

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

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Lecture 01

Welcome to this lesson 1 in the course of manufacturing of turbines. So, this lesson is titled Introduction to Turbines. So, in this lesson we will look at various aspects of turbines, what are turbines, then what are different types of turbines, then we will look at the historical perspective of turbines, what are the applications of turbines and we will wind up the chapter by looking at importance of turbines. Turbines are a very versatile piece of equipment in energy generation sector which utilize the flow of a working fluid to extract energy from the working fluid and convert it into useful work. So, in any turbine what is there? So, there are series of blades are mounted on a rotor disc and this rotor disc is then mounted on a shaft through which we can extract useful oil. So, in summary what happens here that we have a working fluid has some energy in some form say potential energy.

Now what happens in turbine this potential or kinetic energy in the working fluid gets converted into useful work. Consequently this useful work is mostly used for generation of electrical power. We can say that a turbine, it is a, we can say this term Energy conversion device where potential/kinetic energy of the working fluid gets converted into useful one. How this happens? This happens because in the turbine we have series of blades and the series of blades are mounted on a rotor disc which are mounted on a shaft and consequently the shaft rotates.

So, for mostly energy generation sectors we have this combination of a turbo generator which is nothing but a turbine is which converts useful work into electrical power. So, characteristic feature of these turbines is that we have a fluid or a working fluid or a gas. We have set of blades on the rotor and these are connected to a shaft which is capable of performing this work. So, now the different type of turbines are available in these days. Primarily these turbines differ in use of the working fluid.

So, with the help of different working fluids, we can have different type of turbines. So, here we can see a typical steam turbine where we can see these series of blades arranged in different positions on the work shaft and this is the shaft here. So, these turbines, especially steam turbines, they are quite large and you can see the size even big, they are bigger than the human being. Based on the type of button fluid, the turbines which are

popularly used to generate electrical power. These are the gas turbine, then we have the steam turbine, then we have the hydro turbine and lastly we have the wind turbine.

So, we will now look at the classification of these turbines based on several parameters. What parameters make them different because it is important to understand how these parameters they influence the working conditions of the turbine and subsequently the working conditions of the turbines are mapped to what materials go into manufacturing of these turbines. And once the materials are mapped, the selection of the appropriate manufacturing process has to be done in order to manufacture these turbines. So, if we look at the first parameter, which is the energy source, we can also say that this parameter is a working fluid there. So, for example, in gas turbine, the working fluid are hot gases.

So, these hot gases are produced by combustion because we know that gas turbines they function on Brayton cycle and these hot gases are then allowed to pass over turbine blades and these hot gases then basically react with the blades and they basically provide a pulse to rotate the blades with the help of a tangential force And because there are hot gases involved, so operating temperature range of the gas turbine is of the order of 1100 to 1300. So, this operating temperature range is a very important parameter because we have to look at this parameter carefully because this parameter will decide the material of the turbine, what material the gas turbine or maybe the steam turbine will be made up of so that it can appropriately function at this temperature range.

Then we look at the density of the energy source or the working fluid as hot gases are involved in functioning of the gas turbine, so their density is of the order of 0.8 to 0.9 kilogram per meter cube. And gas turbines are generally of a relatively medium size, but high energy density because they spin at very high RPMs. So, they may be spinning of RPMs of the order of 15,000 to 25,000. So, very high RPMs are there in gas turbine, so their energy density like energy produced per unit weight of the gas turbine is built by. Now, because of these operating conditions of high temperature, there are specific challenges which are there in operating of the gas turbine which involve oxidation, then they also involve creep, they also involve fatigue.

So, we have to also look at these challenges because once we are selecting the material for the gas turbine blades, we have to look at that the material is suitable and it does not malfunction under these challenges of oxidation because there is high temperature, there are ambient gases. Creep is basically deformation of materials under high temperature and constant stress. Then fatigue as we know is basically failure of materials under cyclic stresses which can be alternating between tension and compression. Then we look at the second type of turbine which are popularly used in energy generation which are the steam turbines. So, steam turbines as we know they function on the Rankine cycle.

