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Review Article

REVIEW OF STRUCTURAL AND THERMAL ANALYSIS OF GAS TURBINE BLADE

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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. Since the turbine blades are working at high temperature and pressure there are extreme stresses developed on turbine blades. The first centrifugal stresses 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 present paper is review of various analyses done on turbine blades and there are various factors affects on turbine blade. This paper will be helpful for those who are working in the area of power plants.

Keywords: Turbine blade, Thermal analysis, FEM

INTRODUCTION

The turbine is a rotary mechanical device that extracts energy from a fluid flow and converts into useful work and purpose of turbine technology are to extract the maximum quantity of energy from the working fluid to convert it into useful work with maximum reliability, minimum cost, minimum supervision and minimum starting time.

Gas turbine are used extensively for aircraft propulsion, land based power generation and industrial application. Thermal efficiency and power output of gas turbine increases with increasing turbine rotor inlet temperature. The current rotor inlet temperature level in advanced gas turbine is far above the melting point of the blade material. Therefore, along with high temperature development, sophisticated cooling scheme must be developed for continuous safe operation of gas turbine with high performance.

Losses on the turbine consist of mechanical losses due to the friction of rotating parts or bearings, tip clearance losses due to the flow leakage through tip gap, secondary flow losses due to curved passages, and profile

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losses due to the blade shape, etc. More than 60% of total losses on the turbine is generated by the two latter loss mechanisms. These losses are directly related with the reduction of turbine efficiency. Turbine efficiency is the most important factor on the performance of heavy duty gas turbines for power plants, air turbines, or turbo expanders, etc. This efficiency is related very closely with losses in the passage.

REVIEW OF WORK CARRIED OUT

Soo-Yong Cho (2002) studied the Axial-Type 2-D Turbine Blade Shape for Reducing the Blade Profile Losses. A 10.8% reduction of total pressure loss on the turbine rotor is achieved by the process suggested by authors, which is same as a more than 1% total-to-total efficiency increase. The computed results were compared with those using 11 design variables, and show that optimized results depend heavily on the accuracy of blade design.

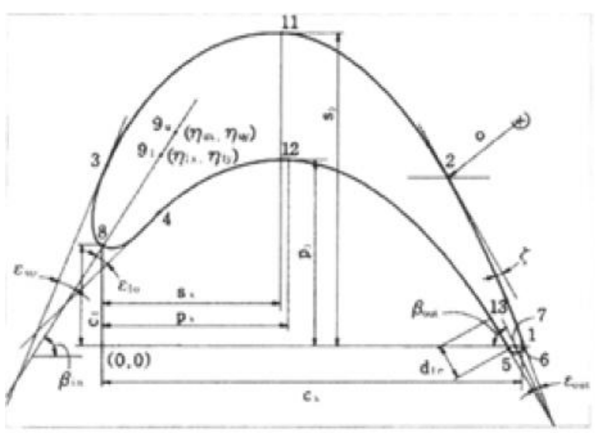
Table 1: List of Shape Parameters for Designing Axial-Type Turbine Blade Profiles

Blade Radius	(R)
Axial and tangential chord	(C_x, C_t)
Inlet upper wedge angle	(£$_{up}$)
Lower wedge angle	(£$_{lo}$)
Half of major axis of upper ellipse	(¦$_{ux}$)
Half of minor axis of upper ellipse	(¦$_{uy}$)
Half of major axis of lower ellipse	(¦$_{lx}$)
Half of minor axis of lower ellipse	(¦$_{ly}$)
Inlet blade angle	($_{In}$)
Exit blade angle	($_{out}$)
Unguided turning angle	(¸)
Number of blade	(N)

Table 1 (Cont.)

Blade Radius	(R)
Leading and trailing edge radius	(r_{le}, r_{te})
Leading and trailing edge turning angle	(©, ª)
Turning angle on pressure surface	(¨)
Peak point of suction surface	(S_x, S_y)
Peak point of pressure surface	(P_x, P_y)
Throat	(-)
Straight section of trailing edge	(d_{te})

Figure 1: Shape Parameters for Designing General Axial-Type Turbine Blades



John and Ramakrishna (2012) summarizes the design and analysis of Gas turbine blade, they have used CATIA and ANSYS software for modeling and analysis, by applying boundary condition, this paper also includes specific post processing and life assessment of blade.

Table 2: Results of Various Material Thermal and Structural Analyses

Structural analysis				
	Graphite	stainless steel	Titanium	With coating
Stress	352147	339.07	327.817	258.892
displacement	6.553	0.147608	256561	.0430927
Thermal analysis				
Temperature	533	533	533	533
Thermal gradient	76.638	715.055	605.119	72.591
Thermal flux	19.16	11.727	10.287	15.97

The paper conclude that using cast iron with partially stabilized zirconium coating is more beneficial than previous materials, due to low stress displacement, good thermal strength, low cost and easy to manufacture (John and Ramakrishna, 2012).

Deepanraj (2011) done the FEM analysis to analyze thermal and structural performance due to the loading condition, with material properties of Titanium- Aluminum Alloy.

Table 3: Temperature Distribution for Different Holes

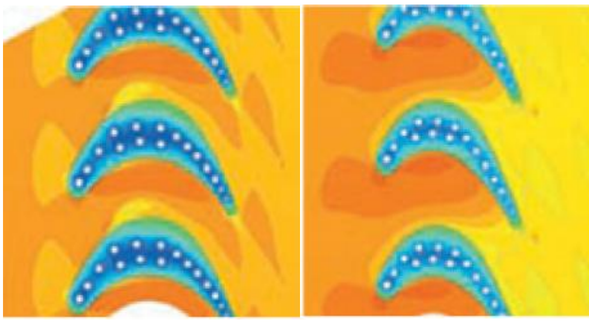
No. of holes	Temperature distribution (°C)
12	679.6
11	707.1
10	755.2
9	784.8
8	792.8
7	827.6

Six different models with different number of holes were analyzed in this paper to find out the optimum number of holes for good performance. it was found that the blade with 8 holes has the best temperature distribution when compared other configurations of the blade when the coolant temperature was 300 ºC (Deepanraj, 2011).

