Design,Analysis And Manufacturing Of A Gas Turbine Blade

M. Rajesh
Assistant Professor
Dept. Of Mechanical Engineering
Swami Vivekananda Institute Of Technology,Sec-Bad, Telangana, India.

M Rama Krishna
Assistant Professor
Dept. Of Mechanical Engineering
Swami Vivekananda Institute Of Technology,Sec-Bad, Telangana, India.

Abstract –

The design and analysis of Gas turbine blade, CATIA is used for design of solid model and ANSYS. How the program makes effective use of the ANALYSIS preprocessor to mesh complex turbine blade geometries and apply boundary conditions. we presented how Designing of a turbine blade is done in CATIA with the help of co-ordinate generated on CMM. And to demonstrate the pre-processing capabilities, static and dynamic stress analyses results, The principal aim of this project is to get the natural frequencies and mode shape of the turbine blade

Keywords: CATIA, CMM, pre-processing capabilities, dynamic stress analyses results.

1.1 Introduction

The word turbine was coined in 1828 by Claude Burdin (1788-1873) to describe the subject of an 1826 engineering competition for a water power source. It comes from Latin turbo, turbinis, meaning a "whirling" or a "vortex," and by extension a child's top or a spindle. Defining a turbine as a rotating machine for deriving power from water is not quite exact. The precise definition is a machine in which the water moves relatively to the surfaces of the machine, as distinguished from machines in which such motion is secondary, as with a cylinder and piston. The common overshot water wheel is a rotating machine, but not a turbine, while an undershot wheel is an impulse turbine, but not generally considered as one. We shall discuss many types of water-driven prime movers in this article, but mainly turbines, for which we will explain the fundamental theory. We shall also discuss steam turbines and gas turbines and their applications. Wind turbines are treated in another article.

Water in nature is a useful source of energy. It comes directly in mechanical form, without the losses involved in heat engines and fuel cells, and no fuels are necessary. Solar heat evaporates water, mostly from the oceans, where it is mixed into the lower atmosphere by turbulence, and moved by the winds. Through meteorological processes, it falls on the earth as precipitation, on the oceans, but also on high ground, where it makes its way downhill to the sea, with evaporative and other losses. A cubic metre of water can give 9800 J of mechanical energy for every metre it descends, and a flow of a cubic metre per second in a fall of 1 m can provide 9800 W, or 13 hp. The efficiency of hydraulic machines can be made close to 1, so that all this energy is available, and it can be converted to electrical energy with an efficiency of over 95%.

The disadvantage of energy from water is that it is strictly limited, and widely distributed in small amounts that are difficult to exploit. Only where a lot of water is gathered in a large river, or where descent is rapid, is it possible to take economic advantage. Most of these possibilities are quite small, as are the hydropower sites along the Fall Line on the Atlantic coast of the United States, or on the slopes of the Pennines in England. These were developed in the early days of the Industrial Revolution, but are now abandoned because their scale is not the scale of modern industry. Each site provided a strictly limited horsepower, and in the autumns the water often failed. For expansion and reliability, all were rapidly replaced by steam engines fueled by coal, which were expandable and reliable. Today, hydropower usually means a large project on a major river, with extensive environmental damage. The fall in head is provided by a dam, which creates a lake that will be of limited life, since geological processes hate lakes and destroy them as rapidly as possible.

Niagara Falls is an excellent example of a hydropower site. It is unique; there is only one, and hardly anything else similar. The Niagara River carries the entire discharge of the Great Lakes, about 5520 m3/s, and the concentrated elevation difference is about 50 m. The visible falls carry nothing like this much water today; most is used for power. Hydropower could destroy the falls as a sublime view; we are lucky it has not. The power available from this discharge and drop is 3.6 x 106 hp. The figures given in the encyclopedia for the power available from the Canadian and U.S. power projects on each side add up to considerably more than this. Perhaps they use more drop, or perhaps they are just optimistic. The first large-scale hydropower development here was in 1896. This was also the site of Nikola Tesla's two-phase plant that pioneered polyphase power in the U.S.

For comparison, the more than 190 million registered motor vehicles in the U.S. probably have an aggregate power capability of neary 2 x 1010 hp, equivalent to 5000 Niagaras. Hydropower and increasing population cannot coexist; the limits of hydropower are fixed and obvious. It is really too bad that small-scale hydropower projects are no longer economically viable. In 1920, about 40% of electric power in the U.S. came from hydropower; in 1989 that percentage had dropped to 9.5%. It was not that hydropower had decreased in absolute terms, but had remained roughly constant while the total market had expanded greatly.

