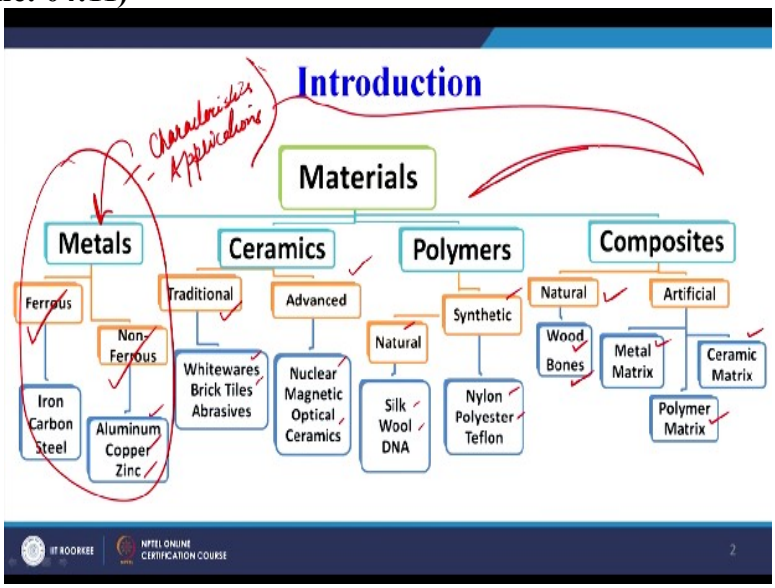

So let us quickly go through the discussion, so this is the broad classification of materials which we have already discussed, I think it must be clear on your screen. So we can see the most commonly used are metals and metals has been used since ages, so metals can further be classified as ferrous and nonferrous and in ferrous we have iron, then maybe carbon is added to iron, then we get steel.

Non-ferrous we have aluminium, copper, zinc, then they are ceramics which can be traditional ceramic such a whitewares or brick tiles, we can have advanced ceramics which are used for nuclear applications which are used for optical ceramics. Similarly polymers we can have natural polymers like silk, wool, synthetic polymers like nylon polyester. So

polymer further we categorise into thermosetting and thermoplastic which we will be seeing in our subsequent slides.

Similarly there are composites which can be natural, for example the wood the bones as well as the artificial such as the metal matrix composite, ceramic matrix composite and polymer matrix composites. So we see that there is a wide variety of engineering materials which are available with the product designer and therefore there is a problem of plenty. Now the designer has to choose that we have already seen that what criteria, what factors the product designer must keep in mind while selecting the engineering material for a particular product which has to be used for a specific application.

So let us now try to see them one by one regarding metals what are the specific properties and where the metals are mostly used and we will take each one of them one by one and will try to address the specific properties of the material as well as the application or the broad applications spectrum of that class of material. For example we will say we will talk about metals, we will try to see what are the sailent characteristics of this family.

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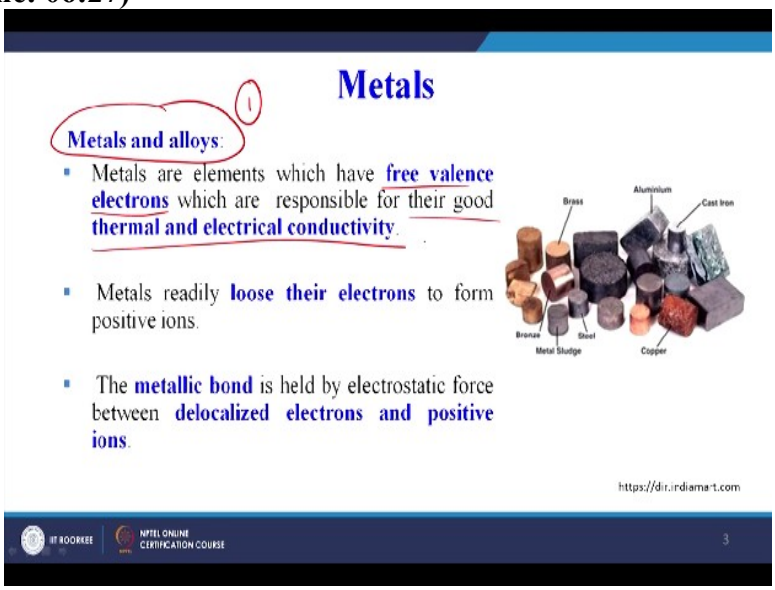

And we will try to see the application and similarly we will try to see all these for the other category of materials also. Now let us try to go one by one, so let us see the metals, so metals and alloys is the first category of materials that we have listed down when we started our discussion on engineering materials. So metals are elements which are free valence electrons which are responsible for their good thermal and electrical conductivity.

