International Engineering Journal For Research & Development

Vol.3
Issue-2

E-ISSN NO:-2349-0721

Impact factor : 3.35

REVIEW ON PERFOMENCE ANALYSIS OF GAS TURBINE BLADE BY USING CAD/CAE

[1]*Mr. Ganesh V. Darade*
Department of Mechanical Engg.
SSPACE, Wardha
ganrajdarade143@gmail.com

[2]*Prof. N. P. Doshi*
Department of Mechanical Engg.
B.D.C.O.E. Wardha
doshinpd@rediffmail.com

[3]*Prof. B. V. Lande*
Department of Mechanical Engg
B.D.C.O.E. Wardha
bv_lande@rediffmail.com

Abstract—

In view to increase operating efficiency the modern gas turbine are designed to operate at elevated temperature which are just few degree the material withstanding temperature. The literature survey reveals that the accurate thermal analysis technique can improve the life of blade as there is possibility of finding solutions on their defects. FEA and CFD tools can provide 99 % of accurate results which is very popular now a days. Combined study using FEA and CFD tools will provide ease for detection of possible defects and their prevention. As these methods are virtual hence no investment of material. Possible temperature counters can be obtained by using FEA tools. Also thermal stresses can be calculated. CFD analysis will provide the flow of hot fluid and can demonstrate behaviour of material under the influence of hot fluid.

This review will help to understand the various problems associated with GT blade. Many outers are focusing on material defects, thermal stresses and harsh working environment which reduce blade life. Hence this review will help to study those defects and scope to improvement in blade life.

Keywords— GT Blade (Gas Turbine Blade), Gas Turbine, Modeling, FEA, CFD

I. Project Objective :

1. Modeling of Gas Turbine Blade by using CAD software.

2. Thermal and CFD analysis of Gas Turbine Blade.

I. INTRODUCTION

Gas turbines are also called as combustion chamber. It is the type of IC engine. Upstream rotating compressor coupled with downstream turbine and combustion chamber in between them. The basic operation of gas turbine is similar to the steam turbine except that air is use instead of water. In gas turbine air is obtain from atmospheric compressor in air is compress. The compressor in air is passed through combustion chamber. Where it is heated considerably the hot air pass or flow over moving blade of turbine which are impart rotation of motion to runner. Major part of develop by the turbine is consume for driving the compressor.

Gas turbines are use for aircraft propulsion, aviation, electric power generation, and industrial purpose. Losses in turbine consist of mechanical losses due to the friction of rotating part or bearing tip clearance losses due to the flow of leakage through gap and secondary losses for a curve passes and profile losses due to blade shape etc. cause by reduce turbine efficiency. For improving thermal efficiency of gas turbine there are three methods uses Regeneration, Inter cooling, and Reheating.

Modern gas turbines are very compact and have high energy conversion rate. Gas turbines reach thermal efficiency to increase thermodynamic parameter like pressure ratio and turbine inlet temperature. In gas turbine engine turbine blade are critical component. If there is failure due to whole system down hence it is necessary to conduct detail failure analysis of turbine blade, in order to understand the problem improving system reliability.

II LITURATURE REVIEW

1. **An investigation of fatigue failures of turbine blades in a gas turbine engine by mechanical analysis**

Author/publisher Jianfu Hou , Bryon J. Wicks, Ross A. Antoniou

Airframes and Engines Division, DSTO Aeronautical and Maritime Research Laboratory, 506Lorimer

Street, Fishermens Bend 3207, Melbourne, Victoria 3001, Australia

Accepted 25 December 2000, Sciencedirect, Elsevier Ltd.

Jainfu How [2000] [1] in this present author had critically examine turbine with reference to metallurgical examination and mechanical analysis. The blade failure can be categories into two group's fatigue including both high fatigue cycle (HFC) and low fatigue cycle (LFC).and Constant stress at high temperature due to the creep in blade.

Metallurgical examination can be very effective to determining whether the failure is related to material defect, initial flows or heat treatment. This examination does not possible variation of design in characteristic of blade and mechanical behavior. Thus this variation may be directly link to mechanism failure. Fractography can be use successfully to determining whether failure in gas turbine blades due to stress or fatigue this quite inadequate in identifying causes of fatigue due to variation in mechanical behavior.

