Mathematical Modeling of Manufacturing Processes

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Lecture - 01
Materials and Manufacturing Processes - 1

Hello everybody. Today, I will start with the mathematical modelling of the manufacturing process the first module but in this module the discussion point is that introduction to manufacturing processes. So, we will discuss the introductory level that manufacturing processes and that specifically the properties of the material and which is helpful to analyze the different manufacturing processes.

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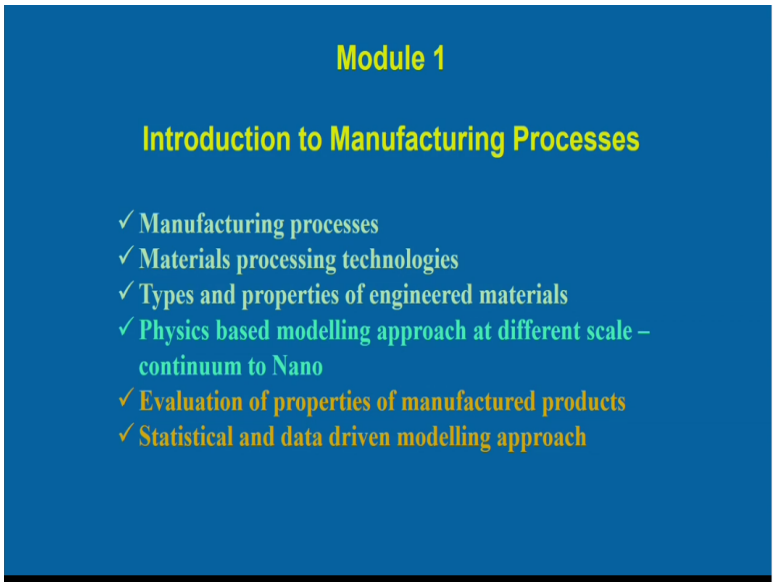

So, the module is arranged in such a way that first some introductory discussion on manufacturing processes, then what are the materials processing technologies, what are the importance and of course all this thing is seen in introductory level because material processing technology itself is a very big chapter and then types and properties of the engineering materials and which is we can found out the very common properties of the materials.

And of course, will try to look into that different scale what are the importance of the mechanical properties and how it influence or how it can decides the mechanical properties or through manufacturing processes whether there is any change of the mechanical properties or

may be other kind of properties and how we can evaluate all these properties, the different engineering approach.

Then, that will try to get an overall view on that, then next part of this module will be the physics based modelling approach and at different scale. Mostly, I will try to discuss exactly the approaches from microscale to the nanoscale or in between the meso-scale or grain scale approach will try to discuss and in terms of the multi-scale modelling approach but here will discuss only the approaches.

But in details the continuum models and continuum scale models, all these phenomena will try to discuss in the next module that which what type of equation we can use it to solve any kind of manufacturing problem. Then, finally will try to look into the evaluation of the properties of the manufactured products and maybe broadly will try to discuss the evaluation of the mechanical properties.

And what kind of testing we can do to check the properties of a material after manufacturing processes and of course then last part of this module will be statistical or data driven modelling approach normally follow in case of manufacturing process. Then, will try to discuss on these things but all these discussion will be confined at the very overall discussion or in general sense will try to discuss all these matters which is I just mentioned in this module.

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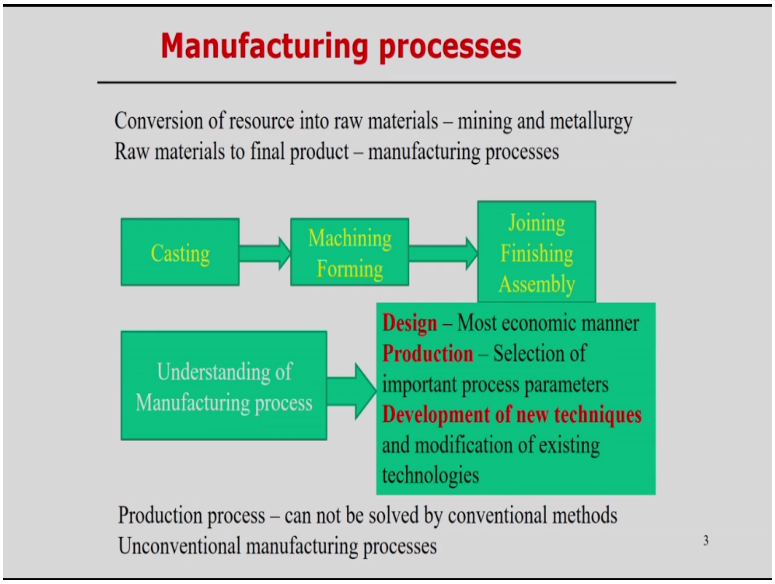

Now, manufacturing processes so from what point to start the manufacturing process. First is the, the first step is that conversion of the resources into raw materials that raw materials is a that subject is broadly in mining and metallurgical section, so will try to look in broadly that how we can convert the natural resources into the raw materials. So, once the raw materials are available and then manufacturing processes deals with from raw materials to form the final product.

So, how we can form from raw materials to the final products? Based on the different type of manufacturing processes, we can get the hierarchy of this process is like that say first step of the manufacturing process is the casting process. You know that casting and solidification is one manufacturing process. Casting means we can get a desired shape and specifically size from the molten material.

So, we get the raw product may be in the form of a roll, in the form of the sheet, we normally use in the steel sheet but that normally forms by the following the casting process and the first step in the casting process, once we get some raw materials in terms of the (()) (04:40) is available, then from that raw materials we can process, we can apply some manufacturing process.

For example, if you want to get the desired complex shape, then maybe it is necessary to perform the machining process for this raw material. So, then machining process can be done or maybe you can get the desired change of the shape and for example one sheet metal to we can get one deep drawing process if we follow and we want to get a particular shape, then we can follow some kind of the metal forming process.

So, casting is the first step to get the in the form of a raw materials or stock materials and from that we can follow different kind of the machining process or forming process to get the, these are the manufacturing processes to get the desired product and of course not from only machining and forming process, manufacturing process also associated with some kind of the joining process if necessary.

If you want to join two components, then we can follow some kind of the joining technologies and that joining of these two components can be in the similar type of the material or it can be dissimilar type of the materials through this joining process. So, once we

get from raw materials to the manufacture components, then it is often necessary to do some kind of the, follow some kind of the finishing operation to get some desired surface finish of the particular product.

Then, we can follow the different kind of the finishing processes and of course not only the finishing process and if you want to get a big product then maybe necessary the assembly of all the different components that can also be done and then after assembly, we can get the final product. So, therefore manufacturing processes actually deals with these 3 different basic steps.

What is the design of a processes and then production of the processes and of course by looking into the production of the processes and gradually development of the new techniques? This is the most of the engineer follow these 3 basic steps and of course this 3 basic steps we need to understand. So, therefore understanding of the manufacturing processes in the light of the design production and the development of the new techniques.

Once we try to develop the new techniques then we need to understand what are the already existing manufacturing technologies and what are the pros and cons, advantages and disadvantages of these particular manufacturing techniques, then only we can propose some kind of the new manufacturing technology and then of course once we need to understand all these things.

First, we look into the design of a manufacturing process but we design the components of a manufacturing system in such that it must follow the most economic manner. That means there are several manufacturing processes available and maybe we want to get a particular product and that follow several sequence of the manufacturing processes we need to follow in the most economic manner in such will try to minimize the cost of this production.

At the same time, the minimum utilization of resources and of course optimize the manufacturing process in that sense that we need to look into the optimum process parameters we have to choose such that we can produce a particular product in the most economic way. So, that is the design of the total manufacturing process or we can say the design of a manufacturing system.

Then, production in these cases, the production, rate of production looking into the demand, all this thing is a part of the manufacturing processes also and that in that cases selection of the important process parameters is the most important here and of course in the production at the same time we need to look into the rate of the production also, how quickly we can produce a particular product, that is also important aspect to look into the overall design of a manufacturing process.