So this is from the chemistry point of view free valence electrons but from the mechanical engineering or application point of view we need to understand that they are having good thermal and electrical conductivity and therefore the wire that we are used for conducting the

electricity are usually made up of metal. So metals readily lose their electrons to form positive ions, the metallic bond is held by electrostatic force between delocalized electrons and positive ions.

So this is form the basics of the may be the basics of the metal the free valence electrons are available which make them good conductor of heat as well as electricity. Similarly they lose their electrons to form positive ions. So this is from the chemistry point of view then they have a metallic bond which is usually prevalent. So let us see now what are the general properties, that was basic structure of the metals.

Now let us see that what are the properties, so these properties are much more relevant for a product designer, a product designer may not be that much interested or may not have interest in what is there inside the metal, what type of bonding is there, the chemist or the people who have interest in the chemistry may have that kind of the may be interest but people who have who are product designer will we focus more on the properties of the table which are highlighting the properties of metals.

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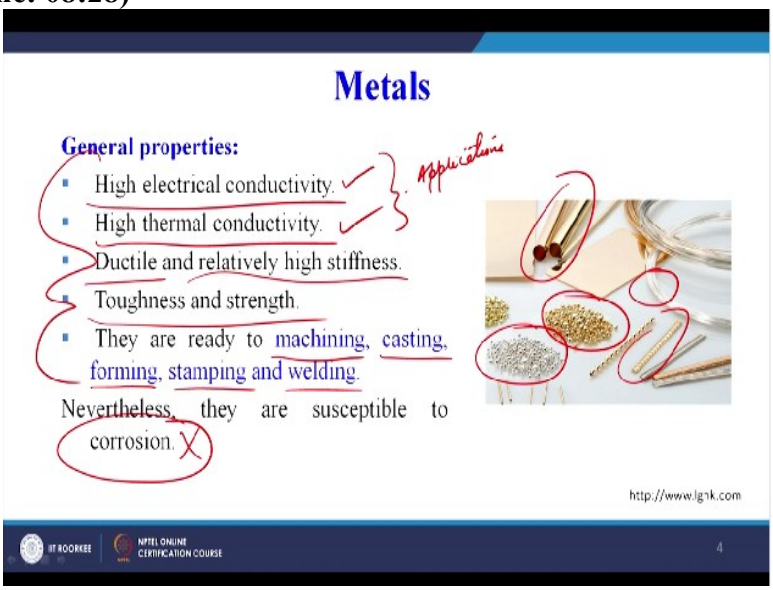

So general properties as we have already seen in the previous slide for metals is they have high electrical conductivity, high thermal conductivity and we will see subsequently that these properties will help us to specify various applications for these materials. So they are ductile, now we see that there is a combination of properties that will help us to realise application for metals.

For example they have high electrical conductivity, now for high electrical conductivity we may use them for electrical wires for conducting the current, but then we need to make the wire and for making the wires suppose the material is not ductile we will not be able to draw

the material of the metal into wires or thin wires. So therefore the ductility also is important, so metals have disadvantage that they are ductile.

They are good conductors of heat, they are good conductors of electricity, they have relatively high stiffness, toughness and strength is also key characteristic of the metals. So they are another point is that they have this properties whether we will be able to manufacture them properly or not whether the manufacturing techniques available for processing of metals. So we can see they are ready.

We can machine the metals, we can cast the metals, we can form them, we can do stamping, we can join the metals using welding. So therefore we can see that metals have good characteristics which make them engineering material for a number of applications. So nevertheless they are susceptible to corrosion. So this is a flip side, so we have to develop our product in such a way that the corrosion does not take place and for that we may like to coat the metal with some thin coating of paint or sometime may like coat it with another layer which can be deposited using advanced techniques such a CVD and TVD.

So that is what corrosion can be taken care of but the best part is that all these properties that are listed here they are easy to manufacture all processing techniques are can be used or available for production of metals and the other characteristic that we have already listed good thermal and electrical conductivity, ductility, malleability. All these properties make metals as an important engineering materials.

Now here we can see some of the applications also these rods can be made easily from metals this thin wires can be made by metals, then maybe this are the metallic powders which are shown here, threads can be cut in the metals, so metals have we can say a lot of application areas and what are the specific application areas we can see.