Fig1. Blade failure location

This paper has concluded that the cause of fatigue failure which may occur as direct consequence of anomalies in the mechanical behavior of the blade, hence failure of blade due to poor quality of material and mixture of HFC and LFC.

2. **"Structural and thermal analysis of gas turbine blade by using F. E. M,"**
Author/publisher Krishnakant P V

International Journal and Science Research Engineering and Technology (IJSRET), Vol. 2, No. 2, pp 060-065.

Available online January 2013.

Krisnakant (2013) [2] had summarize the structural and thermal analysis of gas turbine rotor blade using solid95 element. They had study the temperature effect on the overall turbine blades, in which it is observed that temperature of blade at tip section and minimum elongation and temperature variation at the root of blade.

Maximum stress and strain are observe at root of turbine blade and upper surface along the blade root three different material of construction i.e. N-155 Inconal-625 and HASTEALLOY X material. The blade temperature attained and thermal stress induce are lesser for Inconal-625 as it has better thermal properties.

3. **"Failure analysis of a gas turbine blade made of Inconel 738LC alloy"**
Author/publisher Z. Mazur, A. Luna-Ramirez a, J.A. Juarez-Islas, A. Campos-Amezcua

A Instituto de Investigaciones Ele´ctricas, Av. Reforma 113, Col. Palmira, 62490 Cuernavaca, Morelos, Mexico

Available online 23 November 2004, Sciencedirect, Elsevier Ltd.

Z.Mazur and A. Luna-Ramixz (2004) [3] have studied the failure analysis of 70 MW gas turbine blade of nickel super alloy Inconal-738 with different material. Gas turbine blade made of Nickel super alloy. During operation of power generation of gas turbine blade and other element suffer from hot gases due to turbine engine section increase temperature. This result degradation or damage the part due to mechanical and metallurgical origin. Hence result in reduce equipment reliability. There are different factors occur at the operation conditions can be summarized as fallowing factor: operation environment, high mechanical stresses, and high thermal stresses.

Fig2: View of a failed blade

He found that the blade experience internal cooling hole crack in different airfoil section assisted by coating and base alloy degradation due to the operation of high temperature. Hence blade cooling system can be improve to prevent failure by reducing the airfoil thermal gradient and minimize the airfoil thermal stresses.

1. **"Failure analysis of the 150 MW gas turbine blade"**

Author/publisher J. Kubiak, G. Castilo, G. Urquiza State university of Morelus, A.v universidal 1001, Col Chamilpa, C.p 62209

Available online 29 August 2008

J.Kubiak and G.Castilo (2008) [4] did studied the failure analysis of 150 MW gas turbine blades. A 150 MW gas turbine experience force brake down because of extremely high vibration and subsequent output power reduction. The analysis and visual inspection carried out in first stage of turbine blade. The first row moving blades observe with damage by solid object and particle which originated from destroy blade of the first row.

Fig3: Destroyed moving blade of 1st row

Analyze the result of visual inspection and metallurgical examination could be found that moving blade of first stage fracture and damage the blade. The first stage of blade damage more than other stage of blade cause by hot gases is directly enter in first row of blade. Thus he concluded that the change the design of the root blade.

5. "Analysis of conjugated heat transfer, stress and failure analysis in gas turbine blade with circular cooling passes"

Author/publisher Kyung Min Kim, June SU Park, Tack Woon Lee, Department of Mechanical Engineering, Yonsei University Seoal 120-749, Republic of Korea Available online 8 march 2011.

Tack Woon lee and June Su Park (2011) [5] had done the studied the analysis of conjugated heat transfer stress and failure in gas turbine blade with circular cooling passage. The heat transfer coefficient and stress on blade surface is the role of thermal design of gas turbine blade. They has study the investigation of heat transfer rate and stress in gas turbine blade with 10 circular internal cooling passes.

In this paper heat transfer and stress are calculated of gas turbine blade in industrial power generation system. The main objectives of investigation are: i) To understand heat transfer characteristic in the gas turbine blade. ii) To predict deformation stresses in the turbine blade. This blade has twist shape and to circular cooling passage which are 7 ribs and 3 channel.