So, once we understand the existing process then or the difficulties with the existing process and if you analyze all these aspects then will try to reach maybe some development of the new technologies and of course either development of new technologies or we can suggest the modification of the existing technologies. That is the most important aspect of any kind of manufacturing engineer.

But of course, the production process in certain cases definitely cannot be solved in the conventional, so some particular development or depending upon the complicacy of the particular product, it is not always possible to develop this product by using the conventional processes, what conventional manufacturing processes. For example, we have already mentioned that this normally casting, machining, forming, welding and finishing.

These are the conventional manufacturing processes. So, therefore sometimes it is not possible to follow or by using the conventional manufacturing process to get a particular product. So, in that cases, unconventional manufacturing process are also developed and of course this development happens once we get stuck with the existing, using the existing conventional processes.

So, all this conventional as well as the both non-conventional manufacturing process is their development and of course the approach, the modelling approach. That means by looking into the physical phenomena that is the basic objective of this course and will try to discuss in the discussion in the further modules all this conventional and manufacturing, conventional and non-conventional manufacturing processes.

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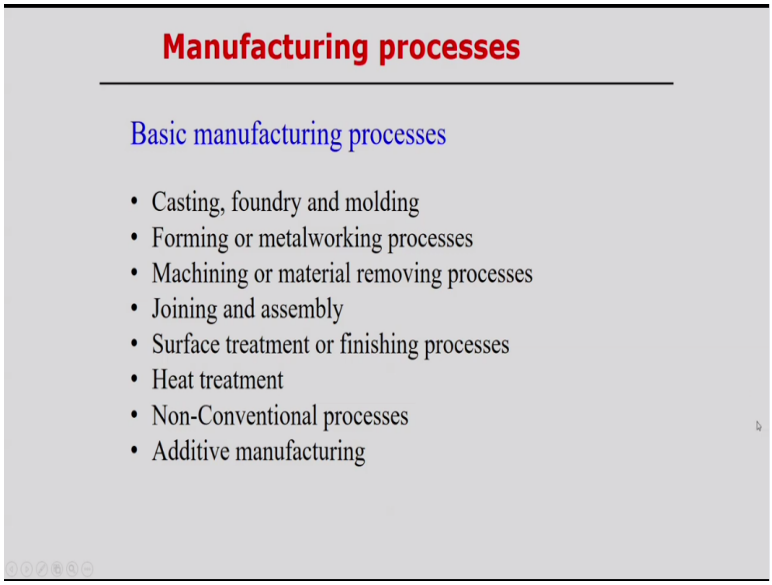

Now, we start with the basic manufacturing processes we know that these are the typical manufacturing processes that casting, foundry and molding together. Casting means we simply understand we collect the materials and we just melt it and get the desired shape with the help of the foundry and of course some molding means to hold the molten material and that for that particular material if you want to get particular shape.

So, then (()) (10:55) pour the molten material in a particular cavity according to the, or desired shape and size. Then, after molding then it is followed by the solidification processes and then we get some kind of the product. This is in general the casting processing that is involved in the manufacturing system or manufacturing process.

Then, metal forming process means the metal forming process, we never melt the material rather in metal forming processes we just try to get the desired shape below the operating temperature below the melting point temperature and this metal forming processes is a one category of the manufacturing process and of course the deformation of the material is the most important aspect in the metal forming process.

Then, machining or material removal process. If you want to get a desired shape, complex shape, so maybe necessary to remove some part of the material to get the particular shape. So, then that kind of to get this things we just removed the material by following the different kind of the machining processes. This is in general the machining processes or we can say the material removal process.

So, in general it is called the subtractive manufacturing processes because here it is necessary to remove the some part of the material with the help of a kind of another tool material then joining an assembly we simply understand if some product development may be necessary to join the two components, to weld the two components, so that is one part of the manufacturing process we can say.

And sometimes, we want to improve the properties of the surface. For example, after machining process or any other processes, after welding processes maybe that particular component may not get the desired mechanical properties, so in that cases, it is necessary to follow some kind of the heat treatment process. So, heat treatment to change, alter the properties within the particular structure.

It is often necessary after following any kind of conventional manufacturing process to conduct kind of the heat treatment just to improve the properties, mechanical properties or any surface properties of a particular material. Then, surface treatment or finishing operation; so once we process through the any kind of the normally in casting or welding or maybe any kind of the metal forming processes.

We may not achieve the desired surface finish what we are expecting in a final product, so in that cases, it is necessary to remove the small amount of the material, so that is called the finishing process. So, with respect to the machining process, the machining process is the large amounts of material normally remove but in case of finishing process very small amount of the materials are removed.

But in finishing process, the objective is to achieve the surface finish, to bring the acetic part of a particular component. Then, non-conventional processes, so apart from this conventional processes there are so many non-conventional processes has been developed when we get face the difficulties by applying of a particular application of a particular size, shape or particulate material and you follow not possible to apply the conventional processes.

So, in those cases nonconventional manufacturing process has been developed. We will discuss the different non-conventional processes also and then finally the additive manufacturing processes. So, additive manufacturing processes is a completely different from subjective manufacturing processes that means with respect to the machining processes. So,

additive manufacturing processes here, we can develop the product by layer by layer deposition process.

So, in these cases as opposed to the machining process, the loss of the material during the process is very less in case of the additive manufacturing process. So, in additive manufacturing process, so normally we can do, we can produce a particular product by using the powder or centering the powder and we want to get the desired shape and of course we achieve the desired shape not a single layer.

So, which is a small layer deposited and after that the deposition of the next layer, so that layer by layer deposition is the main strategy in case of additive manufacturing process. So, all this manufacturing processes will try to look into in details and their modelling approaches in the different types of the modules.

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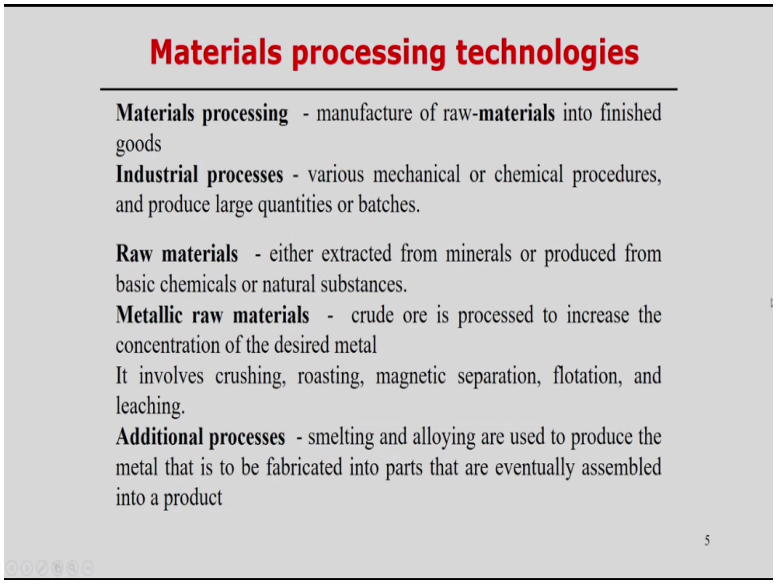

Now, materials processing technology; so material processing, what we understand the manufacturing of the raw materials into the finished good that is in general we call the material processing but industrial process what we collect, what we can from the raw materials. For example, in terms of the steel bar for example what we can do this things.

But that various when we try to produce some raw materials then mechanical or chemical procedures we need to follow and produce the large quantities or batches that means by following the mechanical or chemical procedures from the old material and to extract the raw materials and that normally done as a large quantity in terms of the batch. Raw material is

actually extracted from the minerals or produced from the basic chemicals or can be from natural substance that is called the raw materials.

For example, the metallic raw materials; crude ore is processed to increase the concentration of the desired metal and it involves that crushing for example what we can collect from the nature that crude ore and that ore is not, directly we cannot use the ore for the manufacturing process. So, what happens in the ore, first we crush and then roasting and sometimes if magnetic separation can be followed.