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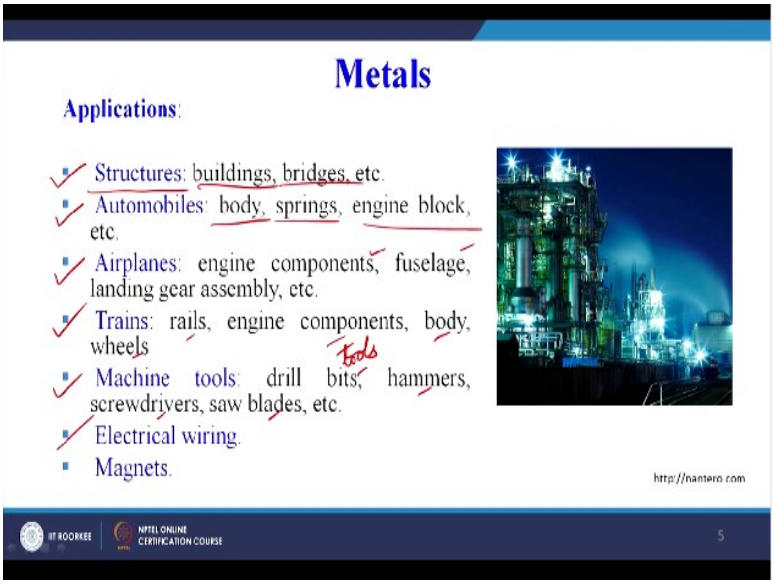

They are used in structure, in buildings we see we have a reinforce metallic reinforcement in concrete, they are used in bridges also, they are used in automobile body, sheet metal body is used in most of the automobile, they are using springs, engine block, so they have application automobile, application in structures, application in airplanes also, the lightweight metals are used there which in other airplanes they can be used for engine components, fuselage, landing gear assembly.

And there can be number of other applications, so we are just highlighting some of the application which are most commonly known to the common people. So trains also all of us travel by train in trains we see rails, engine components, body, wheels are mostly made up of different types of metals only. Similarly the machine tools are the machine we see around in the workshop are made the drill bits tools also.

This is from the tools category hammer, screwdrivers, saw blades, the machine beds, all are made by metals, electrical wiring I have already given an example magnets. So there is a long list of metallic component even these are all engineering applications we are giving when we see to it food we sometimes use the stainless steel plate which is also a metallic alloy. So similarly we can see metals around all of us if we ride a bicycle we will see the bodies made up of a metals.

So there are number of applications where the metals can be used and now after going through this session at the product designer some idea will be frames, some thought process will develop that yes metals cab be use for these types of applications, some of applications are listed here, so wherever strength is required, toughness us required, stiffness is required. So wherever good thermal conductivity is required, good electrical conductivity is required.

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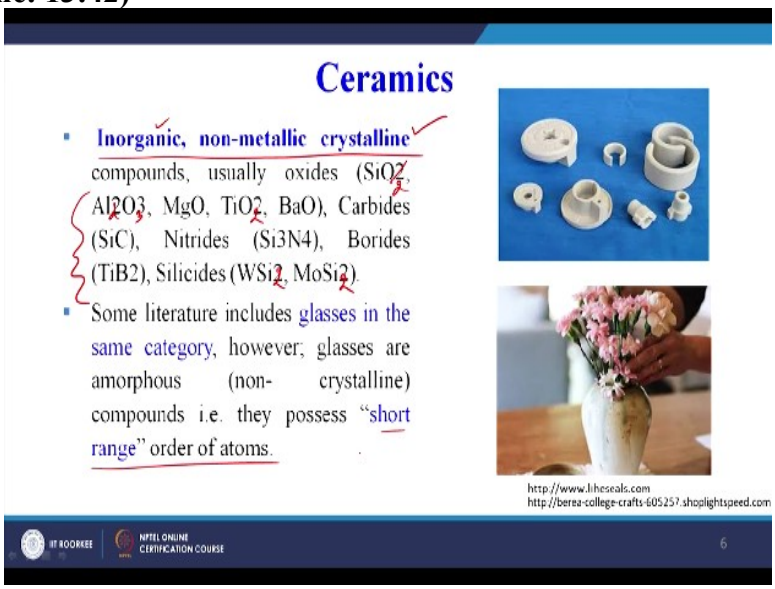

In those cases we will definitely suggest the use of metal as a engineering material for product design. Now let us see the second category that is these are the ceramics, once ceramics we can see they are inorganic, non-metallic crystalline compound. So they are non-metallic so obviously the properties that we have listed for metals ceramics will not have all those properties.

