Manufacturing of turbines (gas, steam, hydro and wind)

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Lecture 04

Welcome to this lesson 4 in this course of manufacturing for turbines. In today's lesson we will learn about manufacturing concepts and classification of engineering materials. The outline of the lesson will be as follows. We will start the lesson by developing concepts of manufacturing. Then we will look at concepts of product design and development. Subsequently, we will look classification of engineering materials where we will look at in detail about metal, alloys, plastics, ceramics and composites.

So what is manufacturing? As this course is dealing with manufacturing of turbines, we are going to see in more detail how the specific turbines like gas turbine, steam turbine or hydro turbine or wind turbine are made. So it is very important to look at what is manufacturing. So manufacturing is basically a concept of making products. So manufacturing word first appeared in English in 1567 and it is derived from a Latin word, Manu factus, which means made by hand.

So in manufacturing essentially what is done? So in manufacturing we have a raw material which is converted into a finished product and the finished product in the end is designed in such a way that it meets out the customer's requirement. so in manufacturing what is happening in between while we are converting the raw material into finished product either we are changing the shape of the raw material or what we are doing is we are adding or removing material or in other words we can say or in an economic sense what we are doing we are adding value to this raw material we can understand this concept by a simple example of clay So we can use clay as the raw material to make finished product which can be say an earthen pot. So now the clay initially will have very less value. It does not have any shape or it cannot be used to fulfill any end need. But if we convert this clay into the earthen pot here, so what we are doing is we are maybe changing the shape or we are maybe adding or removing material.

So we are also adding an economic value to this clip. So in a broader sense, we can say manufacturing is all about making products and these products has to fulfill the customer's need. So manufactured product itself may be used to make several other products. Example here is all the fasteners. Like we look around all the nuts bolts and screw they are themselves products and then combination of these products may be used to make several other products.

Technologically manufacturing is application of physical or chemical processes which alter the geometry or properties and or appearance of the starting material. So which makes product and manufacturing may also include assembly of sub products or multiple parts to make the final product. So in manufacturing in technical sense we can say we have a starting material So during the manufacturing process there will be several inputs into the manufacturing process which include machinery, tooling, power and labour. And by giving these inputs to the manufacturing process we convert the starting material into a processed part. And many manufacturing processes, they also generate scrap or waste.

Example, machining. We know in machining, there are chips of the material produced or some manufacturing process may not produce the scrap or waste. In economic sense, we can say we are adding value to the material, start from the starting material and when we reach to the process part, so the value of this material increases. So, we are adding this value and once we sell, once the company sell this process product to the customer, so it also generates profit by selling it according to the needs of the customer. Next we would also like to understand the concept of product design and development.

Because product design and development concepts are very useful and they are fundamental once we are manufacturing any product be it the turbines like we are going to study. So in product design and development it is basically a concept where the need it starts from the market analysis. So we start the need of the product from the market analysis to understand the design requirements for that particular product. And then the design flow starts, which utilizes the sub components like concept of the product, embodiment of the product, and detail of the product before the end goal is to reach the product specification so as any manufacturing industry can use the product specification to develop the final product. So what happens in each of this stage? So in the stage of concept we determine the functional structure of the component or the product.

So because any product is not a product by itself rather it is a combination of several sub products or sub components which are assembled together to function properly. So we may also seek working principles on which the sub components are working and evaluate and select the appropriate concepts which go into the final product design. In the embodiment stage, we look at development of layout, what will be the scale of the product, what will be the form of the product. We model and analyze the sub-assemblies from various aspects, say mechanical aspects, thermal aspects, aerodynamic aspects and so on. We evaluate and select the layouts of different product or sub-product components.

Then in the detailed part, we analyze each components in detail. So this analysis is done from the engineering standpoint as well as the economic standpoint. We optimize the performance and cost of the product by proper selection of material, selection of the manufacturing process. And then we also decide upon the final choice of materials, which will in turn decide the final choice of or the route of manufacturing processes. So by going around this concept of product design, many of the products have been successfully developed and delivered to the customers.

