A REVIEW ON PERFORMANCE ANALYSIS OF GAS TURBINE BLADES AND COMBUSTION CHAMBER USING CERAMIC COATING

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ABSTRACT - Gas *turbine engine is an internal combustion, driven by the pressure of burning compressed air and fuel. It is widely used in power generation technologies. Gas turbine engine performance depends on ambient and operating conditions. The turbine blades extracts the energy from high temperature gas produced by combustion. No proper cooling would deform the blade which may result in inefficient operating of turbine blades. The performance of the turbine can be improved by cooling of turbine blades as the efficiency depends on inlet gas temperature. Choosing proper material can also assist in using turbine blade at higher temperature. If reaction type turbine is used, making use of proper blade profile can also improve the efficiency. This paper is a review of design process done on turbine blade of reaction type, that will assist those who makes a research operation in this area.*

Keywords: Performance, Turbine blade, Blade Profile, Coatings, Efficiency.

1. INTRODUCTION

Gas turbines are machines that convert fluid power to mechanical power. It is done by using the kinetic energy stored in the fluid or by interaction between turbine blades and the fluid flow. The first one is called as impulse turbine and the later is called the reaction turbine. Impulse turbine needs high pressure head which cannot be offered in industrial applications. So 50% reactions turbines were used. The application of reaction turbines extend from electricity generation in industries to powering the aviation engines

Fig.1- Gas Turbine Engine

The gas turbine has a second turbine acting as an air compressor mounted on the same shaft. The air turbine (compressor) draws in air, compresses it and feeds it at high pressure into the combustion chamber increasing the intensity of the burning flame. It is a positive feedback mechanism. As the gas turbine speeds up, it also causes the compressor to speed up forcing more air through the combustion chamber which in turn increases the burn rate of the fuel sending more high pressure hot gases into the gas turbine increasing its speed even more. Uncontrolled runaway is prevented by controls on the fuel supply line which limit the amount of fuel fed to the turbine thus limiting its speed.

A turbine blade is the individual component which makes up the turbine section of a gas turbine or steam 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. Blade fatigue is a major source of failure in steam turbines and gas turbines. Fatigue is caused by the stress induced by vibration and resonance within the operating range of machinery. To protect blades from these high dynamic stresses, friction dampers are used. 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 and thermodynamic principles are the same. Turbine blades are subjected to very strenuous environments inside a gas turbine. They face high temperatures, high stresses, and a potential environment of high vibration. All three of these factors can lead to blade failures, potentially destroying the engine, therefore turbine blades are carefully designed to resist these conditions. Cooling of components can be achieved by air or liquid cooling. Liquid cooling seems to be more attractive because of high specific heat capacity and chances of evaporative cooling but there can be problem of leakage, corrosion, choking, etc. which works against this method. There are many techniques of cooling used in gas turbine blades; convection, film, transpiration cooling, cooling effusion, pin fin cooling etc. which fall under the categories of internal and external cooling. While all methods have their differences, they all work by using cooler air (often bled from the compressor) to remove heat from the turbine blades. It works by passing cooling air through passages internal to the blade. Heat is transferred by conduction through the blade, and then by convection into the air flowing inside of the blade. A large internal surface area is desirable for this method, so the cooling paths tend to be serpentine and full of small fins. The internal passages in the blade may be circular or elliptical in shape. Cooling is achieved by passing the air through these passages from hub towards the blade tip. This cooling air comes from an air compressor. In case of gas turbine the fluid outside is relatively hot which passes through the cooling passage and mixes with the main stream at the blade tip. A variation of convection cooling, impingement cooling, works by hitting the inner surface of the blade with high velocity air. This allows more heat to be transferred by convection than regular convection cooling does. Impingement cooling is used in the regions of greatest heat loads. In case of turbine blades, the leading edge has maximum temperature and thus heat load. Impingement cooling is also used in mid chord of the vane. Blades are hollow with a core. There are internal cooling passages. Cooling air enters from the leading edge region and turns towards the trailing edge. Film cooling (also called *thin* film cooling), a widely used type, allows for higher heat transfer rates than either convection and impingement cooling. This technique consists of pumping the cooling air out of the blade through multiple small holes in the structure. A thin layer (the film) of cooling air is then created on the external surface of the blade, reducing the heat transfer from main flow, whose temperature (1300–1800 kelvins) can exceed the melting point of the blade material (1300–1400 kelvins). In the narrow trailing edge film cooling is used to enhance heat transfer from the blade. There is an array of pin fins on the blade surface. Heat transfer takes place from this array and through the side walls. As the coolant flows across the fins with high velocity, the flow separates and wakes are formed. Many factors contribute towards heat transfer rate among which the type of pin fin and the spacing between fins are the most significant.