But ceramics will their specific or special characteristic which can make them a engineering material. Now some of the examples are given, it must be written like this, silicon-di-oxide Al_2O_3, magnesium oxide, titanium-di-oxide and barium oxide, number of examples are there. So all these examples fall under the category of ceramics. Now some literature also include glasses in the same category.

However glasses are amorphous, so here we say they are crystalline, most of the ceramics are inorganic and crystalline but glasses are amorphous but they are also a broadly included in the ceramics category only. So compound therefore the short range order of atoms. So they are amorphous in nature.

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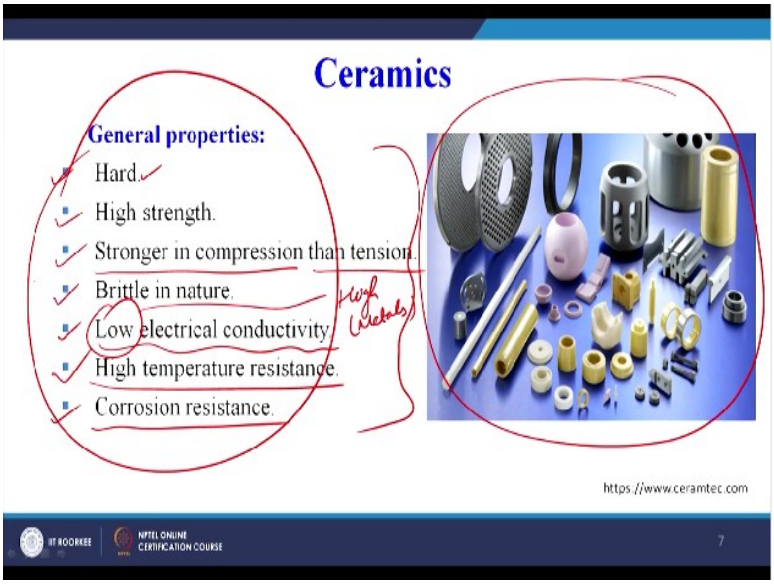

Now what are the general properties, so we are not going more into the chemistry of each and every engineering material, we are going more into the application part and applications depend upon the properties that the material process, posess, so there can be structure-property correlation also, but that is advances topic which may be as a product designer we may try to study or like to study after gaining the basic information about engineering materials.

Because we have seen in metal free valance electrons, so that is the chemistry point of view and this chemistry influences the properties that we have seen on the properties influences the application. So or influence the application, so here also our we are under second and third stage, we are focusing on the properties as well as on the applications. So what are the silent properties of the ceramics that we can see here.

They are hard, they have high strength, they have stronger in compression but not that good in tension, so they are brittle in nature, low electrical conductivity, so you see for metal this low was replaced by high in case of metals. So in case of metals this low is replaced by high. So high means that in metals we have high electrical conductivity whereas in case of ceramics we have low electrical connectivity which means we can select metals where the electrical conductivity has to be ensure or the application where we require high electrical conductivity.

And wherever the electrical insulation is required we can choose the ceramics because they have poor electrical conductivity or low electrical conductivity. So the temperature resistance is another property as I have already told in crucible usually we use the ceramics only.

Similarly they are corrosion resistant whereas in case of metals we have seen that corrosion is the problem.

So we can club these 2 things together, the metals are prone to corrosion, the ceramics are not prone to corrosion they are corrosion resistant, so what we can do, we can make a metal and we require toughness, stiffness, strength everything in our product. So we what we can do, we can select metal as a substrate, we can make the product of our metallic product using a specific metals.

And then we can coat the metallic product with the ceramic coating, so the ceramic coating will make it ceramics or corrosion resistant. So the coating will make the product corrosion resistant whereas the metal will give which is the substrate or the main integral part of the product, the metal will itself have high toughness, high strength, so we will able to club the best properties of the 2 materials.

We have taken the best properties of the metal, we have taken the best properties of the ceramic and we have combine them together to develop a third material which will give us better properties, it will be good in strength, good in toughness, stiffness whereas it will also be corrosion resistance because of the coating given of the ceramic material on the surface of the metal. So therefore many times we combine 2 or 3 different materials together to take advantage of the best properties of these materials.

And that is where the concept of composites coming to picture. So let us see now see we will come to the composites towards the end of today's session, but let us now see that based on these general properties what are the application areas of ceramic. So here we can see some of the applications picture of the ceramics small components are usually made with ceramics and there can be different manufacturing processes for making of ceramics.