1.2 History

The first device that may be classified as a reaction steam turbine was little more than a toy, the classic Aeolipile, described in the 1st century by Greek mathematician Hero of Alexandria in Roman Egypt. In 1551, Taqi al-Din in Ottoman Egyptdescribed a steam turbine with the practical application of rotating a spit. Steam turbines were also described by the ItalianGiovanni Branca (1629) and John Wilkins in England (1648). The devices described by Taqi al-Din and Wilkins are today known as steam jacks.

The modern steam turbine was invented in 1884 by Sir Charles Parsons, whose first model was connected to a dynamo that generated 7.5 kW (10 hp) of electricity. The invention of Parsons' steam turbine made cheap and plentiful electricity possible and revolutionized marine transport and naval warfare. Parsons' design was a reaction type. His patent was licensed and the turbine

scaled-up shortly after by an American, George Westinghouse. The Parsons turbine also turned out to be easy to scale up. Parsons had the satisfaction of seeing his invention adopted for all major world power stations, and the size of generators had increased from his first 7.5 kW set up to units of 50,000 kW capacity. Within Parson's lifetime, the generating capacity of a ur
by about 10,000 timesand
from turbo-generators cor
firm C. A. Parsons and
their licensees, for land pur
exceeded thirty million hors

A number of other variat
have been developed that
with steam. The de Laval
by Gustaf de Laval) acceler
full speed before running it
blade. De Laval's impulse turbine is simpler, less expensive and does not need to be pressure-proof. It can operate with any pressure of steam, but is considerably less efficient. fr:Auguste Rateau developed a pressure compounded impulse turbine using the de Laval principle as early as 1896, obtained a US patent in 1903, and applied the turbine to a French torpedo boat in 1904. He taught at the École des mines de Saint-Étienne for a decade until 1897, and later founded a successful company that was incorporated into the Alstom firm after his death. One of the founders of the modern theory of steam and gas turbines was Aurel Stodola, a Slovak physicist and engineer and professor at the Swiss Polytechnical Institute (now ETH) in Zurich. His work Die Dampfturbinen und ihre Aussichten als Wärmekraftmaschinen (English: The Steam Turbine and its prospective use as a Mechanical Engine) was published in Berlin in 1903. A further book Dampf und Gas-Turbinen (English: Steam and Gas Turbines) was published in 1922.

1.3 Defination of turbine

A turbine is a rotary engine that extracts energy from a fluid flow and converts it into useful work. The simplest turbine have one moving part, a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts an the blade or the blades react to the flow, so that they move and impart rotational energy to the rotor. Early turbines examples are wind mills and water wheels.

Its chief operation is to convert energy into mechanical form in the cylinder which is the heart of various reciprocating engines principally diesel and Spark ignition..The advantages offered by the turbine are its relative compactness and the fact that the reciprocating output of the turbine is usually what is want to turn a wheel, propeller, generator or pump.Gas, steam and water turbines usually have a casing around the blades that contains and controls the working fluid.

1.4 Types of Turbines:

1. Steam Turbines
2. Gas Turbines
3. Transonic Turbines
4. Contra rotating Turbines
5. Sartor less Turbines
6. Ceramic Turbines
7. Shrouded Turbines
8. Shroud less Turbines
9. Blade less Turbines
10. Water Turbines
    a) Pelton wheel Turbine
    b) Francis Turbine
    c) Kaplan Turbine
11. Wind Turbines, it operates without nozzle

1.5 Gas Turbine

A gas turbine is a rotating engine that extracts energy from a flow of combustion gases that result from the ignition of compressed air and a fuel (either a gas or liquid, most commonly natural gas). It has an upstream compressor module coupled to a downstream turbine module, and a combustion chamber(s) module in between. Energy is added to the gas stream in the combustor, where air is mixed with fuel and ignited. Combustion increases the temperature, velocity, and volume of the gas flow. This is directed through a nozzle over the turbine's blades, spinning the turbine and powering the compressor Energy is extracted in the form of shaft power, compressed air, and thrust, in any combination, and used to power aircraft, trains, ships, generators, and even tanks

1.5.1 Gas Turbine for Power Generation:

The use of gas turbines for generating electricity dates back to 1939. Today, gas turbines are one of the most widely-used power generating technologies. Gas turbines are a type of internal combustion (IC) engine in which burning of an air-fuel mixture produces hot gases that spin a turbine to produce power. It is the production of hot gas during fuel combustion, not the fuel itself that the gives gas turbines the name. Gas turbines can utilize a variety of fuels, including natural gas, fuel oils, and synthetic fuels. Combustion occurs continuously in gas turbines, as opposed to reciprocating IC engines, in which combustion occurs intermittently.