Next, we would also like to understand the concept of engineering materials, their classification because understanding of engineering material is the key for developing any product because selection of engineering material ultimately influences the selection of manufacturing processes as we go forward. So here I start the concept with the example of a water kettle. So we can see water kettle is not a new product. It has been used for several centuries for the same requirement that is heating the water. So earlier this may be made of some ancient materials like shown here.

Then the materials like brass or bronze may be used and the modern kettle we know is electrically operated and it has a heating element inside. But the basic functionality is same, but as new and new materials, new and new technologies kept on developing, the shape, the size, the functionality of this product has changed. So, by understanding this concept with this simple example, we look into how the engineering materials were evolved and how their relative importance kept on changing in different times in the past. We start this from around 10,000 BC which was the Stone Age. On the y-axis we can see the relative importance of materials and on the x-axis we can look at the timeline.

So, in the 10,000 BC when we are in the Stone Age, so at that point of time broadly the engineering materials they were classified and are also classified in the same manner till date. So, we had metals, we had polymers and elastomers, we had composites, we had ceramics and glasses. So, in the 10,000 BC to 5000 BC that is the time between the Stone Age and Bronze Age Very less metals were discovered. So perhaps gold was one of the initial metals which were discovered. In terms of polymers and elastomers, we had wood skin from various animals, fibers from various plants and animals.

And we know that this combination of wood, skin and fibers were used for making the clothing or maybe some tools etc. Then we had composites in form of straw and brick which was initially developed and this was widely used to make houses or settlements. And in terms of ceramics and glass, we had stone, flint and pottery, the initial ceramics which were discovered and we know they were used to make some vessels, tools for hunting and so on. So, next we entered the Iron Age. In the Iron Age, as the name itself is suggesting, so after the Bronze Age, the copper and bronze were also discovered and in the Iron Age, the iron was also discovered.

And here what we can observe that the relative importance of metals starts increasing at the expense of the relative importance of other polymers and elastomers as no significant polymer or elastomer were developed or invented here. Paper was also invented in this era around 5000 BC to 0 AD and glass was also invented. Next, as more and more metals were discovered like cast iron was developed in 1500 to 1800 AD and then here more refractory and cement were developed in terms of ceramics and glasses and some glues were also developed in polymer and elastomer classification. Then we entered the age of steel in the 1900s. So, this time was around the industrial age where more steel and emphasis was more on ferrous based materials like cast iron and steel.

And we can see the relative importance of metals it drastically increased compared to the previous times. Rubber was also invented during this time and more refractory ceramics were also developed. So then after the 1900s, so there was a lot of development in terms of new metals, which included light alloys, super alloys, titanium and zirconium based alloys. Essentially, this development was attributed to the World War I and World War II, where a lot of technological development is driven by the war effort. And of course, during this time, not only metals but several new polymers like bakelite, nylon, polyethylene, etc. were also developed.

And in terms of development in ceramics and glasses, new types of fused silica, cements, pyroceramics were also developed. At the end of the World War I and II, we entered the age of polymers. And during this age, not only newer polymers in terms of epoxies, polyesters, high modulus polymers, but also in case of metals, glassy metals, aluminum, lithium alloys, dual-phase steels, microalloy steels, newer superalloys were developed. And these also contributed to a larger extent in the race for the space, that is the space age when there was a lot of focus on sending the missions to moon or maybe the solar system, other planets in the solar system. And during this stage, you will also observe that there were several composites made up of glass fiber, carbon fiber, Kevlar were also developed as these materials were largely used in spacecrafts where we wanted to minimize the weight.

And of course, in terms of ceramics, tough engineered ceramics like aluminum oxide, silicon nitride, etc. were also developed. And moving on from the silicon age, we come to the age of molecular engineering where newer metals will keep on developing, which mostly improve the quality and control and processing. High temperature polymers are developed, ceramic based composites are developed a nd newer types of ceramics are further developed like high entropy ceramics, etc. So we can see the engineering materials have been keep on evolving starting from 10,000 BC or media to now.

And they will keep on evolving in the future as well, depending on what are the needs of the products, what are the needs of the products in the society. This is a continuously evolving topic and looking at forward in this we can say that classification of engineering materials is still based on the basic classification of metals, plastics, ceramics and composites. In next few slides we will just understand the basics of each of them because the understanding of basics of each of them helps to select the appropriate material by knowing what properties each of them exhibit and then how those properties can be used in any specific engineering application. So, in terms of metals, we know metals are further classified based either they are ferrous metals or non-ferrous metals. So, ferrous metals are basically iron based metals where iron is dominant in composition.