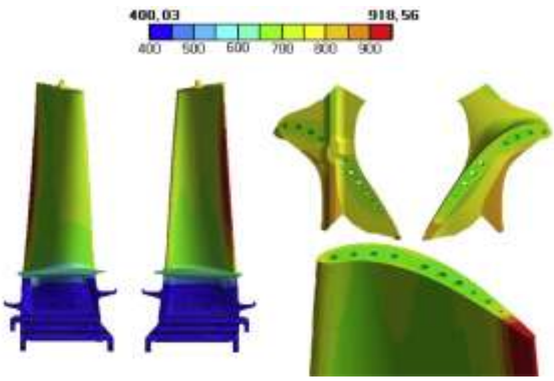

Fig4: Total stress on the blade

This paper concluded that maximum heat transfer coefficient occur at leading edge of gas turbine blade and minimum heat transfer rate at trailing edge of blade on both suction and pressure side. Maximum heat transfer is at tip section than the hub section. In additional suction side is lower than value of pressure side.

6. "Brittle fracture of gas turbine blade caused by the formation of primary b-NiAl phase in Ni-base superalloy"

Author/publisher Liang Zheng, Chengbo Xiao, Guoqing Zhang

Science and Technology on Advanced High Temperature Structural Materials Laboratory, Beijing Institute of Aeronautical Materials, Beijing 100095, China

Available online 31 August 2012, Sciencedirect, Elsevier Ltd

Liang Zheag (2012) [6] did studies fracture of gas turbine blade due to formation of primary β-Ni Al in Nickel base super alloy. Nickel base super alloy commonly use for manufacturing of gas turbine blade. During manufacturing process the cast nickel base super alloy K403 turbine blade from some mold assembly broken down in to small pieces at the section trailing edge in shell removal process. The failure blade was sampled and for what reasons fracture of blade are investigated by chemical analysis and micro hardness measure the major cause of failure.

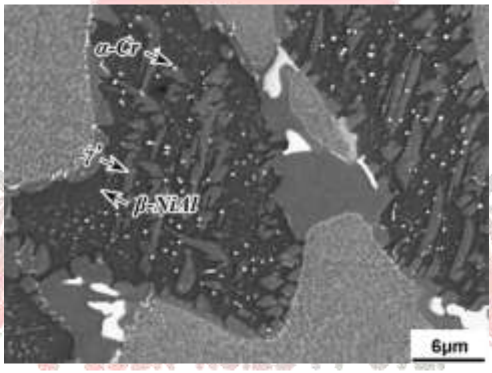

Fig5: Microstructure of failure K403 blade

Hence this found that fracture of K403 blade was fail due to abnormal layer of primary β-Ni Al phase formation. The primary β phase as a brittle phase and β-Ni Al phase tend to crack and fracture due to low impact at that time of shell removal cause by blade fracture. Hence solution can find that the blade beyond the limit of Al and Ti content for K403 speciation should be rejected and melting process of the K403 master alloy can be use accurately under control.

7. "Failure of gas turbine blades"

Author/publisher J.M. Gallardo, J.A. Rodriguez, E.J. Herrera

Grupo de Metalurgia e Ingenier´ıa de los Materiales, E.S. de Ingenieros de la Universidad de Sevilla, Camino de los Descubrimientos s/n, 41092 Sevilla, Spain

Accepted 5 November 2001, Sciencedirect. Elsevier Ltd

J. M. Gallardo and E. J. Herrera (2001) [7] had summaries by first stage blade of gas turbine had suffer from several deterioration around 10 500 h but expected service was 4000 h. they conduct three turbine blade and two pieces for study. It can be visual observation and study optical microscopy X-ray diffraction (XRD) scanning electron microscopy (SEM) and dimensional metrology carried out. The blade can be damage at tip due to wear cause by it suffers from high temperature of hot corrosion and some blades are failing at leading edge.

Fig6: Uneven clearance between blade tip and rotor lining

This paper are concluded that frailer of turbine blade should be attributed a misfit between rotor of sector of lining produce by defective mounting. This in turn in gave place to a strong friction of blade and minimum clearance.