Krishnakanth (2013) did the structural and thermal analysis of gas turbine rotor blade using solid95 element. The results show that temperature has a significant effect on the overall turbine blades. Maximum elongations and temperatures are observed at the blade tip section and minimum elongation and temperature variations at the root of the blade. Maximum stresses and strains are observed at the root of the turbine blade and upper surface along the blade roots three different materials of construction, i.e., N-155, Inconel 625 and HASTEALLOY X materials. The blade temperatures attained and thermal stresses induced are lesser for Inconel 625 as it has better thermal properties.

Michel Arnal (2007) had done the CFD and CAE analysis of perforated type blade geometry of turbine for ANSYS Inc. in 2007. They have also done ANSYS CFX temperature simulation of the blade surface. Streamlines of result show flow from the inlet into the plenum and from the cooling channel outlets into the hot gas.

Figure 2: Temperature Contours in the Flow Field and Through the Blade



Sagar Kauthalkar (2008) had investigated the deformations and stresses induced in blade geometry they have found out the maximum elongations and temperatures are observed at the blade tip section and minimum elongation and temperature variations at the root of the blade. Temperature distribution is almost uniform at the maximum curvature region along blade profile. Temperature is linearly decreasing from the tip of the blade to the root of the blade section. Maximum stress induced is within safe limit.

Avinash Sarlashkar (2002) summarizes the architecture and capabilities of BladePro, an ANSYS based turbine blade analysis system with extensive automation for solid model and

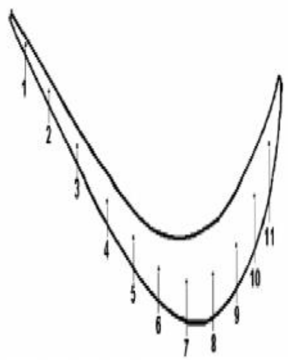
F.E. model generation, boundary condition application, file handling and job submission tasks for a variety of complex analyses.

Ganta Nagaraju (2008) had done the study which involves various failure mechanisms and the general practices followed by a blade designer for deciding a blade configuration. The studyconcluded that designs and generals of turbine blade to do further optimization, Finite element results for free standing blades give a complete picture of structural characteristics, which can utilized for the improvement in the design and optimization of the operating conditions.

Figure 3: Points of Hardness Measurement 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



Patil (2010) investigated the failures occurring in the blade geometry by various techniques like micro structure analysis, metallurgicaland mechanical examinations, etc. The fretting fatigue mechanism as the main cause of several premature failures of Ti_6Al_4V alloy compressor blades was characterized.

Daniel K and Van Ness II (2006) measured velocity, flow direction and total pressure within the clearancegap as well as blade surface and endwall static pressure in a five-bladed linear cascade for threeclearance gaps. They used a three-hole probe for measurements within the gap. They noted some separation bubbles near the pressure side corner, which took the form of vortices. They alsoconcluded that the regions close to the tip contributes little to the total leakage through the gap.

Majid Reazazadeh Reyhani (2013) had demonstrate and validated the methods used for calculating blade temperature and life. Using these methods, a set of sensitivity analyses on the parameter affecting temperature and life of a high pressure, high temperature turbine first stage blade is carried out. Result shows that increasing thermal barrier coating thickness by 3 times, lead to rise in blade of life by 9 times. In addition considering inlet cooling temperature and pressure, deviation in temperature has greater effect on blade life. One of the interesting point that can be realized from result is that 300 hours operation at 70% load can be equal to one hour operation at base load. The life estimation results demonstrated that the minimum life occurs at same point as maximum temperature. This indicate that most dominant factor for blade creep life is temperature and weakest point for fatigue failure mechanism is the fir-tree region of the blade.

Prasad (2013) used finite element analysis in the present work to examine steady state structural and thermal performance for N155 and Inconel 718 nickel chromium alloys. Four different models consisting of solid blade and blades with varying number of holes (5, 9 and 13 holes) were analyzed.

Table 4: Max Temperature vs No. of Holes

No. of Holes	0	5	9	13
N-155	1182.8	1000.1	901.75	826.96
Inconel 718	1181.7	990.2	889.25	816.59

It is found that Inconel 718 has better thermal properties as the blade temperatures and thermal stresses induced are lesser. On analyzing 4 different models with a varying no of holes, it is inferred that the blade model with 13 holes is best suited.

CONCLUSION

The main objective of this work is to taken an account of previous work carried out on gas turbine blade. From the review it can be noted that there are various factors like blade angle, blade geometry, number of perforated holes and the material of the blade can affect structural as well as thermal stresses. The cast iron with partially stabilized zirconium coating is more beneficial due to low stress displacement, low cost and easy to manufacture. The temperature has significant effect on the overall stresses induced in the turbine blades. The blade temperature attained and thermal stresses induced are lesser for Inconel 625 as it has better thermal properties. The blade with 8 holes has the best temperature distribution when compared other configurations of the blade when the coolant temperature was 300 ºC. The bending stresses are lower for the blade with 8 holes. Hence it can be conclude that gas turbine blade can be designed then performing FEM analysis by using ANSYS to check the failures and suggest the remedies for the same.

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