Floatation that means we can separate out the lighter and heavier components and all these processes following these things we get the materials and that is normally smelting and we follow the casting process normally in these cases. So, once we collect the raw materials after metallic raw materials from the crude ore. That means we just convert the crude ore to the metallic raw materials.

And then raw materials are basically melting and then it is necessary some alloying, that means we can produce, we can make it in the form of the alloy by adding other components and finally we produce the metallic alloy. That is basically fabricated into the final components through some manufacturing processes and we can get the desired product or directly we can eventually assemble to the desired products by following some kind of the manufacturing processes.

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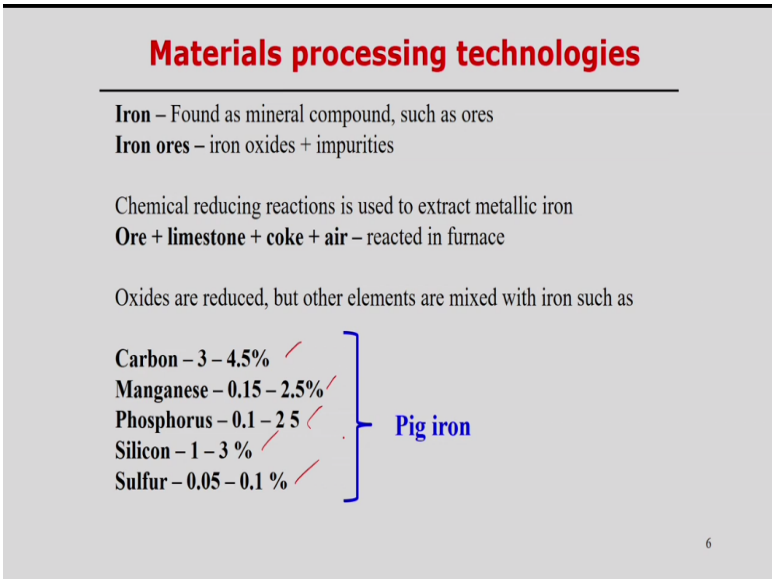

Now, material processing and we can take one example, for example the iron, iron normally found as mineral compound such as ores and then basically iron ores is the mixture of the iron oxides and some impurities. So first step we try to improve, we try to remove the impurities from the iron oxide. Then, we try to reduce the oxides, so therefore chemical reducing reaction should happen to extract the actually in that form almost pure iron from the iron ores.

But how we can extract, so once we remove the impurities from the iron ore, the iron oxides are along with the limestone, coke, air, all are bring together and they are actually melt in the furnace, reacted in the furnace by application of the heat energy. Now, these oxides are removed because we add the other components limestone, coke and air. That actually helps to remove the oxides and finally to bring the almost pure iron.

But sometimes oxide is reduced that is fine but at the same time other elements are also mixed with the iron such that we can produce the some kind of the wrought iron ore which is called pig iron. So, we can see that different components actually mixed. Carbon normally 3 to 4.5% is mixed with the iron ore, manganese can also be mixed, phosphorus is mixed, silicon certain percentage and sulfur, all are mixed and then we produce some kind of raw materials which is called the pig iron.

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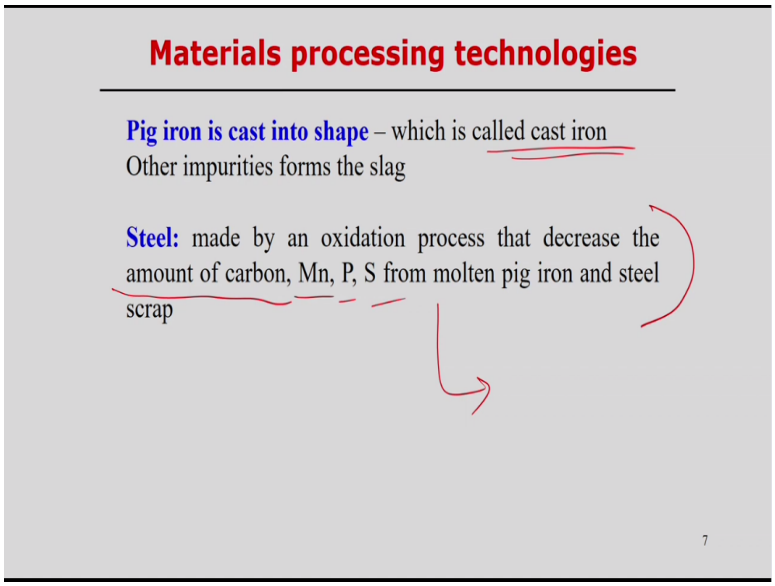

So, once pig iron is cast then once the pig iron is cast the desired shape which is called the cast iron and other impurities actually in the pig iron is forms into the shape through the casting process and that is called the cast iron and of course other impurities forms in the

form of the slag and that we just simply remove the slag. Steel can also be made but steel can also made by the further oxidation process and that decreases the amount of the carbon.

So, normally the cast iron carbon percentage is more and then if we reduce the further carbon percentage from the iron ore then we can produce the steel and of course this steel is processed through further oxidation and just to reduce the amount of the carbon and of course Mn, sulfur, phosphorus is normally removed from the cast iron or maybe you can remove from the pig iron.

And then steel can be formed or of course in this process so during the removal of this different components carbon, manganese, phosphorus and sulphur. Then, at the same time, the steel scrap can also be added and finally we can make it to the desired shape the steel product and of course is in general this is done normally following the casting processes. So, from the iron ore, we can produce the both cast iron and then or in the sense we can say the pig iron or we can produce the steel.

And then steel is basically we can utilize the steel through following the different manufacturing process and to produce the different type of the products. So, once the material processing or the iron ore to the either steel and cast iron then the start of the manufacturing process with respect to that how we can process this material steel or cast iron to convert into the desired product and of course this conversion from steel to final desired product, intermediate components are the different manufacturing processes.

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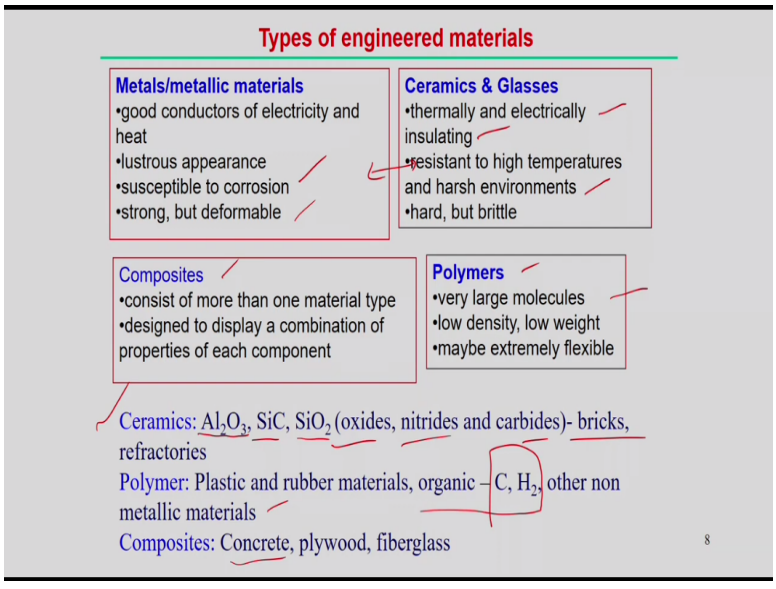

Now, with the introduction of the different manufacturing processes now we will try to look into the properties of the engineering materials or what types of the engineering materials normally used for the human being and for the development of the society. So, what are the different type of engineering materials normally is the 4 basic categories. We can see that first is the metals and metallic materials we can say.

Second one is the ceramics and the glasses is the another category, composites is another category and polymer. These are the 4 basic category of the materials and of course there are certain specific type of materials also available but metals and metallic materials we understand it is a good conductor normally, the electricity and heat normally but susceptible to the corrosion is involved basically the iron steel product or iron product.