So, all these cast irons, steels, stainless steel, spool steel, die steel, etc. They come in this category of ferrous based metals. Non-ferrous-based metals include aluminum, copper, titanium, tungsten and many others. In terms of plastics, they are classified as thermoplastics, thermosets and elastomers. So, in thermoplastics, all these examples like acrylics, ABS, nylon, are included.

In thermosets, epoxies, phenolics, polyamides are included. Elastomers include rubbers, silicone, and polyurethane. And ceramics, we know all oxides, nitrites, carbides, glasses, pipe, diamond, they come in the category of ceramics. and composites basically they are multi-based materials. They are made from either combining the materials previously discussed and composites are broadly classified based on what is the matrix in them.

They can be polymer matrix composites abbreviated as PMC. It can be metal matrix composite abbreviated as MNC or it can be ceramic matrix composite abbreviated as CMCs. So, to make any product we know that broadly we have this menu of engineering materials which includes either metals, polymers, elastomers, glass or ceramics or they can be hybrids. So, either of the material will be selected to make any product and we will see in this course how specific examples of gas turbine, steam turbine, hydro turbine or wind turbine, they pick the appropriate and you will understand why that material is chosen for the particular application and then how the selection of the material decides the future course of manufacturing processes for that particular product. So, we will see some highlights about various properties and basic structure of different materials.

We start with metals. So, metals we know is any material when freshly prepared or polished it shows a lustrous appearance and it is a good conductor of heat and electricity. Metals typically they are malleable means they can be hammered into sheets or they are ductile that means they can be drawn into wires. And metal may be a chemical element like iron or it can be any alloy like stainless steel. So if you look in the periodic table, so most of the elements that come in the category of metals. Metals, they also have some distinguishing features.

Metals, they consist of atoms that are arranged in a regular repeating structure. So they have a periodic arrangement of atoms. They have relatively good strength. They have high densities. They are malleable and ductile, which means they exhibit high plasticity. They are resilient to fracture. It means they can absorb a lot of energy, so this means they are tough. They are excellent conductors of heat and electricity because of the free electrons. They are opaque to visible light. They have a shiny appearance. Of course, this is when they are freshly cut or polished.

They have inclination towards forming cations through electron loss. This means they react with oxygen to form oxides. And most of the metals, they can also be recycled easily. So metals they find application in all such products like electrical riding, structures of solar buildings, garages, chassis of automobiles, springs, etc, airplane components, engine components, fuselage, landing gear, etc, trains, machine tools, etc. So, ferrous and non-ferrous, we have already discussed.

So, in ferrous, we have appreciable content of iron. They are often magnetic. In non-ferrous, they have very less or no iron content, and they are often non-magnetic. Then there is a special class of metals and alloys, which are known as refractory metals and alloys. So, how they are different than metals? So, in refractory metals and alloys, they are extraordinarily resistant to heat and wear.

So, wear here is basically a phenomenon of gradual loss of material and two parts are in relative motion to each other. Refractory materials, they are also having high melting points of the order of 2000 degree centigrade. So, they also exhibit high hardness at room temperature. So, examples of refractory metals include niobium, molybdenum, tantalum, tungsten and lithium. Then we have alloys, here particularly we are talking about metallic based alloys.

So alloy is a substance which has metallic properties and it is composed of two or more metals. Of course, one of the elements has to be metal, other may be non-metal in some cases. Alloy may have a fixed or a variable composition. For example, in gold and silver, to form an alloy, the proportion of gold and silver may be adjusted freely.

This is because their atomic radius is very near. Or in some cases, like titanium and silicon-based alloys, so here the ratio is fixed because only in that particular ratio the alloy is formed. And in other cases, the alloy will not be formed. So, the aim of making any alloy is generally to improve the properties compared to the pure metals, properties like making them less brittle, making them harder, making them resistant to corrosion or having a more desirable color and texture. So in ideal scenarios where we want to look at the use of alloys, so they are used in scenarios where we need to have high strength to weight ratio, especially in case of aerospace and automobile. Examples of alloy include steel, which is an alloy of iron and carbon, or bronze, which is an alloy of copper and tin.