So, steam turbines are very popular with thermal based heat sources primarily the fossil fuel based, coal based plants are there. Then steam turbines are also popular in nuclear power plants where heat is presently generated from nuclear fission where a larger molecule of uranium is broken down into smaller molecules. So, then in the steam turbine, the working fluid here is the steam. So, the name is steam turbine and this is not only steam, but this is steam which is superheated or it can be ultra superheated. So, since the steam is superheated or ultra superheated, the operating temperature range of the steam turbine, it comes in the range of 600 degree to 700 degree Celsius.

So, the density of the working fluid that is the superheated or ultra superheated steam, it becomes 1.2 to 1.3 kilogram per meter cube. So these are also medium to large turbines, but mostly medium turbines are used in energy generation sector. And because of these specific working conditions, the working fluid, so these turbines also experience cavitation or sometimes erosion or maybe high temperature corrosion may be there.

So, material selection has to be done for the steam turbine in order to overcome these specific set of challenges in the operation of the steam turbine. Next is the hydro turbine. So, hydro turbine as the name is indicating it utilizes water as the working fluid. So, hydro turbines are very popular especially when we have a perennial river system in which we have sufficient quantity of water all around the area. So, in India, all the rivers which are originating from the Himalayan mountains, so they offer this capability to have several hydropower plants and we have several hydropower plants in the mountainous states of the country.

So, the operating temperature range in case of hydro turbine is 15 to 25 degree centigrade. Because water is available at this temperature range in the universe. So, generally in this temperature range the turbines are operating. Now, here you will see that the density of the working fluid is significantly higher than what density was available in gas turbine and in steam turbine. So, here density of water as you know theoretical density of water is approximately 1000 kilogram per meter cube.

And to handle a working fluid which is so dense, the turbines are very large and these are extremely large turbines which are installed in the hydropower plants. Now, these turbines, they also experience several challenges like oxidation is absent here, but they experience cavitation, they experience slurry erosion. Slurry erosion is a very pertinent challenge in hydro turbines because of the high sediment load in the rivers, especially during rainy season. So, we have to look at materials of the turbine which can overcome these specific set of challenges and the turbine may be able to function properly. Then we have the wind turbine.

So, wind turbine are basically a renewable source. They extract energy from a renewable source that is wind and wind turbines they are installed in locations where the wind is

available at a constant velocity. So the operating temperature range of wind turbine is 20 degree to 40 degree centigrade. So as wind is used as the, or air is used as the working fluid, so density is one kilogram per meter cube. So wind turbines are also very large.

So they may be up to say 180 meter to 200 meter in diameter. And they are made so large because we want to have every possibility of extracting energy from the flowing wind when the wind passes over the airfoil shape of the turbine blades. But the wind turbines, they also experience several environmental effects. from the rain or maybe the environment in which they are installed like offshore environment or maybe the sunlight because the materials which go into making these wind turbines, they have to be light in weight, high strength. So, these materials, they offer these capabilities, but they also have this specific set of operating channels.

Next, we look at the historical perspective of turbines. So, turbines as old as water wheels in ancient civilizations and windmills which are used for grinding grains were used as turbines since ancient times. So, all these development took place in the ancient times and then we had in the Alexandria's time some developments. But significant developments in the history of turbines took place with the development of steam engine by James Watt in late 18th century. So, in the 19th century Parsons and Dalhousie steam turbines were developed and in the mid 20th century jet engine developed and modern turbines they operate with high efficiency and many of the turbines are also functioning on renewable sources like wind.

So, if you look at the development of turbines from early developments to modern innovations, so in the initial times, say in the 5000 BC, wind was used to propel boats along the Nile River. Subsequently, wind power pumps were developed in China and Middle East for grinding grains. Then in the 12th century, vertical windmills were used in several parts of Europe to grind the flour. Then we had development of several wind and pump companies in US and windmills were developed in 1850s and subsequently the commercial wind farms were established in 1980s and subsequently we can see that first offshore wind turbine was installed in 1991. And offshore wind turbine became operational in the largest wind farm in 2003.

And then across United Kingdom, there were more than 2000 wind farms which were operating. So then in the year 2012, several developments took place and high power wind turbines were also developed there. And then there was the US grid connected offshore turbines were developed and then largely we can see that more and more developments have taken place especially in the case of wind because it is a renewable source of energy. So, now we look at what are the applications of turbine. So, in the application of turbine, so we have steam turbines which are predominantly used with thermal power sources like coal, nuclear, solar and which are used to generate electricity.