The Operation of a gas turbine engine is based on Brayton's Cycle. The thermal efficiency and output power can be improved by increasing the turbine inlet temperature. This pose a challenge in materials used in turbine blades. It is observed that the most of the gas turbine engines operate on higher temperature than the material can withstand. The losses in turbine are due to friction, local flow pattern and the profile of the blade. These losses are directly related to the efficiency of the turbine. The gas turbine is comprised of three main components: a compressor, a combustor, and a turbine. The working fluid, air, is compressed in the compressor (adiabatic compression - no heat gain or loss), then mixed with fuel and burned by the combustor under constant pressure conditions in the combustion chamber (constant pressure heat addition). The resulting hot gas expands through the turbine to perform work (adiabatic expansion). Much of the power produced in the turbine is used to run the compressor and the rest is available to run auxiliary equipment and do useful work. The system is an open system because the air is not reused so that the fourth step in the cycle, cooling the working fluid, is omitted.

2. LITERATURE REVIEW

Kalapala Prasad [1] et.all investigated the gas turbine blade aiming for numerical analysis of the twisted airfoil. The natural frequency of the gas turbine blade is evaluated by adopting Hozler's Method. The author analysed the shape of the blade and twisted it to make it more efficient. The natural frequency obtained through Hozler's Technique is analysed so as to improve the efficiency of the turbine.

Tim J Carter [2] et.all described about the failures of gas turbine blades. Most of the failures were detected and the appropriate action taken to prevent the failures. The causes wee identified as exposure to high temperature causes the blade to under go creep. Also the properties of combusted gas cause corrosion in the blades. The continuous load on the turbine blade causes fatigue failure.

X.Q. Cao [3] et. all investigate the properties of barrier coating for the ceramic materials used in the gas turbine engines. The Ceramic materials used for coating have increased the life of blade by protecting it from oxidation, corrosion and wear. Here the top ceramic coating which protects from the heat and acts as the thermal insulation

Teju [4] et.al investigated the design and analysis of gas turbine blade. The turbine blades were designed with two different material named Inconel 718 and titanium T-6. Thermal analysis were carried out to investigate the temperature flow which develops due to thermal loading. A structural analysis were carried out to investigate the Shear stress and displacement.

C dhatchanamoorthy[5]et.al analyzed the gas turbine combustion chamber and improving combustion efficiency by using ceramic material coating. Here ceramic coated combustion chamber produced more thrust at the same time combustion chamber life also increased.

3. DISCUSSION AND CONCLUSION

According to kalapala prasad [1], the turbine blade has been twisted and the reduced values of natural frequency indicates the aluminum alloy effectiveness compared with other materials. This implies twisted is needed to increase the blade efficiency. And to find the natural frequency is to calculate the torsional stiffness of the single blade. This natural frequency is required to analyse the shape of the turbine blade as it influences the parameters like vibration due to excess speed of the gas turbine engine. Fig (1) describes about the nomenclature of the airfoil, to consider the shape of the blade. Through the sections fig1 and fig 3 of rectangular and triangular are easy to find the various parameters like natural frequency, damping factor, and the logarithmic decrement value. Tim J Carter [2] discussed about the failures of gas turbine blade. The failures were caused due to excess amount of moisture content present in the air above the sea level. The failures are caused due to high temperature damage such as corrosion, erosion, wear, creep and fatigue. Fatigue failure is very rare unless initiated by isolated circumstances. Due to the high temperature exposure either corrosion or creep will occur. The operating temperature is above the melting point for aluminum alloys. Owing to weight, nickel based alloys were accepted. The creep cracks were mostly identified on the trailing edge of the blade airfoil region. The Primary cracking is due to creep. The exhaust of the combustion chamber product releases sulphur, sodium or even lead. These chemical particles destroy the turbine blade easily. In order to prevent the turbine blade material the Ni-alloy is manufactured at elevated temperature and the adequate coatings is preferred to that material. This is to be done to save the turbine blade life.

Theju V [4] had done a comparative research on the design of gas turbine blades. This comparative research shown a detailed discussion about the design and stress of turbine blade of a jet engine. This comparison is made with two different materials named Inconel 718 and Titanium T6. Titanium is a grade of heat treated steel and it is non Magnetic. It is a poor conductor of heat and electricity. It is a great resistant to corrosion when compared to Platinum. Inconel is a Oxidation-corrosion resistant material when get heated it become thick and stable. It is Typically used in High Temperature applications. The analysis attempt has been carried out to investigate the stresses and temperature develop in the gas turbine blade. They would have designed with CATIA V5, and have analyzed the temperature and stresses, was easily analyzed by using ANSYS Software. The inconel 718 has a small deformation in the material as well as lesser value of yield strength and young modulus. Although the cost of the material is high it generates a very good material properties when compared to the Titanium T6.

Hence the ceramic coating over the combustion chamber or the gas turbine blades may increase the life of both the combustion chamber and the turbine blades. These ceramic coatings act as the thermal insulation over the gas turbine blade and protects from the heat.

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