1.5.2 How Do Gas Turbines Work?

Gas turbines are comprised of three primary sections mounted on the same shaft: the compressor, the combustion chamber (or combustor) and the turbine. The compressor can be either axial flow or centrifugal flow. Axial flow compressors are more common in power generation because they have higher flow rates and efficiencies. Axial flow compressors are comprised of multiple stages of rotating and stationary blades (or stators) through which air is drawn in parallel to the axis of rotation and incrementally compressed as it passes through each stage. The acceleration of the air through the rotating blades and diffusion by the stators increases the pressure and reduces the volume of the air. Although no heat is added, the compression of the air also causes the temperature to increase.

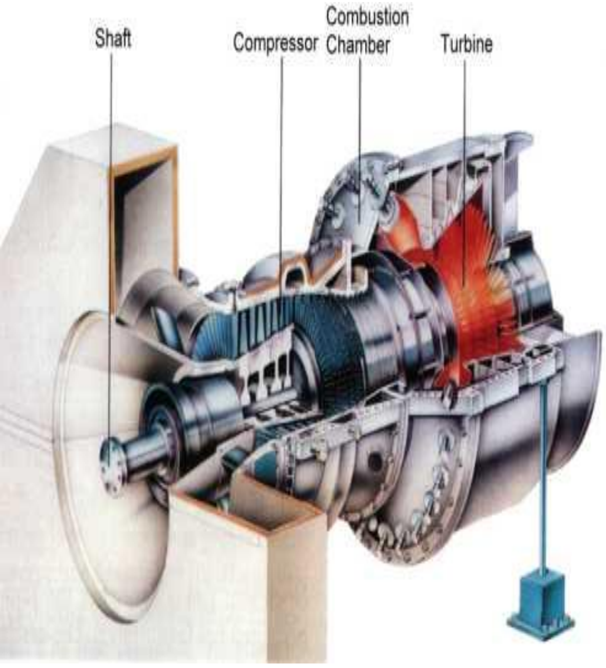

Fig no 1.5.1

The compressed air is mixed with fuel injected through nozzles. The fuel and compressed air can be pre-mixed or the compressed air can be introduced directly into the combustor. The fuel-air mixture ignites under constant pressure conditions and the hot combustion products (gases) are directed through the turbine where it expands rapidly and imparts rotation to the shaft. The turbine is also comprised of stages, each with a row of stationary blades (or nozzles) to direct the expanding gases followed by a row of moving blades. The rotation of the shaft drives the compressor to draw in and compress more air to sustain continuous combustion. The remaining shaft power is used to drive a generator which produces electricity. Approximately 55 to 65 percent of the power produced by the turbine is used to drive the compressor. To optimize the transfer of kinetic energy from the combustion gases to shaft rotation, gas turbines can have multiple compressor and turbine stages.

Fig no 1.5.2
Alstom GT24/GT26 Gas Turbine

Because the compressor must reach a certain speed before the combustion process is continuous – or self-sustaining – initial momentum is imparted to the turbine rotor from an external motor, static frequency converter, or the generator itself. The compressor must be smoothly accelerated and reach firing speed before fuel can be introduced and ignition can occur. Turbine speeds vary widely by manufacturer and design, ranging from 2,000 revolutions per minute (rpm) to 10,000 rpm. Initial ignition occurs from one or more spark plugs (depending on combustor design). Once the turbine reaches self-sustaining speed – above 50% of full speed – the power output is enough to drive the compressor, combustion is continuous, and the starter system can be disengaged.

1.5.3 Gas Turbine Performance

The thermodynamic process used in gas turbines is the [Brayton cycle](). Two significant performance parameters are the pressure ratio and the firing temperature. The fuel-to-power efficiency of the engine is optimized by increasing the difference (or ratio) between the compressor discharge pressure and inlet air pressure. This compression ratio is dependent on the design. Gas turbines for power generation can be either industrial (heavy frame) or aeroderivative designs. Industrial gas turbines are designed for stationary applications and have lower pressure ratios – typically up to 18:1. Aeroderivative gas turbines are lighter weight compact engines adapted from aircraft jet engine design which operate at higher compression ratios – up to 30:1. They offer higher fuel efficiency and lower emissions, but are smaller and have higher initial (capital) costs. Aeroderivative gas turbines are more sensitive to the compressor inlet temperature.

The temperature at which the turbine operates (firing temperature) also impacts efficiency, with higher temperatures leading to higher efficiency. However, turbine inlet temperature is limited by the thermal conditions that can be tolerated by the turbine blade metal alloy. Gas temperatures at the turbine inlet can be 1200ºC to 1400ºC, but some manufacturers have boosted inlet temperatures as high as 1600ºC by engineering blade coatings and cooling systems to protect metallurgical components from thermal damage.