8. "Failure of a low pressure turbine rotor blade of an aeroengine"

Author/publisher S.K. Bhaumik, M. Sujata, M.A. Venkataswamy, M.A. Parameswara

Failure Analysis Group, Materials Science Division, National Aerospace Laboratories, P.O. Box 1779, Bangalore 560 017, India

Available online 30 January 2006, Sciencedirect, Elsevier Ltd

S.K.Bhaumik and M. Sujata (2006) [8] had done the failure of low pressure turbine rotor blade of aero engine. An aero engine the operating temperature achieves higher and higher engine power and efficiency. Thus it is necessary temperature withstanding capabilities of material use their contraction which is developing at great challenges. Basically Ni-base super alloy are use in gas turbine blade and blade were coated with platinum alminide.In aero engine gas turbine operate generally high temperature and it can operate at below 900^{o}C.in Ni-base super alloy has high temperature mechanical properties. Thus the advantages of high temperature capacity of super alloy have been achieved by optimizing the alloying contains to a maximum limit.

Fig7: Fracture of LPTR

In this paper failure of aluminum coated low pressure turbine rotor blade of aero engine is presented. It concluded that failure of low pressure turbine blade due to variation in engine cause by crack in aluminide coating layer.

9. "Common failures in gas turbine blades"

Author/publisher Tim J Carter

P.O. Box 1535, Roosevelt Park, Johannesburg 2129, South Africa

Accepted 1 July 2004, Sciencedirect, Elsevier Ltd

Tim J Carter (2004) [9] did studies the common failure of gas turbine blade. The modern gas turbines are use in aviation application generally high level of reliability and failure rate consider low. The turbine blades operate at elevated temperature at very edge of metallurgical alloy development. There are three probable damage effects on the turbine blades, this belong to high temperature corrosion, mechanical damage through creep and fatigue. The use of light alloy at high temperature section in the engine and it not feasible hence they cannot be design to give acceptable creep properties at high temperature needed for turbine operation. In aluminum alloy the property temperature is above the melting point.

The most common material for turbine blade are nickel base super alloy material. These alloys are able to withstand the very aggressive environment of high temperature and high stress found within the hot gas path of turbine engine. Nickel base super alloy turbine blade material has level of resistance to creep. This paper concluded that elimination fatigue and creep in turbine blade at that time of design stage.

10. Failure analysis of a second stage blade in a gas turbine engine

Author/publisher Poursaeidi , M. Aieneravaie, M.R. Mohammadi

Department of Mechanical Engineering, Zanjan University, Zanjan, Iran

Available online 14 December 2007, Sciencedirect.

E. Poursaeidi and M.R.Mohammadi (2007) [10] have studied the failure analysis of second stage blade in gas turbine engine. The failure of second stage gas turbine blade was investigated by mechanical and metallurgical examination of a fail blade. Blade materials are generally nickel base and cobalt base super alloy because of this super alloy has better strength at elevated temperature. This make suitable for fabrication of gas turbine component.

They identify the cause of failure blade in gas turbine blade the complete investigation has been carried out both mechanical analyses and metallurgical examination. Metallurgical examination can very effective to determining whether failure is related to mechanical mark or poor surface finish.

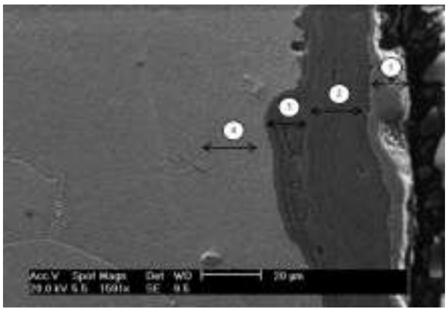

Fig8: Region of microprobe analysis

Micro structural evaluations find the blade airfoil near to failure of surface and blade root. There are lots of cracks of initialization of surface. During mechanical analysis it was found a distinct accordance between the results of vibration of turbine blade fracture across the blade airfoil due to the formation of non protective nickel and cobalt oxide.

11. "Study on the root causes for the premature failure of an aircraft turbine blade"

Author/publisher E. Silveira, G. Atxaga, E. Erauzkin, A.M. Irisarri

INASMET – Tecnalia, Automotive Unit, Mikeletegi Pasealekua 2, 20009 San Sebastian, Spain

Available online 4 March 2008, Sciencedirect.