And then strong, very strong but it can be deformed, that is a typical characteristics of the metallic materials. Ceramic and glasses is normally opposite to the thermally and electrically nonconductive, maybe thermally and insulating almost, so it acts as an insulator and of course at the same time, it is resistant to very high temperature and of course this ceramics and glasses normally can be used in the harsh environments.

But it is very hard at the same but ductility is very low that means it is very brittle metal. These are the typical characteristic which is completely different from the metallic materials. Now, composites is as simple as that making consist of more than one type of the metal is mixing, we can make the material such that the combination of properties, it retains the combination of the properties of the both the components when you make the composite materials.

Then, we can use a polymers; polymers are very large molecules, we can typical characteristics of that and its low density, low weight, weight is very low and of course it is very much flexible, we can get the desired shape and size so easily as compared to the metallic material. Now, ceramics we can get some example that it is a combination of the metals, nonmetals.

Pure aluminium is the metallic material but aluminium oxide is a ceramics. Silicon carbide, silicon dioxide, all are the kind of ceramic materials basically oxides, nitrides and carbides

normally are the ceramic materials, the application, the bricks, formation of the bricks, tiles, refractories, there we can find the application of the ceramics.

Polymer; plastic and the rubber material and of course the organic normally consists of carbon and hydrogen the main component and of course other nonmetallic materials also involved to make the polymer, it is a component, so example is the plastic and rubber materials. Composites; we can say the concrete, we can consider concrete as the composite material.

Plywood, fiberglass and plywood also a composite metal, this plywood can be forms the mixing of the different fibres from the wood and mix it. It can be continuous and it can be discontinuous. So, all this type of engineering materials normally used in the daily life.

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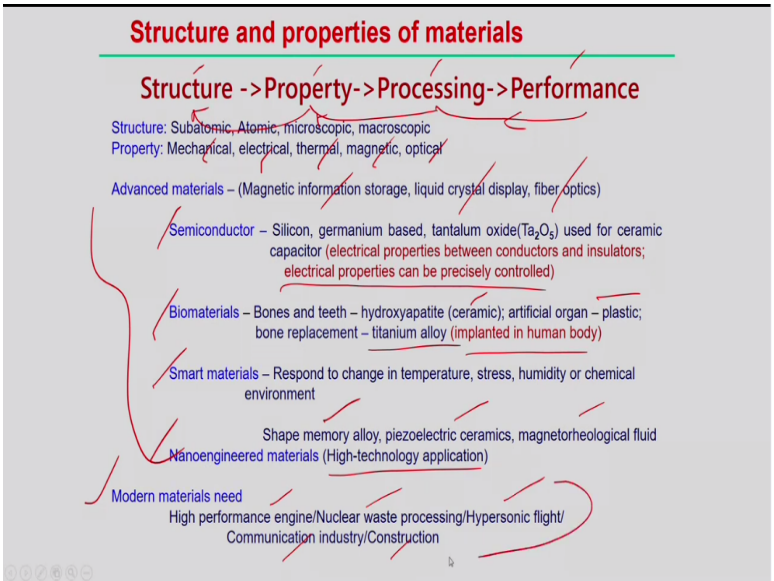

But we need to understand the properties of this engineering material and structure and properties of the engineering materials because the pillar of the manufacturing process and analysis is resting on the 4 steps. First one step the structure, property, how we can process and perform. First, if you want to understand the performance of a particular engineering component, then we need some relation and need to know what are the structure and the properties.

We can start with the structure, what is the specific structure of a particular material and then if the property depends on the structure of the materials of course and then once we know the

particular property, then we need to think about if this is a particular property what are the manufacturing processing technologies we can apply for this particular type of the material.

So, all are related actually and then once we know the manufacturing processing, after following the manufacturing processing we can make the product and the four steps, once we make the product then we try to analyze what are the performance of this product. So, this link performance with the processing, processing with the property and property with the structure is very much needed for a particular mechanical engineer.

So, structures that when you analyze the structure of a particular component or particular material and then there are several scales to understand the structure of a particular material. For example, the subatomic scale, the atomic structure, what is atomic structure and then atomic scale, then microscopic scale, microscope grain scale and the microscopic scale means you can see the structure and properties, we observe the properties of a particular material when you try to look into through the microscope.

Then, microscopic scale what are the properties and then macroscopic properties. So, macroscopic properties means if we simply do the tensile testing of a specimen, what is the tensile strength, yield strength, ultimate tensile fracture strength of a particular material. We can say that is the macroscopic property but this macroscopic property depends on the microscopic scale, what is the understanding of the microscopic behaviour and then microscopic behaviour also depends on the atomic.

So, there are several ways, different scale we can analyze the properties and all are related and but once we understand what are the properties in the macroscopic scale, then we need to link with the through the multi-scale approach of the properties at the different scales. So, that property of a material we understand that there are different types of the properties, mechanical properties, electrical, thermal, magnetic, optical properties.

Depending upon all these properties that we can analyze what type of manufacturing processes we can apply for a particular material if we know all this, if we know their properties also. So, therefore based on these properties the different manufacturing technology has been developed. Advanced materials, the properties is like that magnetic

information storage that is for advanced kind of material, liquid crystal display, LCD, what are the particular property and the fibre optics, all this kind of application we can.

These properties are important in case of the modern application for a kind of advanced materials. Then, the material, semiconductor we can see that silicon, germanium based, tantalum oxide used for the ceramic capacitor, they are used for properties of the semiconductor is in between the conductors and insulators and of course the electrical but most important semiconductor is that electrical properties can be very precisely control.

That is the main purpose of using the semiconductor device. Biomaterial, we can see the different types of the biomaterials, different types of the materials, for example bones and teeth, artificial bones and teeth can be made from hydroxyapatite, that is one type of the ceramic and then artificial organs can be made from the plastic and bone replacement can be from the titanium alloy.

Of course, that is implanted, titanium alloy can also be implanted component in human body, so all this engineering materials basically when we use some as biomaterials so they must follow some kind of the biocompatibility that kind of properties needed for, not all materials fit for the biomaterials. Then, smart materials also available. We can use the smart materials for example in case of kind of sensor; actuator the smart material can be used.

So, the basic properties of the smart material we can look into that how this material behaves, change with respect to temperature or with respect to stress or with respect to humidity or chemical environment in case of smart material. Then, example is a shape memory alloy, piezoelectric ceramics, magnetorheological fluid. So, shape memory alloy is a sense, it has very small change in temperature, it changes the behaviour, so that kind of normal material.

For example, steel or iron that may not behave that kind of shape memory effect in a normal temperature or very small change in the temperature. So, there is the specific properties of the material and that is that type of materials is we normally use in daily life. Piezoelectric, magnetorheological fluid also that fluid properties influenced by the magnetic field. And of course apart from that some certain materials are also developed.

That is called the nanoengineered materials, that means by introducing the nanoparticle, by mixing with the properties of the nanoparticles with the materials the nanoengineering materials are also been developed. So, that is for the high technology application or maybe very specific application or if you want to achieve very specific properties, maybe nanoengineering materials is most applicable there.

But apart from all this development in the properties of the materials and of course and this properties all these materials are important for a manufacturing engineer because if you know the properties of the material then it will be easy to decide what type of manufacturing process can be followed or can be used in a particular component or a particular product but modern materials need looking for the application in that kind of areas.

For example, high performance engine, nuclear waste processing, hypersonic flight making, that communication industry, construction industry. The people are looking for application of this particular area that and for particular material or from the materials point of view, development of the materials is needed to fulfill this kind of demand in this particular area.