Because of the power required to drive the compressor, energy conversion efficiency for a simple cycle gas turbine power plant is typically about 30 percent, with even the most efficient designs limited to 40 percent. A large amount of heat remains in the exhaust gas, which is around 600ºC as it leaves the turbine. By recovering that waste heat to produce more useful work in a combined cycle configuration, gas turbine power plant efficiency can reach 55 to 60 percent. However, there are operational limitations associated with operating gas turbines in combined cycle mode, including longer startup time, purge requirements to prevent fires or explosions, and ramp rate to full load.

1.5.4 Types of Gas Turbine

There are different types of gas turbines. Some of them are named below:
1. Aero derivatives and jet engines
2. Amateur gas turbines
3. Industrial gas turbines for electrical generation
4. Radial gas turbines
5. Scale jet engines
6. Micro turbines.

1.6 Gas Turbine Blade

The gas turbine is an internal combustion engine that uses air as the working fluid. The engine extracts chemical energy from fuel and converts it to mechanical energy using the gaseous energy of the working fluid (air) to drive the engine and propeller, which, in turn, propel the airplane

A turbine blade is the individual component which makes up the turbine section of a gas turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. The turbine blades are often the limiting component of gas turbines.To survive in this difficult environment, turbine blades often use exotic materials like superalloys and many different methods of cooling, such as internal air channels, boundary layer cooling, and thermal barrier coatings. The blade fatigue failure is one of the major source of outages in any steam turbines and gas turbines which is due to high dynamic stresses caused by blade vibration and resonance within the operating range of machinery. To protect blades from these high dynamic stresses, friction dampers are used.

Blades of wind turbines and water turbines are designed to operate in different conditions, which typically involve lower rotational speeds and temperatures.

The gas turbine is an internal combustion engine that uses air as the working fluid. The engine extracts chemical energy from fuel and converts it to mechanical energy using the gaseous energy of the working fluid (air) to drive the engine and propeller, which, in turn, propel the airplane.

In a gas turbine engine, a single turbine section is made up of a disk or hub that holds many turbine blades. That turbine section is connected to a compressor section via a shaft (or "spool"), and that compressor section can either be axial orcentrifugal. Air is compressed, raising the pressure and temperature, through the compressor stages of the engine. The temperature is then greatly increased by combustion of fuel inside the combustor, which sits between the compressor stages and the turbine stages. The high temperature and high pressure exhaust gases then pass through the turbine stages. The turbine stages extract energy from this flow, lowering the pressure and temperature of the air and transfer the kinetic energy to the compressor stages along the spool. This process is very similar to how an axial compressor works, only in reverse.

The number of turbine stages varies in different types of engines, with high bypass ratio engines tending to have the most turbine stages.The number of turbine stages can have a great effect on how the turbine blades are designed for each stage. Many gas turbine engines are twin spool designs, meaning that there is a high pressure spool and a low pressure spool. Other gas turbines use three spools, adding an intermediate pressure spool between the high and low pressure spool. The high pressure turbine is exposed to the hottest, highest pressure air, and the low pressure turbine is subjected to cooler, lower pressure air. The difference in conditions leads to the design of high pressure and low pressure turbine blades that are significantly different in material and cooling choices even though the aerodynamic andthermodynamic principles are the same.[4] Under these severe operating conditions inside the gas and steam turbines, the blades face high temperature, high stresses, and potentially high vibrations. Steam turbine blades are critical components in power plants which convert the linear motion of high temperature and high pressure steam flowing down a pressure gradient into a rotary motion of the turbine shaft.

Conclusion

Turbine entry temperature has increased by ~500 oC over last 6 decades and about 150 oC of that is due to improved superalloys and introduction of DS / SC technologies for blade casting. Advanced thermal barrier ceramic coatings on platform and full airfoil have contributed to another about 100 oC of this improvement. The developments in gas turbine materials and coatings have been largely due to increasing demands placed by the aircraft sector – higher engine thrust, thrust to weight ratio and fuel efficiency – necessitating higher operating temperatures and pressures. The land based industrial gas turbine industry has placed its own demands on materials, bringing in resistance to hot corrosion as an important requirement. Several SC superalloy compositions have been developed for ′γaircraft gas turbines on one side and land based gas turbines on the other side. Partial solutioning has been adopted in a number of SC IGT alloys to avoid incipient melting and control the extent of recrystallisation. Intense R&D is also going on development of advanced materials for gas turbine engine application – intermetallics, ceramics, composites, chromium / molybdenum / platinum based materials to improve the engine efficiency and bring down the harmful emissions. Major improvements in the coating technology have also been achieved. Present day coatings last 10-20 times longer than the coatings used in the late 90’s. As much as 100% improvement is now being achieved in the blade life in the field through the process of coating. TBCs are being used in the first few stages in all advanced gas turbines. Intense R&D is underway to improve the thermal fatigue of the TBC’s and thereby increase their life. This includes development of techniques for production of uniform and high density coatings.