Steam is produced by boiling water. So, this boiling water may be produced by generating heat by combusting fossil fuels or maybe the nuclear reaction fission reaction. Second type of turbines are the gas turbine which are used in natural gas power plants in combined cycle power plants, where the combustion of natural gas it produces high pressure gas that drives the turbine.

So, here we can see a cut section of the steam turbine where we can see the high pressure section and the low pressure section in the steam turbine. Next, we look at other applications of turbine. So, turbines are not only used in energy generation, but they are also used in aviation sector. For example, the aircraft engine where they are used to generate power which can propel the aircrafts. So, here we have the combination of compressor and a combustor which are fixed ahead of the turbine and based on the Brayton cycle they operate.

And in case of hydroelectric the water is used as we have discussed in the dams to generate electricity. And hydroelectric turbines they provide the mechanism as water can flow over the turbine and it can generate sufficient electricity. So, as we know in case of turbines there may be impulse turbine or there may be reaction turbine. So, depending on the design of the turbine appropriate mechanism may be used. And then wind turbine as we have already talked about this.

So, wind turbine they convert the wind's kinetic energy into the mechanical energy by use of rotor blades and these rotor blades are made up of high strength lightweight materials and the rotational energy of these blades is then transformed into electrical energy by using a generator which is available in the nacelle of the interval. So, along with the generator, there is also a gearbox to adjust speed and there may be control systems to optimize the performance of the wind turbine as the wind condition, direction, speed is constantly changing. So, this optimization has to be done using control systems which control the angle of attack, pitch of the blades so the optimal generation of energy can take place. Next, we would like to look at what is the importance of turbine. So, importance of turbines include the high conversion efficiency that they should be very efficient in converting the useful work into electricity.

So, turbine should maximize the conversion of fluid energy or gas energy into mechanical work or electrical power. The high efficiency will enable to reduce energy costs and improve the productivity in manufacturing. Secondly, the turbines, they also help in cleaner energy production. They help to reduce the carbon footprint, for example, the wind turbine, hydro turbine. Turbines, especially using renewable sources, they also have lower greenhouse gas emissions.

They also support global efforts to combat climate change and meet environmental regulations. They are also useful in facilitating cleaner energy sources for several

manufacturing operations. So, in terms of the versatility of turbines for various sectors, so turbines are not only used in power generation, they are also used in marine and aviation sector. They are also used in industrial applications where we have seen they used to drive the industrial machinery like compressors, pumps, generators, they maintain high productivity and efficiency.

Here we can see a photograph of a Rolls Royce marine gas turbine, which is shown here. So, here we can see the entrance section, the compressor section, the fans are there, then we have the compressor, then we have the combustor and lastly we have the turbine section here. So, if we want to summarize the lecture what we have learned today. So, we would like to see that we have firstly looked at what are turbines, then we have we have looked at the different types of turbines. So, in this we have looked the classification of turbine based on the working fluid. For example, we have seen the gas turbines, their operating conditions, steam turbines, then we have looked at hydro turbines.

Then lastly, we have looked at wind turbine. Then we have looked at historical perspective, history of turbines here. Then we have looked at the applications of turbines where we assume they are used in generation of electrical power. We have seen their application in aviation. We have seen application in industrial processes to run compressors or pumps. And lastly, we have looked at the importance of turbines.

We have looked at how they help to minimize greenhouse gases. They help in minimizing the carbon footprint, especially the turbines, which are using renewable sources of energy like wind and power, and how high-efficient turbines are needed will be realizing energy needs and so on. So, all these aspects have been summarized in this lesson 1. And with this we conclude the first lesson and just this is the summary of the next lecture what we are going to cover. So, in the next lecture we will be covering the need of turbine by understanding the role of turbine in modern energy systems by looking at efficient energy conversion, renewable energy integration, addressing the rising energy needs, environmental advantages, the adversatility, technological advantages, economic contribution in future prospects.

So, with this we wind up the lesson one of this course.

Thank you.