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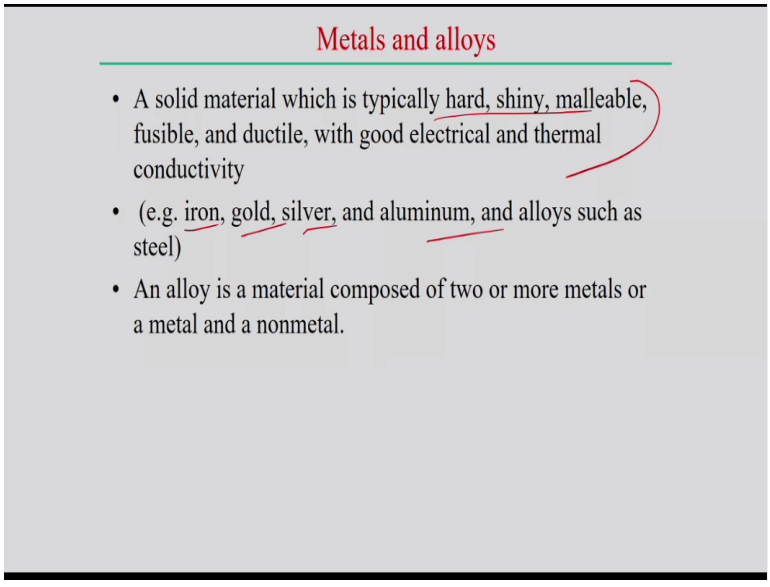

Now, we will try to look into that different metals and alloys that means in overall idea or overall knowledge about the different types of the metals and alloys normally used in engineering application. So, metals and alloys, we can see the metals, definition of the metals is I think not necessary at this level, it is typically hard, shiny, malleable, ductile.

These are the typical properties along with the good electrical and thermal conductivity normally happens on the metals. We know that iron, gold, silver, aluminium and their alloy under these categories of metal alloys and all are having different kind of the properties. For example, normally silver, gold having very high thermal conductivity but iron alloy having the less thermal conductivity. So, different metallic alloy having the different kind of the properties.

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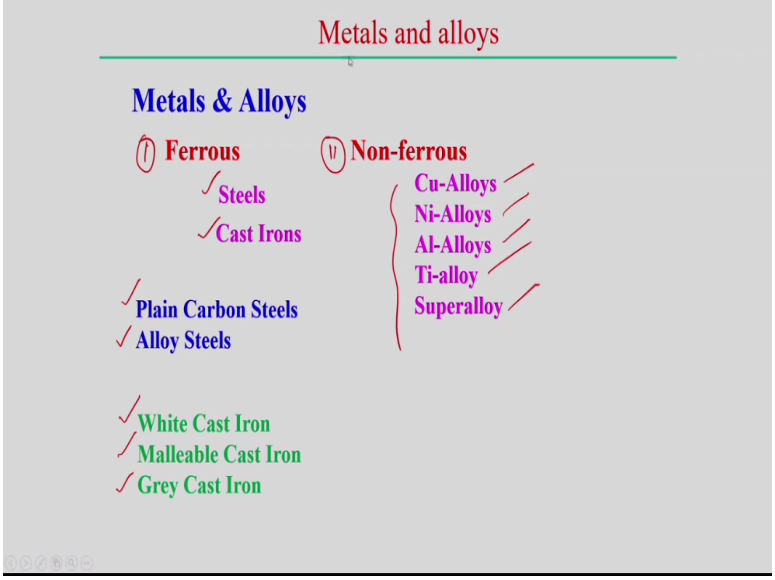

Then, if we categorize the different metals and alloys, we can see these are the engineering materials normally available. First is that metals and alloy we can categorize that ferrous metal two categories, first is the metals and alloys that in general ferrous metals and non-ferrous metals. So, in ferrous metals normally this steels and we can categorize the steels and cast irons and among the steels there are plain carbon steel or alloy steel.

And among the cast iron, these are the white cast iron, malleable cast iron, grey cast iron. These are the typical categorization of the different metals and non-ferrous metals; non-ferrous metals we can use in the engineering mostly copper alloy, nickel alloy, aluminium alloy, titanium and titanium alloy, of course superalloy and maybe some other alloying elements we can use mostly.

But this is the mostly used in engineering or most commonly used engineering materials which is under the category of the non-ferrous. So, difference between the ferrous and non-ferrous, in ferrous metal is the main component is the iron and non-ferrous metal is the iron is

not the main components then it depends on the other components. So based on that, different types of the non-ferrous metals has been developed.

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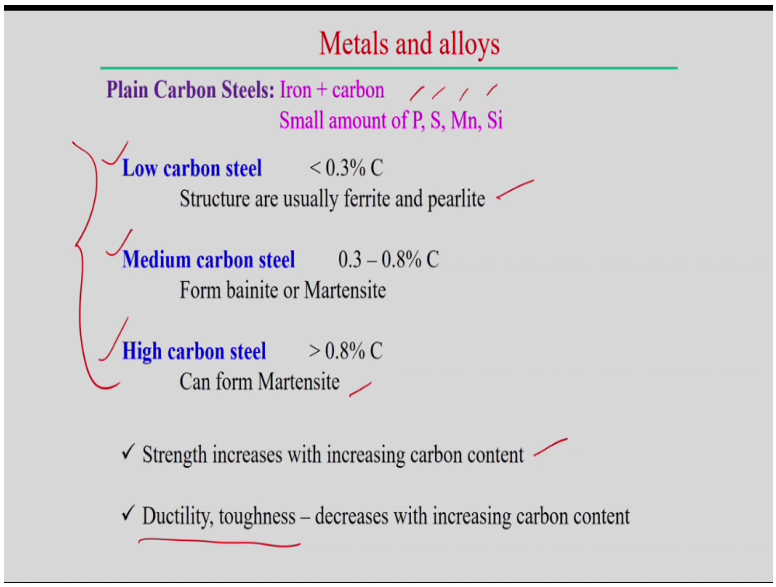

Now, this plain carbon steel may be the components of the plain carbon steel as simple iron+carbon but apart from that small amount of the phosphorus, sulfur, magnesium, manganese and silicon. So, these are the typical components of the plain carbon steel but we can see, we try to look into the overall look into that plain carbon steel can be different, three different.

Low carbon steel is based on the carbon percentage, low carbon steel carbon is less than 0.3% and of course the structure of the low carbon steel are usually ferrite and pearlite and mixture of the ferrite and pearlite in general sense I am talking about. Medium carbon steel, the range of the carbon percentage is around 0.3% to 0.8% carbon and of course the structure is made from the bainite or martensitic structure but there may also exist ferrite and pearlite structure as well also.

High carbon steel normally greater than 0.8% of carbon and it form the martensitic structure also. So, these are the 3 different category of the plain carbon steel but in general the strength actually increases with increasing the carbon content and of course not only the carbon content, what is the form of the carbon existing with the particular material and how it is distributed, the strength depends on that.

But in general it increases with carbon content at the same time the strength increases, the ductility and the toughness actually decreases or we can say that ductility and toughness decreases with increasing the carbon content. This is the general conclusion of the plain carbon steel.

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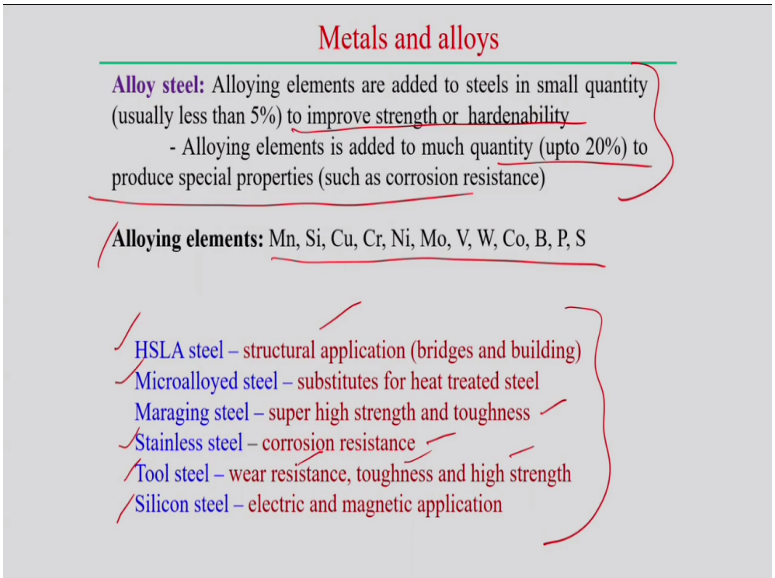

Now alloy steel, alloy steel apart from the not only the carbon is not only alloying elements but apart from carbon there are other alloying elements with small quantity normally added to improve or to get some certain type of the properties, normally the strength and hardenability and sometimes not only the strength and hardenability sometimes to impart particular for example if you want to impart the corrosion resistance, improve the corrosion resistance of a particular steel.