For metal if you remember in the today slide only we have seen that metals can be machined, metals can be casted, the can be forced, they can be extruded, so they can be drawn into thin wire, they can be beaten into thin sheets. So metals have all the manufacturing processes applicable to them. Whereas for ceramics there are specific processes that are used for processing of ceramics.

One of them can be a powder metallurgy and there can be other techniques also that can be used for processing of ceramics, and if you wish to have a discussion on this particular topic how ceramics can be made we have already recoded sessions on processing of non-metals in which way focused on the processing techniques for ceramics. But the title today are the

course that we are currently discussing that is manufacturing guidelines for product design we cannot have a liberty to discuss that how ceramics are manufactured.

So our focus primarily is to list down the application spectrum of ceramics that in what type of applications they can be used. So let us see now where they can be used based on these properties or general characteristics that they possesses.

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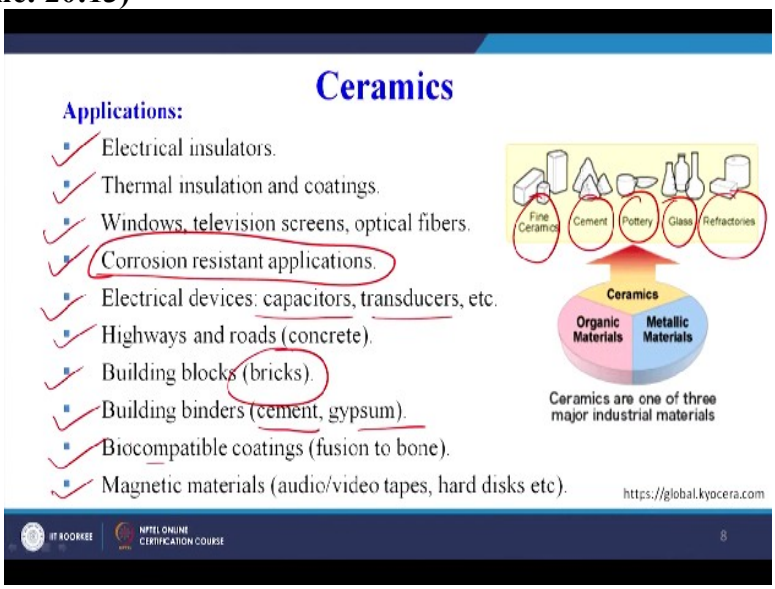

So ceramics as we can see there are fine ceramics, cement, pottery items, glass, refractories which are used for high temperature applications, so as I have already told as they are poor conductors or low they have they possess low electrical conductivity, therefore they are used as electrical insulators. Thermal insulation and coating, this is another application because their poor conductors of heat also.

They are used if the glasses we see glasses they are used in windows, television screens, they are used as optical fibres, then as they have resistance to corrosion, they are used for corrosion resistant application, they are used in electrical devices such as capacitors, transducer, they are used in highway and roads as concrete, they are used as building blocks such as bricks, building binders, such as cement and gypsum.

They are used for biocompatible coatings as I have already fusion of the bone even the white cement sometimes that used for teeth also use of ceramic materials, they are used in magnetic materials, audio/video tapes, hard disk. So you can see the properties we have seen corrosion resistance, poor thermal conductivity, low electrical conductivity, high compressive strength.

So all these properties lead to these specific applications, so now we can keep galaxy of application or we can keep a library of applications in our mind that which are the specific

application areas for ceramics. So once we are designing a particular product we know the product is being designed for this particular application, we can very easily single out ceramics for that particular application.

If it matches the service requirements for which the product is being designed. So we have seen 2 different types of engineering materials by now, the first one were the metals we have seen the specific application areas of metals, second is ceramics, we have seen the specific application area for the ceramics. Now let us move to the polymers.

