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Thermal Analysis of Steam Turbine Blades

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ABSTRACT:

Turbine blades of a gas turbine are responsible for extracting energy from the high temperature, high pressure gases. These blades are operated at elevated temperatures in aggressive environments and are subjected to large centrifugal forces. As many as 42 percent of the failures in gas turbine engines were only due to blading problems and the failures in these turbine blades can have dramatic effect on the safety and performance of the gas turbine engine. In this research paper, an attempt has been made to analyze the failure of gas turbine blade through Mechanical analysis. The blade under investigation belongs to a 30 MW gas turbine engines used in marine applications and is made of epoxy-resign and inconel 680 superalloys. Before failure, the turbine blade was operated for about 10000 hours while its service life was expected to be around 15000 hours. Mechanical analysis has been carried out assuming that there might be failure in the blade material due to blade operation at elevated temperature and subjected to large centrifugal forces. The gas turbine blade model profile is generated by using CATIA V5R20 software. The turbine blade is analyzed for its thermal as well as structural performance.

INTRODUCTION

A steam turbine is a mechanical device that converts thermal energy in pressurized steam into useful mechanical work. The steam turbine derives much of its better thermodynamic efficiency because of the use of multiple stages in the expansion of the steam. This results in a 32closer approach to the ideal reversible process. Steam turbines are made in a variety of sizes ranging from small 0.75 kW units used as mechanical drives for pumps, compressors and other shaft driven equipment, to 150 MW turbines used to generate electricity. Steam turbines are widely used for marine applications for vessel propulsion systems. In recent times gas turbines, as developed for aerospace applications, are being used more and more in the field of power generation once dominated by steam turbines. The gas turbine obtains its power by utilizing the energy of burnt gases and the air which is at high temperature and pressure by expanding through the several rings of fixed and moving blades, to get a high pressure of order of 4 to 10 bar of working fluid which is essential for expansion a compressor is required. The quantity of working fluid and speed required are more, so generally a centrifugal or axial compressor is required. The turbine drive the compressor so it is coupled to the turbine shaft, If after compression the working fluid were to be expanded in a turbine, then assuming that there were no losses in either component, the power developed by the turbine can be increased by increasing the volume of working fluid at constant pressure or alternatively increasing the pressure at constant volume. Either of there may be done by adding heat so that the temperature of the working fluid is increased after compression. To get a higher temperature of the working fluid a combustion chamber is required where combustion of air and fuel takes place giving temperature rise to the working fluid. The turbine escapes energy from the exhaust gas. Like the compressor, turbine can be centrifugal or axial. In each type the fast moving exhaust gas is sued to spin the turbine, since the turbine is attached to the same shaft as the compressor at the front of the engine, and the compressor will turn together, The turbine may extract just enough energy to turn the compressor. The rest of the exhaust gas is left to exit the rear of the engine to provide thrust as in a pure jet engine. Or extra turbine stages may be used to turn other shafts to power other machinery such as the rotor of a helicopter, the propellers of a ship or electrical generators in power stations. The present paper deals with the first type is centrifugal stresses that act on the blade due to high angular speeds and second is thermal stresses that arise due to temperature gradient within the blade material. The analysis of turbine blade mainly consists of the following two parts: Structural and thermal analysis. The analysis is carried out under steady state conditionsusing Ansys software. The study has been conducted with two different materials epoxy-resign and inconel 680 superalloys. Turbine rotors used in power plants are subjected to high temperature especially during start up cycle. The rotor of steam turbine is subjected to temperature variations in short periods of time due to the start and stop cycles of the turbine. This causes sudden changes in the temperature with transient thermal stresses being induced into the turbine rotor. The transient effect is due to the changes in the material properties like Density, Specific heat and Young's Modulus. The estimate of thermal stresses induced in the turbine rotor is important in determining the start up cycle of a steam turbine. Thermal gradients developed during thermal transients are the key source of stress generation in the rotor. Under such conditions there is the probability of failure of turbine rotor if the turbine rotor is not designed taking into consideration the transient effect. There are many Finite element packages available for conducting the transient thermal analysis. Some of the packages are NASTRAN , ABAQUS , ANSYS , NISA , PROMECHANICA etc. These packages allow the designer to vary the ambient temperature with time, vary the convective heat transfer coefficients and heat flux with time/temperature, and also allow heat generation to be applied. A significant amount of design effort invested to determine the optimal process Parameters for start-up (e.g. steam temperatures, run-up and loading gradients), in order to achieve the fastest possible starts without exceeding allowable material stress limits Turbine driven forced induction device used to allow more power to be produced by an engine of a given size. A turbocharger increases mass of air entering the engine cylinder enabling more fuel burning in engine cylinder to produce more power. Performance is improved as energy is recovered from exhaust waste. In exhaust gas turbocharging exhaust gas energy is used to drive turbine. The turbine is coupled to compressor, which draws in combustion air, compresses it and then is supplied to engine inlet. The turbocharger was invented by Swiss engineer Alfred Buchi (1879-1959), who received a patent in 1905 for using a compressor driven by exhaust gasses to force air into an internal combustion engine to increase power output but it took another 20 years for the idea to come to fulfillment.

