Gas turbine blade failures: An overview

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Abstract

Gas turbine components have to operate in extremely strenuous conditions where service temperature can reach nearly to the melting point of the materials. Blades inside the turbines have to face high stresses, vibrating environment and high temperature. All these factors will activate variety of degradation modes onto the components of turbine resulting in the catastrophic failure of the turbine. Due to this turbine will fail to meet his functional requirement and consequently in this event power plant will remain shut down for approximately one month resulting in the huge economic loss and more importantly stoppage of service to the society. This review article discusses and presents common failures found in the gas turbine.

Keyword: Gas turbine; Oxidation; Surface degradation; High-temperature.

Introduction

Failure of the turbine blade occurs in power plants time to time. In order to enhance efficiency and reliability of the gas turbine, detailed investigations must be done onto (a) external damage of the surface which includes oxidation [1-2], fatigue [3-4], corrosion [5-8], creep [1,5,8] and degradation of surface because of overheating [9], and (b) internal damage which includes microstructure damage as $\gamma'$ [Ni3(Al, Ti)] phase aging, formation of the brittle phases, grain growth, precipitation of the carbides and void formation at grain boundary [10]. However, degree of the deterioration for individual blade may varies because of operating temperature, speed of rotation, mode of the operations, total time of service and differences in manufacturing [1]. Study carried out by Rao. et al. found that 42 times out of 100 gas turbine fails due to problem of worn out blades only [11]. Another study presented by Dundas also observed that failures related to fatigue, creep and cooling of turbine blade added 62% of total damage costs [12]. Therefore, failure of the turbine blade results from combined effect of aforesaid mechanisms. As whole these failure mechanisms dramatically reduces the service life and performance of such device. This review article discusses and presents common failures found in the gas turbine.
I. Fatigue

Fatigue, means repeated stressing and can lead to the turbine blade failure independently of the temperature level. The centrifugal loading & oscillatory vibrations are present. Fretting fatigue can cause failure of these mating components. The damage to blade and casing.

Mishra. et al., carried out systematic investigations to assess the root cause of turbine blade failure in jet engine. Visual examinations of jet engine don’t show any signs of abnormality. Moreover, no evidence of blade overheating and discs was noticed [13]. However during FPI cracks were confirmed on blades fir-tree serrations along with non uniform loading. It was confirmed during microscopic observations that HCF was responsible for failure of blades. Authors reported that cause of the fatigue is cyclic load that arises from fretting mechanism. Barella. et al., carried out experimental studies to find the cause of failure [14]. Blade material was Inconel-718, a Ni-based superalloy and failure of the blade occurs after 22,400hrs of service. It was found after several examinations that primary cause of failure was fracture mechanism associated with HCF originated by fretting fatigue onto fir-tree lateral surface. Kubiak. et al., in their work investigate the turbine blade (first stage) of 150MW turbine which fails because of sudden high vibrations. Authors reported that due to LCF mechanism a crack was generated at the blade root which propagates due to high [15].

Fatigue failure in turbine blades was the dominant mechanism in gas turbines. Oscillatory sliding displacements of relatively small amplitude between contact surfaces of the blades and disc are termed as fretting and results from cyclic loading of any one of contact members. As a remedial measure introduction of compressive layer under the surface is adopted to increase fatigue strength. Furthermore, to avoid such failures methods to reduce co-efficient of friction between fretting surfaces can also be adopted.

11. Corrosion

Elevated temperature structural conditions which contain contaminants such as sulfates, chlorides along with erosive particles. These salt contaminants can reduce fatigue strength of the turbine blades. Maximum number of shut downs in power plants results from corrosion-fatigue failure.

The blade failure takes place because of erosion and elevated temperature sulfidation corrosion [16]. Hot corrosion in gas turbines results from contaminants like sodium sulfate, sodium chloride and vanadium oxide that were present in the gases during combustion. [17-18].

To obtain elevated temperature strength and micro-structural stability content of Al and Cr in superalloys can kept in range of 5-12% & 3.4-5% respectively that can also reduces corrosion and oxidation resistance of superalloys. Hence a preventive measure appropriate oxidation and corrosion resistance coatings can be deposited by using two methods: (a) Diffusion coating, and (b) Overlay
coatings. The selection of candidate coating material may vary according to the operating environment and also on the substrate they are being deposited. Therefore, role of every element in composition is vital in combating the oxidation and corrosion rates.

III. Overheating

At elevated temperatures TCP phases were formed due to high Cr%, which reduces the strength of the material for long term. TCP occurs due to overheating and this instability in structure of alloy can result in the reduction of strength and ductility in alloy. Sushila. et al., investigated the failure of first stage gas turbine blade made up of IN738. Objective of the investigation was to evaluate the crack at the tip of trailing edge and degradation of coating. During investigation it was found that due to overheating blade surface was completely degraded [19-20]. The superalloys can be utilized for the deposition of coatings to combat hot-corrosion [21-25].

IV. Conclusion

- Failures can’t be avoided completely but can be minimized by depositing coatings of appropriate materials.
- The most frequently occurring failure mechanisms in turbine blade are of two types: (a) external damage of the surface which includes oxidation, fatigue, corrosion, creep and degradation of surface because of overheating, and (b) internal damage which includes microstructure damage as γ’ [Ni3(Al, Ti)] phase aging, formation of the brittle phases, grain growth, precipitation of the carbides and void formation at grain boundary.
- Hot corrosion in gas turbines results from contaminants like sodium sulfate, sodium chloride and vanadium oxide that were present in the gases during combustion.
- At elevated temperatures TCP phases were formed due to high Cr%, which reduces the strength of the material for long term. TCP occurs due to overheating.

References