E. Silveira (2008) [11] had studied the root cause premature failure of set of blade belonging to a high pressure turbine of an aircraft engine has been carried out. The blade can manufacture by harden nickel alloy. Basically use of nickel base super alloy in gas turbine component due to high temperature and high pressure contain is wildly extended.

This study contain in photographic analysis by scanning electron microscopy and microstructural examination by scanning electron microscopy and identify this phase of X-ray energy dispersive spectrometry. The first step in study in visual examination of gas turbine blades and find out causes of blade fracture with the help of both optical and scanning electron microscope

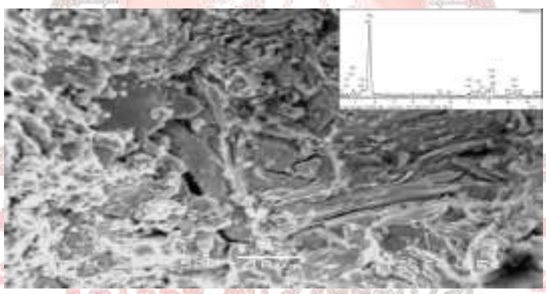

Fig9: Carbide on fracture surface of blade

They found that fracture surface blade due to presence of large carbide and their impact factor. This paper concluded that the failure of blade due to thermo mechanical fatigue and contribution of creep.

12. "Study on Design of Turbine Blade and failure analysis"

Author/publisher Ganta Nagaraja

International Journal of Innovative Research in Engineering science and technology. Available online 2008

Ganta Nagaraj (2008) [12] have did studied of the various failure of mechanism and the general practice followed by a blade designer for design blade geometry and blade configuration. The study concluded that design and analysis of gas turbine blade can carry out optimization, Finite element result for free standing blade give a complete structural characteristic, which can utilize for improvement in design and optimization of operating condition.

on the Blade Cross-Section

Chemical composition of Inconel 738LC superalloy (wt%)

Alloy	Ni	C	Cr	Co	Mo	W	Al	Ti	B
IN 738LC	Bal	0.11	16	8.5	1.75	2.6	3.4	3.4	0.01

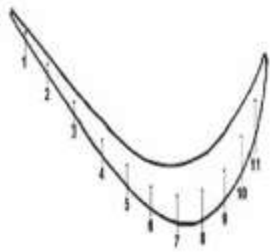

Fig10: point of hardness measurement

CONCLUSION

By studying the literature available on gas turbine blade the improvements in blade life can be done by performing CAE analysis. Hence FEA and CFD process are most sophisticated process for gas turbine study.

The pre-stressed modal analysis of the dynamic characteristics of the blade during service shows that the second vibration mode of the blade is most critical because the maximum stress corresponding to this mode is coincident with the point of crack initiation. The first bending mode, which is the one most easily excited, is not associated with blade failure.

Spotty attack by hot-corrosion was also observed in un-worn areas of the blades and lining. Nevertheless, the deterioration was very lean and localized. It seems that hot corrosion, caused by sodium sulphate was not solely able to produce the observed failure.

Cracks were found in the cooling holes to 0.4 mm deep. It was evaluated that crack initiation/propagation was derived from a mixed fatigue/creep mechanism. Substrate crack initiation and propagation was facilitated due to grain boundary brittleness caused by formation of a grain boundary continuous film of carbides.

The engine failure was due to fatigue fracturing of a low pressure turbine blade. Excessive vibration in the engine is believed to have resulted in generation of shallow cracks in the brittle platinum aluminide coating layer. These cracks have acted as stress raisers and subsequently, a number of fatigue cracks had initiated at the coating – blade material interface, which propagated progressively across the thickness of the blades. Once the fatigue crack had reached a critical length in blade-A, it had fractured leading to other damages in the engine. The fatigue crack in blade-B was still below the critical length. Coating cracks in blades-C and D were developed during secondary damages following the primary failure in blade-A.