Then, we can add certain alloying elements relatively much quantity up to 20% to produce the special properties for example corrosion resistance. So, that means to impart the certain particular properties we can add a particular alloying element. So, this is the of course there is differential influence of the alloying elements, I am not going into that direction but in general the alloying elements in steel are this.

All these components can be added to impart the, to add particular properties or different properties we can introduce by using the alloying elements but of course all alloying elements having the different influence on that. In general, the alloy steel is the high strength low alloy steel has been developed, it is normally application, we can very structural application, bridge and building, there we can found out this application, the HSLA steel.

Then, microalloyed steel, microalloyed steel it is normally acts as a substitute for the heat treated steel. Then, maraging steel, super high strength and toughness depending upon the what are the different kind of the phases exist and distribution of these phases and particular morphology it creates and based on that it achieves the very high, super strength and toughness the maraging steel.

Stainless steel, of course we know the stainless steel, it is mainly used for corrosion resistance and of course the chromium content is very high normally in stainless steel that actually imparts the kind of corrosion resistance properties in stainless steel, that is the main properties of the stainless steel. Then, tool steel, the particular tool steel has been developed looking into the wear resistance, toughness and the high strength.

Basically, the tool steel is designed in such a way that even at elevated temperature it can retain its hardness, so that is why tool steel has been developed. Then, silicon steel has been developed looking into the electric and magnetic application, so electric and magnetic application is the requirement, there you can utilize the silicon steel.

So, basically by looking into the different requirement and different areas, there is a gradual development of the different types of the steels and accordingly it is applied and these are all under the category of the alloy steel.

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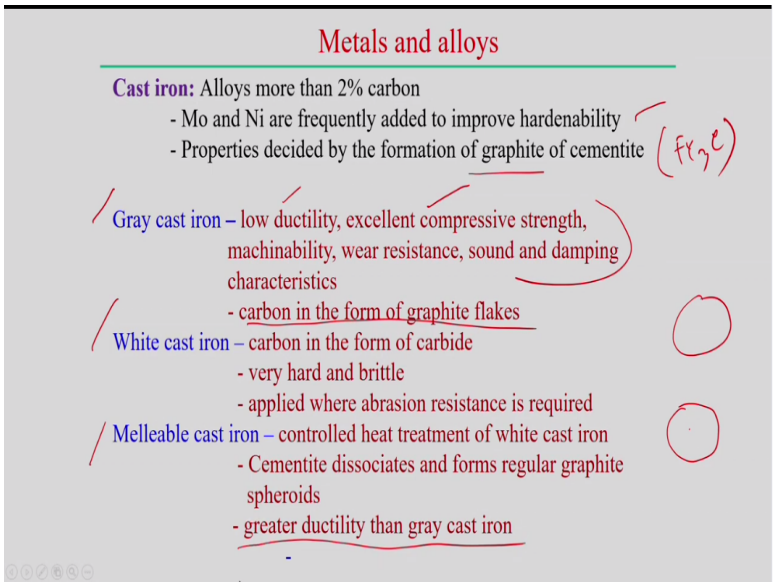

Now, we try to look into the cast iron also. Cast iron normally categorize when the iron along with the more than 2% of the carbon if we look into the iron carbon equilibrium diagram or phase diagram, we can see that more than 2% carbon is added with the iron that is under the category of the cast iron less than 2% it is under the category of the steel. So, apart from the carbon percentage in cast iron, there is molybdenum and nickel can also be added to improve the hardenability.

And of course but the properties depends on the what, the carbon exist within the cast iron, that means either carbon exist in the form of graphite or carbon exist in the form of the cementite, cementite means iron carbide, so properties depends on that. So, cast iron we have seen the category of the cast iron is gray cast iron, white cast iron, malleable cast iron, normally these 3 categories.

And gray cast iron normally in general the cast iron is little bit brittle as compared to the steel but as compared to that gray cast iron having the low ductility, ductility is little less but gray cast iron having excellent compressive strength, good machinability properties, wear resistance properties and most important thing is that sound and damping characterizing capabilities are very good in case of the gray cast iron.

Because if carbon exists in the gray cast iron in the form of the graphite flakes and that graphite flakes usually act as absorbers of the kind of the vibrating load. So, that is why gray cast iron having very good damping properties, of course in case of machinability, the graphite act as a lubricant also. So, it basically makes the ease of machining, so that is why gray cast iron having this kind of properties because of the carbon exists in the form of the graphite flakes.

Then, white cast iron but in white cast iron carbon form exist in the form of the carbide, so Fe3C is actually very hard, so that is why white cast iron is very hard as well as very brittle material. Therefore application where the abrasion-resistant is the more requirement, in that cases we can apply white cast iron. Malleable cast iron, malleable cast iron actually normally produced by through the heat treatment controlled from the white cast iron.

So, such that the cementite Fe3C or carbide cementite is basically decomposed, dissolves and try to form the regular graphite spheroids so that graphite almost spherical shape actually

converts from the iron carbide through the heat treatment process. So, therefore once graphite ferrous exists within the structure we can expect the good ductility as compared to the, even greater ductility even as compared to the gray cast iron. So, these are the 3 different types of the cast iron normally we use.

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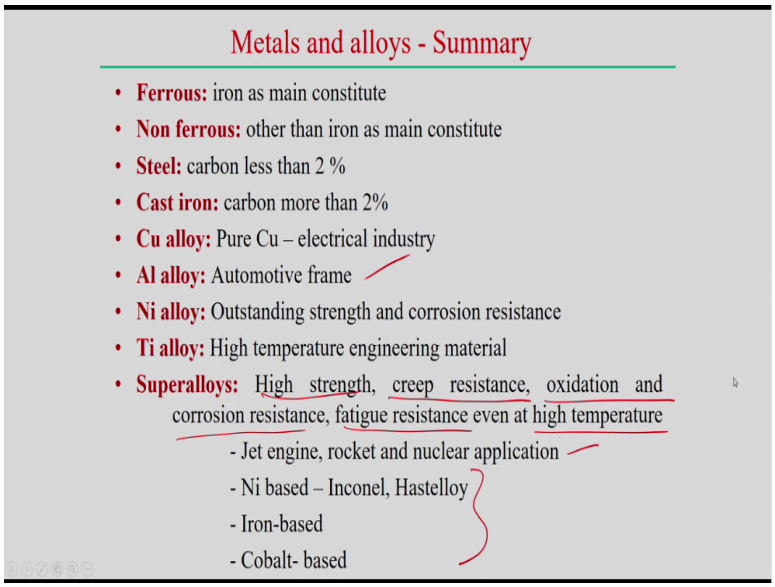

Metal in summary, metal and alloy we can see that ferrous metals we understand that iron is the main component, non-ferrous other than iron as the main constitute for the non-ferrous metals and alloys. Steels, we can categorize as less than 2% carbon. Cast iron, carbon percentage is more than 2% and then there are different non-ferrous alloy also, for example copper.

There are several applications and several types of the alloy elements as possible using the copper and adding with the other alloying elements but pure copper is normally restricted to the application of the electrical industry because thermal conductivity is very good in case of the copper. Aluminium alloy, now the development of the aluminium alloy is all the aluminium is pure aluminium is very soft but aluminium alloy.

The development of the aluminium alloy in such that even that can be used for the engine component also, automobile engine components can be used. So, therefore apart from that automobile automotive frame, the application of the aluminium alloy we can found out. Nickel alloy having the outstanding strength and corrosion resistance properties, so we can find out the application of the nickel alloy, there are several nickel based alloy.