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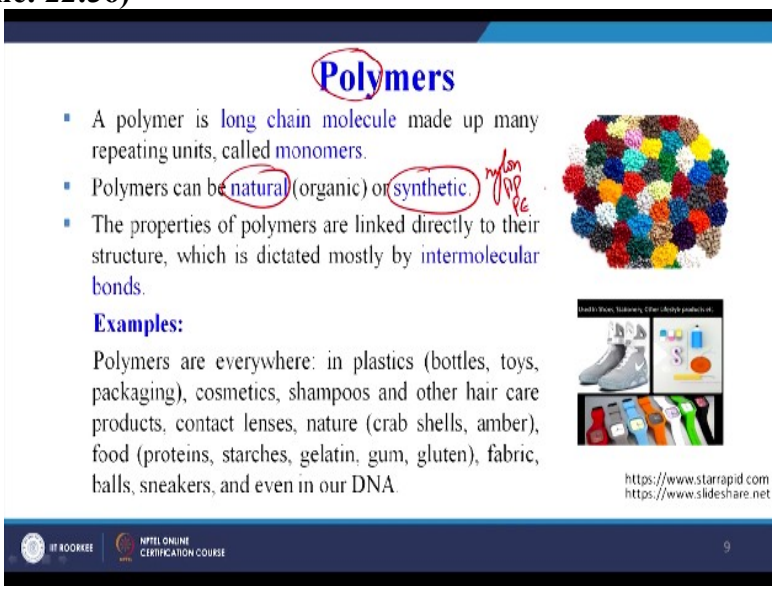

So a polymer is a long chain molecule because the word poly itself explains that a polymer is a long chain molecule made up of many repeating unit called monomer. So different monomer when they polymerize they make a polymer. Polymers can be natural or they can be synthetic, so there can be natural polymers, there can be synthetic or manmade polymers, such as we can say nylon or polypropylene or polyethylene.

There can be number of synthetic polymer, we will see the examples in the subsequent slides, the properties of polymers are lead directly to their structure which is dictated mostly by the intermolecular bonds. So this is again from the chemistry point of view that the intermolecular bonds in the polymer will influence their properties and these properties will subsequently affect the application areas.

Now based on the kind of bonding that is developed during the processes of polymerization we can have thermoplastics and we can have thermoset. Now depending upon the polymer being a thermoplastic it will be used for specific applications. Similarly polymer being a thermostat it will be used for specific application because of the intermolecular structure inside the polymer.

So examples are polymers are everywhere so if you see in the normal this classroom only are the recording studio, if you look at the various application of the various products that we are using here, at least we can list from 10 to 15 different products which are made out of the polymers in my I am using a pointer as a slide changer as well as list stylus both are made up of polymers.

Two products currently I am using, third the pen I am carrying is also having a plastic body, so we can see just in and around only 3 products of polymers we have seen. So polymers are everywhere, bottles, toys packaging, cosmetics other hair care products contact lenses, and nature also crab shells, amber. In food also polymers, they are protein, starches, gelatine, gum, gluten, and then the fabric balls, sneakers and even in our DNA.

So polymers we see all around spectacles there with that we are using many time the frame will be made up of plastic because they are lightweight materials. So wherever the weight is an issue definitely we will like to propose the use of a plastic material. Now polymers as I have already listed they can be thermoplastic and theycan be thermoset.

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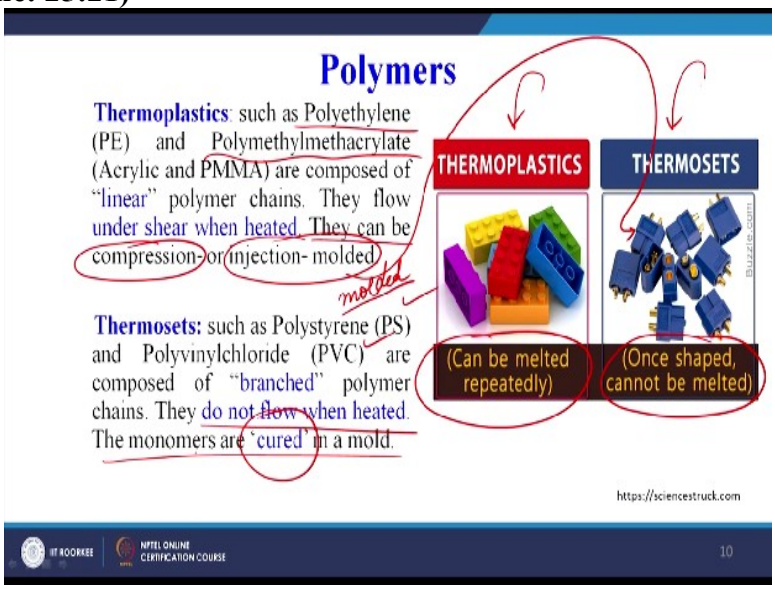

Now thermoplastic we can see mostly the toys that we see for our children are made up of thermoplastic, we have building blocks show here, so they can be melted repeatedly, so which means that we can recycle the thermoplastics. Where a thermosets once they are shaped they cannot be re-melted or melted again. So we can see many of our electrical installations are the polymer that we use for shoes and switches electrical switches.