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CLASSIFICATION OF STEAM TURBINES

Steam turbines may be classified into different categories depending on their construction, the process by which heat drop is achieved, the initial and final conditions of steam used and their industrial usage as follows:

A. According to the Number of pressure stages:

Single – stage turbines with one or more velocity stages usually of small power capacities, mostly used for driving centrifugal compressors, blowers and other similar machinery. Multistage impulse and Reaction turbines, made in a wide range of power capacities varying from small to large.

B. According to the direction of steam flow: Axial turbines, in which the steam flows in a direction parallel to the axis of the turbine. Radial turbines, in which the steam flows in a direction perpendicular to the axis of the turbine. One or more low pressure stages in such turbines are made axial.

C. According to the Number of cylinders:

* Single cylinder turbines

• Multi cylinder (2, 3 and 4 cylinders) turbines, which can have single shaft, i.e. rotors mounted of the same

• shaft, or multiaxial, having separate rotor shaft and have their cylinders placed parallel to each other.

D. According to the method of governing:

Turbines with nozzle governing.

• Turbines with bypass governing in which steam besides being fed to the first stage is also directly led to one,

• two or even three intermediate stages of the turbine.

E. According to the Principle of Action of Steam: Impulse turbines.

• Axial Reaction turbines.

• Radial reaction turbines without any stationary guide blades.

• Radial reaction turbines having stationary guide blades.

F. According to the Heat Drop Process:

Condensing turbines with exhaust steam let into condenser with Regenerators, Condensing turbines with oneor two intermediate stage extractions at specific pressures for industrial and heating purposes.

Back pressure turbines, the exhaust steam from which is utilized for industrial and heating purposes.

• Back – pressure turbines with steam extraction from intermediate stages at specific pressures.• Low – pressure (Exhaust pressure) turbines in which the exhaust steam from reciprocating steam engines,

• power hammers, presses, etc is utilized for power generation.

Mixed – pressure with two or three pressure extractions with supply of exhaust steam to its intermediate stages.

G. According to the Steam Conditions at inlet:

Low – pressure turbines using at pressures 1.2 to 2 ata

.• Medium – pressure turbines using steam at pressure up to 4.0 atp.

• High – pressure turbines using steam at above40 ata.

• Very high pressure turbines using steam up to 40 ata and higher pressure and temperature.

H. According to their Usage in industry:

Stationary turbines with constant speed of rotation primarily used for driving alternators.

• Stationary turbines with variable speeds meant for driving turbo blowers, air circulators, pumps etc.

- Non stationary turbines with variable speeds employed in steamers, ships, railway (turbo) locomotives etc

TYPES OF STEAM TURBINES

The necessity to keep down the production costs lead to standardization of the types of steam turbines, such as back pressure, condensing, extraction back pressure and extraction condensing, injection condensing

Condensing turbines

- Back pressure turbines
- Multiple extraction turbines
- Injection condensing turbines for combined cycle plant
- Reheat condensing turbines for utility type
- Most of the industrial steam turbines are high speed turbines for the power output range of 1-30MW with speed reduction by turbo gears which in turn means smaller sizes and higher efficiency for the turbine for the output of 30MW and above the turbine speed is 3000rpm.