Then, titanium alloy normally we use the high temperature engineering application, therefore titanium alloy is mostly used for the aerospace also, we can found out the application of the titanium alloy because of these property high temperature material. So, therefore all these properties retain even at high temperature. Then, apart from this there are superalloys also developed.

And that superalloy they achieve very good high properties kind of combination of the high strength, creep resistance properties, will discuss the creep resistance, oxidation and corrosion resistance properties also, fatigue resistance even at very high temperature. So, therefore to get the requirement of particular properties for a particular application then superalloy we can find out the applications jet engine, rocket engine, nuclear application.

And of course superalloy can be formed in this way also, nickel based superalloy, one example is the Inconel, Hastealloy, these are the example of the nickel based superalloy. Then, of course superalloy can be formed iron based and superalloy can be formed also cobalt based. So, these are the overall view of the different types of the metals and alloys are normally used on engineering application.

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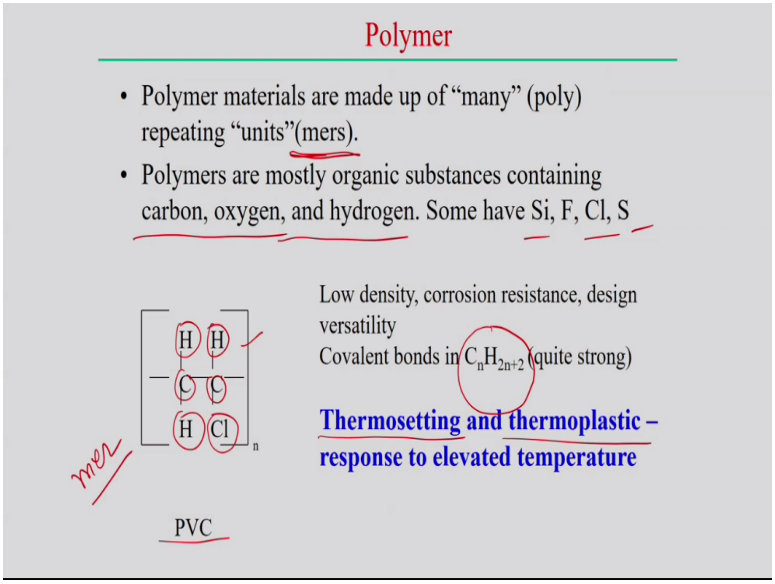

Now, we try to look into the polymer. So, polymer is, polymer material is actually made up of many poly repeating the mers units basically. So, one example, suppose this is one polymeric material, this is the one unit which is called mer, so repetition of the unit to form a long chain kind of things so that this is typical structure but polymers are mostly organic substances and containing the carbon and oxygen merely, carbon, oxygen and hydrogen.

And of course some structure having the silicon, chlorine and sulfur also. So, here you can see the one example is a polymer structure is a PVC polyvinyl chloride. So, this structure is hydrogen making the bonding with the carbon and apart from that there is a one chlorine atom also there, this is the typical but this represents the one this n means so here the one it indicate one mer unit mer.

So, now this mer is added to make a long chain and this is the typical structure of the polymer. The properties of the polymer is low density, corrosion resistance, design, so we can design, we can impart the different types of, we can impart some color and all these things so we can versatility in the design can be followed in case of polymer material but normally if you make organic substances carbon and hydrogen in this form CnH2n+2.

And that normally you can found out the polymer material in this point the covalent bond, the bonding between the carbon and hydrogen but this is a normal structure of the polymer but this can be look into the two parts, one is a thermosetting, one is the thermoplastic polymer. So, then thermosetting and thermoplastic polymer is based on that how it response at the temperature, based on that we can classify this two parts.

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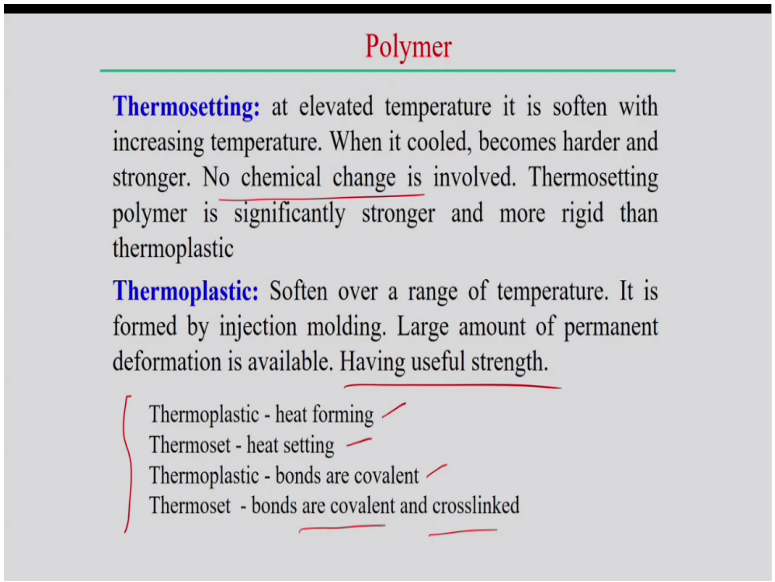

We can look thermosetting is basically at elevated temperature the material it becomes soften and then when it is cooled then we get the desired shape and it becomes more harder and stronger. So, therefore this process involves no change in the chemical composition and

thermosetting polymer is significantly stronger, is more stronger, more rigid as compared to the thermoplastic.

So, therefore thermosetting polymer means, thermosetting means it is set with the desired shape with the application of the temperature but other is thermoplastic polymer is basically a soft over a range of the temperature we can process even for the injection molding and in this cases large amount of the permanent deformation is possible and of course it is having useful strength but strength is less than as compared to the thermosetting polymer.

In general, thermoplastic basically heat forming, we can say that thermoplastic is the heat forming but we get the desired form shape by heating and then thermoset is basically heat setting, heat forming and thermosetting is basically heat by application of the heat we can set the particular shape and size. Then, thermoplastic is the bonds normally are covalent bond.

But thermosetting polymer basically both bonds are covalent as well as the crosslinked bond are there, so since existence of the crosslink bond makes it more harder or more stronger as compared to the thermoplastic material. So, this is the overall structure of this thermosetting and thermoplastic.

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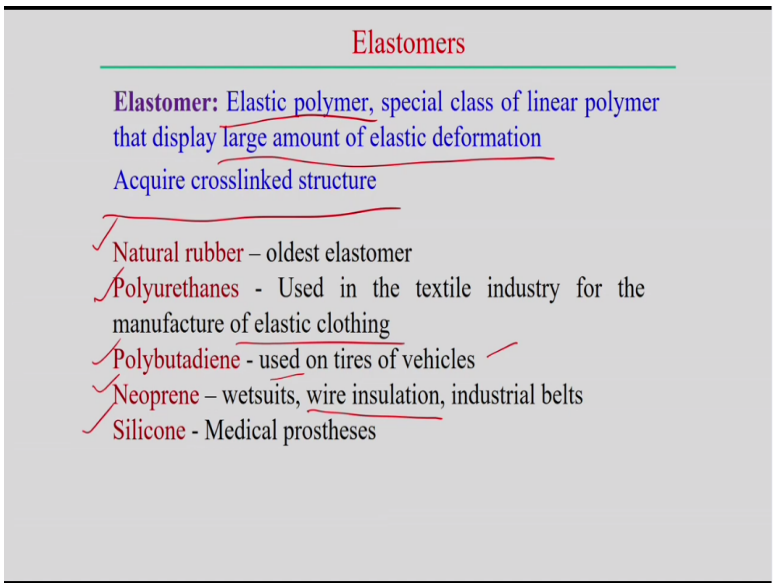

Now elastomers; elastomers is the, basically we can say the elastomer is a kind of polymer, elastic polymer we can say, it is called the elastic polymer and it is a kind of special class of the linear polymer that display the large amount of the elastic deformation, it is associated

with the large amount of the elastic deformation and acquire crosslinked structure. So, elastomer it can achieve the crosslink structure also.