If there is a short circuit it will burn, it will not melt it will not drop done the polymer again but it will do it will burn out. So which means it cannot be re-melted again. So thermosets

cannot be re-melted or re-shaped again where a thermoplastics can be melted repeatedly. The thermoplastic examples are given here, polyethylene, polymethylmethacrylate, PMMA, are composed of linear polymer chains.

They flow under shear when heated, they can be compression or injection moulded, so the processes are also listed here that thermoplastics can be made by compression moulding process, they can also be made by the injection moulding process. And these parts which are shown here blue in colour must have been made by the injection moulding process. Whereas the thermosets such as polystyrene, polyvinylchloride are composed of branched polymer chain, they do not flow when heated.

But they will burn out on excessive heat, the monomers are cured in a mold, so they are we can see these are molded, thermoplastics are molded, whereas thermosets are cured. So chemically we accelerate the polymerization processes by adding a hardener and then after a sufficient amount of time as depending upon the type of thermoset we are using they will get solid or they will get cured.

So that is the differentiation between thermoplastic and thermoset and that dictates the application areas for which we are using them. So as a product designer when I have to choose a polymer within polymer also I must see that whether I must do the thermoplastic material for this application or I must propose the thermoset material or thermoset polymer for this product.

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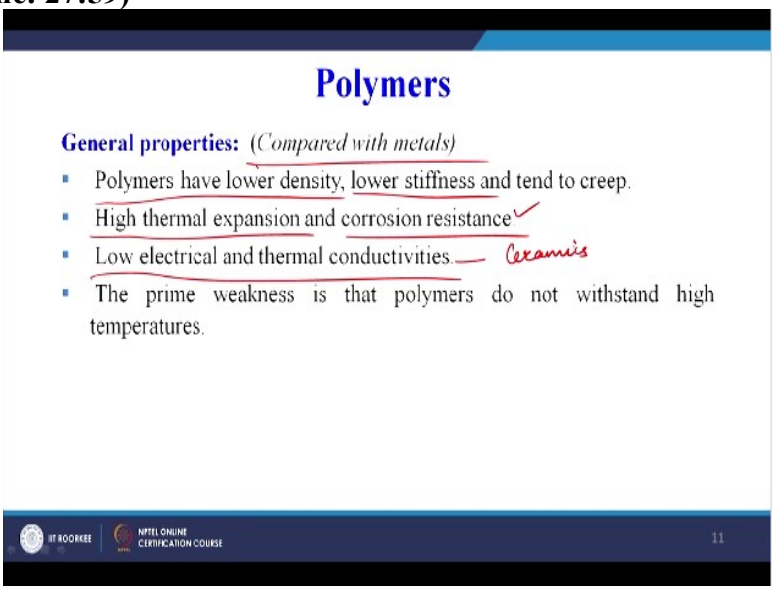

Now what are the general properties those are in comparison to the metals, polymers have lower density, lower stiffness, and they tend to creep. So that density is low therefore they are used for lightweight application, stiffness is also low and they tend to creep. High thermal

expansion and corrosion resistance, they can be used for corrosion resistance whereas there is a tendency of high thermal expansion.

So low electrical and thermal conductivity which is also a property that we have seen for ceramics, low electrical and thermal conductivities. The prime weakness is that polymers do not withstand high temperatures. So that is one major problem. So wherever high temperature are there, there we will propose the use of ceramics or depending upon the temperature the metal.

Polymers are not used for high temperature applications they are used for low temperature applications only. So these are the salient properties of polymers which will dictate their application areas. Now when you see any plastic product for exam I see this pointer or a slide changer we will see that it is not going to be subjected to a very high temperature. We do not want we do not require high thermal conductivity.

We do not require high electrical conductivity in this product, so whatever properties that are listed out here are suitable for making this in a plastic material. So therefore depending upon the application we will see that what are the properties that the engineering material posess and what can be the specific application areas for that particular engineering material. Now applications we see plastics all around this 3 examples I have just given you.

So they are used for clothing and upholstery, vinyl polyesters, nylon, mouldable products like computer casing, telephone, there use a biomaterials, water resistant coatings, low friction materials that is Teflon, adhesives and glues, the many times we use glue to join that plastic parts that are broken, so many times to join wooden parts also, suppose glues are nothing but they are polymers.