VARIOUS PARTS OF STEAM TURBINE

a) Nozzle: The nozzle expands steam of comparatively low velocity and high static pressure within considerable increase in velocity. The nozzle is so positioned as to direct the flow of steam into the rotor passage.

b) Diffuser: It is a mechanical device that is designed to control the characteristics of steam at the entrance to a thermodynamic open system. Diffusers are used to slow the steam's velocity and to enhance its mixing into the surrounding steam. In contrast, a nozzle is often intended to increase the discharge velocity and to direct the flow in one particular direction.

Flow through nozzles and diffusers may or may not be assumed to be adiabatic. Frictional effects may sometimes be important, but usually they are neglected. However, the external work transfer is always assumed to be zero. It is also assumed that changes in thermal energy are significantly greater than changes in potential energy and therefore the latter can usually be neglected for the purpose of analysis.

c) Blades Or Buckets: The blades or buckets form the rotor flow passage and serves to change the direction and hence the momentum of the steam received in the stationary nozzles.

d) Guide Or Guide blades: Often a turbine is arranged with a series of rotor flow passages. Intervening between the blades comprising the rotor passages are rows of stationary guide blades. The purpose of this guide is to reverse the direction of steam leaving the preceding moving blade row so that general direction of steam leaving the preceding moving blade rows is similar.

If guide blades were not provided, opposing force would be exerted on the rotor which would largely negate each other.

e) Casing Shell Or Cylinder: The turbine enclosure is generally called the casing although the other two names are in common use.

The nozzle and guide are fixedon casing, which in addition to confining the steam serves as support for the bearings. Sometimes the word cylinder is restricted as a cylindrical form attached to inside of the casing to which the guides are fixed.

f) Shaft, Rotor, Spindle: These terms are applied to the rotating assembly which carries the blades.

g) Disc Or Wheel: The moving blades are attached to the disc which in turn is keyed to the shaft.

h) Diaphragm: The diaphragm which is fixed to the cylinder or casing contains the nozzle and serves to confine the steam flow to nozzle passage.

i) Packing: Packing in the form of carbon rings minimizes the leaking in the annular space between the diaphragm and shaft.

j) Thrust Bearings: Usually a combination of Kingsbury and collar types absorbs the axial forces.

k) Exhaust Hood: The exhaust hood is the portion of the casing which collects and delivers the exhaust steam to exhaust pipe or condenser.

l) Steam Chest: The steam chest is the supply chamber from which steam is admitted to the nozzles.

m) Governor: The governing system may be designated to control steam flow so as to maintain constant speed with load fluctuations to maintain constant pressure with variation of demand for processed steam or both.

n) Throttle Or Stop Valves: The throttle and stop valves are located in the steam supply line to the turbine. The stop valve is hydraulically operated quick opening and shutting valves designed to be either fully opened or shut. On small turbines the stop valves may be manually operated but in any case is intended for emergency use or when fully shut down. The throttle valve is used in smaller turbines in addition to stop valve as a means of regulating steam flow during the starting or stopping the operation.

CONCLUSION

Turbine blades of a gas turbine are responsible for extracting energy from the high temperature, high pressure gases. These blades are operated at elevated temperatures in aggressive environments and are subjected to large centrifugal forces. As many as 42 percent of the failures in gas turbine engines were only due to blading problems and the failures in these turbine blades can have dramatic effect on the safety and performance of the gas turbine engine. In this research paper, an attempt has been made to analyze the failure of gas turbine blade through Mechanical analysis. Designing is done in CAD TOOL namely CATIA V5R20 and then imported into ANSYS 16 for further static and thermal analysis Two materials have been choosen namely, **INCONEL 360,** EPOXY CURE RESIN which are known as very good materials for turbine blades because for its strength and thermal properties Form the above analysis we compare that inconel 360 material have good mechanical properties when compared to EPOXY CURE RESIN.

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