Example of these elastomers is the natural rubber is the oldest elastomer, then polyurethanes then that used in the textile industry and making some kind of manufacture of elastic clothing. Then, polybutadiene used in the tires of vehicles, this kind of elastomer you can use. Neoprene in the wire insulation, basically wire insulation insulating belts, we normally find the application of the neoprene.

And the silicone is the medical prostheses, so all these cases we can use these are the typical application of the different types of the elastomers.

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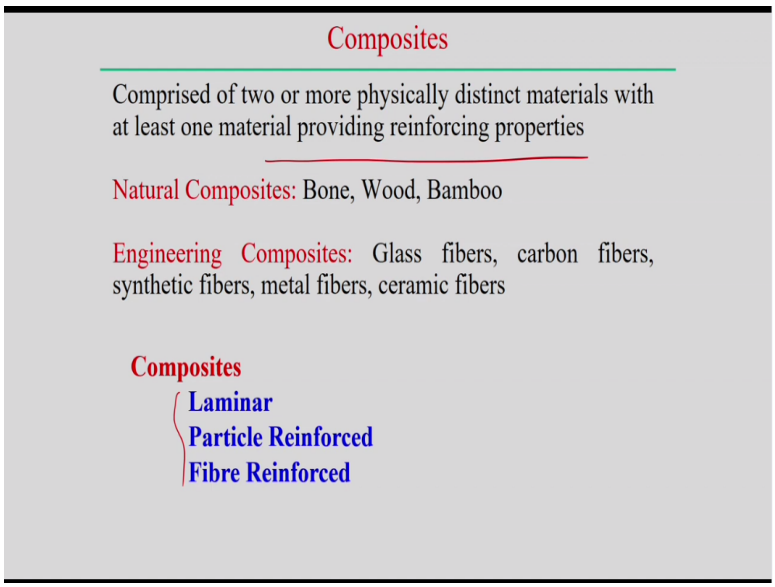

Composites; composites consists of the two or more physically distinct material but with at least one of the material providing the reinforcing properties. So, then natural composites we can say the bone, wood, bamboo these are the natural composites and their vacancy even for the wood also we can find out the fiber and bamboo we can find out the fiber also, that fiber brings the reinforcing properties to the composite material.

Engineering composites; we can create the glass fibers, carbon fibers, synthetic fibers, metal fibers, ceramic fibers that impart this fibers actually impart the strength of the component but this fiber can exists in the form of the continuous way or maybe in form of the discontinuous way. The properties of the composites may be depends on what are the two or more components has been used.

So we can expect some intermediate properties when mixing the two components to form a kind of composite materials. So, these are the 3 basic, laminar, particle reinforced or we can say the fiber reinforced composites.

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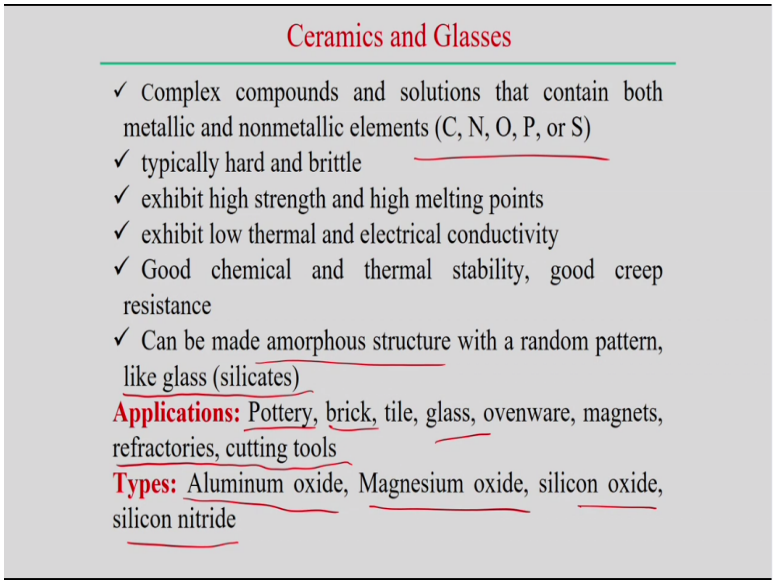

Another kind of the material that is the ceramics and the glasses, so ceramics and the glasses the complex compounds of the solution that contain both the metallic and nonmetallic. We already discussed the ceramics having both metallic and nonmetallic components and nonmetallic that is carbon, nitrogen, basic carbides, nitrides, oxides that and the phosphorus and sulfur. These are apart from the nonmetallic components we can add.

Typically, ceramics are very brittle and hard but of course it exhibits the very high strength, high melting point, characterized by the low thermal conductivity and low electrical conductivity but good chemical and the thermal stability. So, of course the creep resistance is very high and these ceramics can be used at high temperature application also and can be made from the amorphous structure which is not a regular crystal structure we can found out.

But rather we can make the amorphous structure with the random pattern like glass, this kind of structure we can observe in case of the ceramics also that is why glass and ceramics is normally under the same category. Application; pottery, brick, making the brick, tiles, glass, magnets, there also we can find out cutting tools, refractories, here we can find out the lots of application of the ceramics materials.

And what are the types, say aluminium oxide we can say it is a ceramic material, magnesium oxide, silicon oxides, nitrides. There have been basically oxides and nitrides of the different metals. They come under the category; they are called the ceramic materials.

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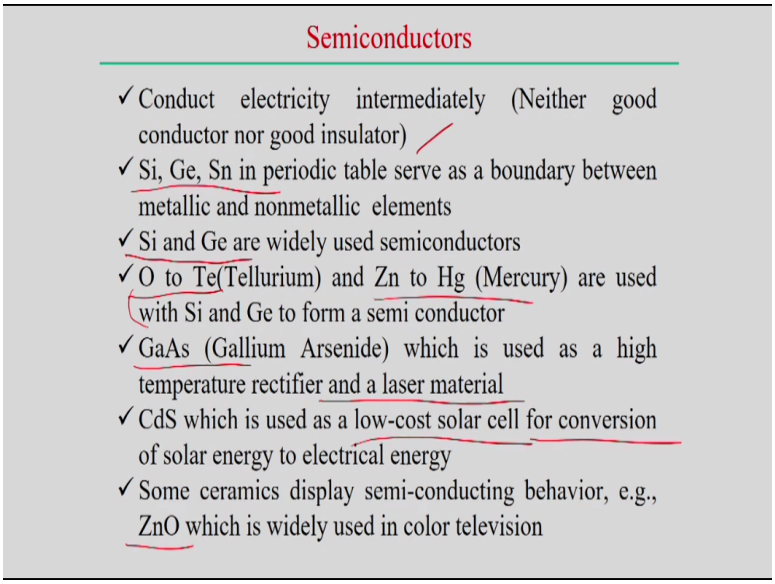

Then, semiconductor is the one type of the interesting properties of the one type of the materials, so semiconductors is basically conduct electricity between the metals and nonmetals, between the metals and insulator, so some intermediate way but in semiconductor the most important that what, the electrical conductivity can be controlled, that is the most important part in the semiconductor.

So, if we look in the periodic table, we can see silicone, germanium and tin in the periodic table serve as the boundary between the metals and nonmetals. So, therefore silicon and germanium can be used, widely used as a semiconductor materials but oxygen, Tellurium Te, zinc to mercury can be used with the silicon and germanium to form a semiconductor. So, these impart to control the electrical conductivity to the semiconductor by adding these types of materials.

And that we choose from the analysis of the periodic table, for example gallium arsenide which is one type of, this is the high temperature rectifier and laser material also. So, to induce the laser radiation so that is a one type of the semiconductor material. Then, cadmium sulfide also low cost solar cell we can use, we can find application of the semiconductor and that particularly used for the conversion of the solar energy into electrical energy.

So, cadmiums are one type of the semiconductor material. So, of course apart from that some ceramic also display the semiconducting behaviour. For example, zinc oxide which is also a kind of semiconductor device but mostly used in case of the color television.