The catastrophic failure of the blade has occurred by the following sequence:

1. Formation of the non-protective nickel and cobalt oxides.

2. Formation of the chromium sulfide and depletion of the alloying elements.

3. Degradation of the metal beneath the scale.

4. Progression of the pitting over the concave and convex surfaces of the blade.

5. Deepening of the pits at the leading and trailing edges due to the bending stresses.

6. Development of the interdendritic corrosion at the leading edge and initiation of the crack.

7. The propagation of crack by the fatigue mechanism because of the vibration of blade in a resonant condition.

8. Reduction of the cross-section area and the final fracture at the trailing edge.

REFERENCE

[1] Jianfu Hou , Bryon J. Wicks, Ross A. Antoniou
An investigation of fatigue failures of turbine blades in a gas turbine engine by mechanical analysis
Airframes and Engines Division, DSTO Aeronautical and Maritime Research Laboratory, 506Lorimer Street, Fishermens Bend 3207, Melbourne, Victoria 3001, Australia
Accepted 25 December 2000, Sciencedirect, Elsevier Ltd.

[2] Krishnakant P V "Structural and thermal analysis of gas turbine blade by using F. E. M," International Journal and Science Research Engineering and Technology (IJSRET), Vol. 2, No. 2, pp 060-065.Available online January 2013.

[3] Z. Mazur, A. Luna-Ramirez a, J.A. Juarez-Islas, A. Campos-Amezcua
"Failure analysis of a gas turbine blade made of Inconel 738LC alloy"
A Instituto de Investigaciones Ele´ctricas, Av. Reforma 113, Col. Palmira, 62490 Cuernavaca, Morelos, Mexico
Available online 23 November 2004, Sciencedirect, Elsevier Ltd.

[4] J. Kubiak, G. urquiza, G. Castillo "Failure analysis of the 150 MW gas turbine blade" State university of moerlos, centro de investigation ingeniriag ciencisas aplicadas Universidad, CICAP, 1001, chamilpa,c.p. 62209

Available online 29 august 2008.

[5] Kyung Min Kim, June SU Park, Tack Woon Lee, "Analysis of conjugated heat transfer, stress and failure analysis in gas turbine blade with circular cooling passes" Department of Mechanical Engineering, Yonsei University Seoal 120-749, Republic of Korea Available online 8 march 2011.

[6]Liang Zheng, Chengbo Xiao, Guoqing Zhang "Brittle fracture of gas turbine blade caused by the formation of primary b-NiAl phase in Ni-base superalloy" Science and Technology on Advanced High Temperature Structural Materials Laboratory, Beijing Institute of Aeronautical Materials, Beijing 100095, China Available online 31 August 2012, Sciencedirect, Elsevier Ltd

[7] J.M. Gallardo, J.A. Rodriguez, E.J. Herrera Failure of gas turbine blades

Grupo de Metalurgia e Ingenier´ıa de los Materiales, E.S. de Ingenieros de la Universidad de Sevilla, Camino de los Descubrimientos s/n, 41092 Sevilla, Spain Accepted 5 November 2001, Sciencedirect. Elsevier Ltd

[8] S.K. Bhaumik, M. Sujata, M.A. Venkataswamy, M.A. Parameswara"Failure of a low pressure turbine rotor blade of an aeroengine" Failure Analysis Group, Materials Science Division, National Aerospace Laboratories, P.O. Box 1779, Bangalore 560 017, India Available online 30 January 2006, Sciencedirect, Elsevier Ltd

[9] Tim J Carter "Common failures in gas turbine blades"P.O. Box 1535, Roosevelt Park, Johannesburg 2129, South Africa Accepted 1 July 2004, Sciencedirect, Elsevier Ltd

[10] Poursaeidi , M. Aieneravaie, M.R. Mohammadi Failure analysis of a second stage blade in a gas turbine engine Department of Mechanical Engineering, Zanjan University, Zanjan, Iran Available online 14 December 2007, Sciencedirect.

[11] E. Silveira, G. Atxaga, E. Erauzkin, A.M. Irisarri "Study on the root causes for the premature failure of an aircraft turbine blade" INASMET – Tecnalia, Automotive Unit, Mikeletegi Pasealekua 2, 20009 San Sebastian, Spain Available online 4 March 2008, Sciencedirect.

[12] Ganta Nagaraja "Study on Design of Turbine Blade and failure analysis' International Journal of Innovative Research in Engineering science and technology. Available online 2008