They are used for containers, example is shown here, they are used for liquid crystal, synthetic oil and greases also a polymer, soaps and surfactants are also polymer. So polymers also find a lot of application, to just emphasize on the importance of polymer we can see that there are institutes which teach only about polymers science and engineering. So you can get your degrees even in polymer science and engineering.

And that justifies the application of polymers, but nowadays there is lot of focus on the waste disposal and recycling of the polymers and that is the big concern in which the world fraternity as well as the engineering brotherhood who are trying to find out solution even the government is going to pass regulations or is in the process of passing regulations to minimise the use of polymers which are non-biodegradable.

So the focus now in future is going to be of for developing the polymers which are biodegradable as well as recyclable. Finally we come to the last category that are the composites.

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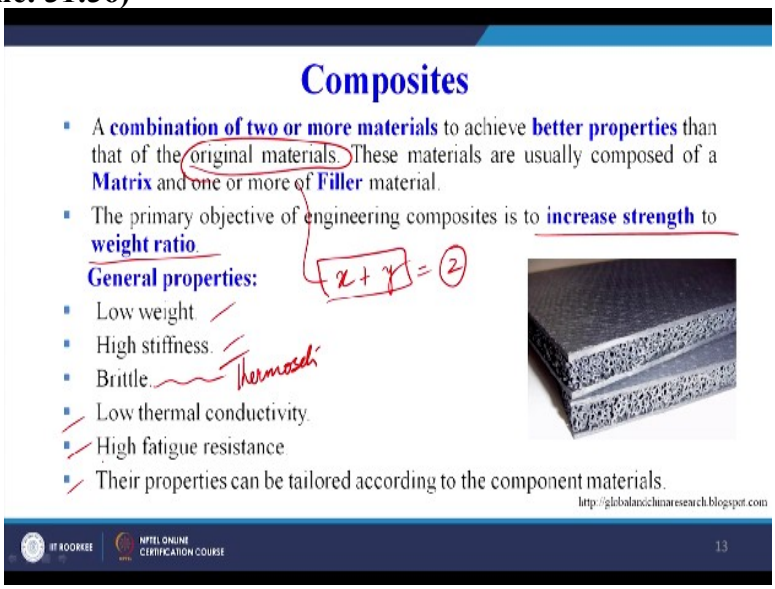

Now a composite is a combination of 2 or more materials to achieve better properties than that of the original materials. So suppose the original materials are x and y so when we want to develop a composite material we will like to take the best advantages of x and y the properties and then develop a new material z which is having the best properties of x and y and one example already I have told in the beginning of today's session that when we require high strength and stiffness as well as stiffness we take metal.

Then we coat it with a ceramic to make it corrosion resistant, so that is your combining 2 different materials together to develop third material which is going to give you the best properties of the 2 individual constituents. So these material are usually composed of a matrix and one or more of a filler or a reinforcing material. So the primary objective of engineering composites is to increase strength to weight ratio.

So this is specifically increase strength to weight ratio for 1 specific family of composite material that is a polymer matrix composite, we have other types of composites also like metal matrix composites, ceramic matrix composites. So we will see what are the general properties of composites they have low weight, high stiffness, brittle when we talk of the thermosets as the matrix material.

In case of thermoplastics there are not that brittle they have low thermal conductivity, high fatigue resistance, their properties can be tailored according to the component material, but

depending upon the final application we can choose the type of the matrix that we are going to use the type of the reinforcement, type of the filler, then we can even decide on the number of layer that we are going to use for making a composite material.

We can decide the material for each layer also, so composite is also very big family in which further classification is there on terms of the matrix and in terms of the reinforcement that we use. Now the composites we can see the application area of the composite.

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They are used in sports equipment golf clubs shafts are made by composite, tennis rackets, bicycle frames, then smart materials they are used for sensing and responding, aerospace materials they are used for lightweight application because already we have seen high strength to weight ratio is one advantage that we have with a composite materials specifically with the polymer matrix composite materials.

And therefore they are finding lot of applications in the aircraft industry, thermal insulation concrete we can have brake materials so composite are also finding lot of applications all around the globe and in future they are further going to be used to satisfy the human needs and requirements. So with this we come to the conclusion of our discussion on engineering materials and that is the closure for the week 2.

In week 3 we will start discussing the other aspects related to the product designs specifically related to the manufacturing guidelines for product design. In today's session we have tried to see the basic properties of 4 different types of engineering materials and the application areas related to the properties of these materials, we have covered metals, ceramics, we have covered polymers as well as the composites and with this we conclude the 2nd week of our discussion, thank you.