Then we have special alloys known as super alloys where we can add 10 or more elements mixed together. These are especially useful in manufacturing of gas turbines. We will see the details of super alloys in the next module. Examples include Inconel based alloys like 718 is one of the alloys series, super alloys series of Inconel.

Next are plastics or polymer. So, plastics and polymers, they are synonymous with respect to large molecules. And these molecules are formed by repeating structural units known as MERS. And atomic, these atoms in the polymers, they share electrons with very large molecules. Molecules are formed by sharing electrons by covalent bonds under heat, pressure, or catalyst. And polymers, they are usually consisting of carbon plus one or more elements like hydrogen, nitrogen.

So here we can see the repeating units in the Nylon-66, which is a very popular polymer. Polymerization reaction in plastics, it develops the monomer linked into large molecules. And polymerization reaction can be of two types. It can be a condensation polymer reaction where small molecules like water, etc., they condense on. Or it can be an addition polymerization reaction where bonding is without reacting products and we have a faster reaction rates. So, in polymers, there are covalent bonds between muds and sometimes there may also be secondary bonds in form of van der Waals bonds or hydrogen or ionic bonds in the polymer chains. So, distinguishing features of polymers or plastics include they are very resistant to corrosion or chemicals. They have low electrical and thermal conductivity given their covalent bonds and covalent bonds means there are all electrons are shared.

They have low density. They have high strength to weight ratio and especially reinforced. They are useful in noise reduction. They are available in wide choice of colors and transparencies. With plastics, of course, we can manufacture several complex products at relatively low cost. So thermoplastics are basically the polymers which can be molded into desired shape upon applying heat and pressure. Thermosets are basically long-chain polymers where we develop crosslinks, a three-dimensional network of bonds. So, in thermoplastics, all the molecules can move easily upon application of forces, but in thermosets, once their crosswinds are formed, so heat and pressure cannot change the position or shape of the molecules. So, in case of thermoplastic, the temperature goes beyond the glass transition temperature. So, they convert into glassy state.

But in case of thermosets, they often char or burn. So, thermoplastics can be compared to ice creams, which we can understand they can be melted and frozen again. Whereas thermosets are like equivalent to baking a cake. Once it is done, so we can eat it again. So, here we can see the difference between the bonding in case of thermoplastics. So, the atoms are, the molecules, non-chain polymer molecules are loosely bonded in case of thermosets.

The non-chain polymer bonds are interconnected by the cross-stems which are developed because of the, it can not be, they won't do it upon that. So, here are the examples of all the polymers which are there in the second example. Next category of plastics, they come in the category of elastomers. So, elastomers are basically elastic polymers, means they have large strain upon application of small forces.

So, these are amorphous materials with low transition temperature. These materials, they exhibit large strain. Therefore, they are able to undergo large elastic deformation without capture. So, elastic deformation here basically means that upon the removal of load, so they may regain the original shape. Given this unique property, they have this ability to absorb shock loading. They are often soft and have low elastic modulus and their structure is highly kinked because of which they are able to regain the shape quickly upon removal of external load.

So, examples of elastomers include rubber which are used in tires, seals and couplings. Synthetic rubber again used for shock absorbers, beds. seals, gaskets and other solutions. Here we can see a typical load elongation curve for rubber where the area under the curve is known as the series loss which is the capacity to dissipate energy or damp vibration in shock loading conditions. So with this we wind up the lecture for today and I will now summarize what we have covered.

We have covered the concepts of manufacturing, what is manufacturing, we have looked at manufacturing both from economic sense and technical sense. We have looked at concepts of product design and development. We have looked at the classification of engineering materials. in which specifically we have looked in detail about metals and polymers.

The next set of engineering materials we will cover in the next lecture. In the next lecture, we will cover the remaining engineering materials which will be on ceramics. After that, we will come to detailed discussion about the manufacturing processes in general, which we will move to the specific products which are in this course, that is the gas turbine, starting with the gas turbine.

Thank you.