Heat Transfer Analysis Of Gas Turbine Blades

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Abstract- *Cooling of gas turbine blades is a major consideration in the design of gas turbine blades due to high operating temperature working conditions for greater thermal efficiency for the stage. Several methods of cooling of gas turbine blades coupled with innovative geometry for cooling passages are in existence. This work essentially incorporates two important modifications to the geometry of the cooling passage. Firstly an innovative circular holes on turbine blade in the area accessible near the leading edge has been incorporated. Secondly hexagonal holes on the blade for improved cooling through recirculation. Hence the overall enhancement in cooling rate due to both Circular and Hexagonal holes has been compared.*

Keywords- Cooling, circular holes, hexagonal holes, Turbine blades.

I. INTRODUCTION

Gas turbines have become one of the most important prime movers especially in aircraft propulsion, land-based power generation, and industrial applications. The greatest advantage of gas turbines is that it produces comparatively greater energy per unit size and weight. Its compactness, low weight and multiple fuel capability make it a natural choice for power plants for many diverse applications.

The gas turbine entry temperatures (TET) have risen considerably from the beginning of the 1970's from around 1500 K to over 2000 K for modern turbines (Adami et al. 2003). Nevertheless the need for an increase in thermal efficiency of gas turbine plant, both in industrial and aerospace sectors, still demands higher values of TET without compromising on the structural integrity of the turbine components. Thermal efficiency and power output of gas turbines increase with increasing turbine entry temperature. It is clear from Brayton cycle (Figure 1.1) that the major objective is to increase the turbine pressure ratio which increases the gas turbine thermal efficiency, accompanied by an increase in TET (Horlock et al. 2001).

Brayton cycle

This calls for a relook in the design of turbine engine and various associated components to achieve the above objective. The current TET level in advanced gas turbines is far above the melting point of the blade material. Further the variation in the temperature within the blade material (which causes thermal stresses) must be limited to achieve reasonable durability goals. Thus it is contingent to cool the turbine blades so that blade metal is within permissible metallurgical limits.

II. PROBLEM STATEMENT

Due to high centrifugal forces and high temperature working conditions the gas turbine blades are experiencing high stresses. Due to the high stresses in turbine blade there may be chance of failure or change in the shape of turbine blade. To prevent the failure or change in the shape of the turbine blade we should know the amount of stresses and deformation acting on the blade. The main intention of this work is to know the amount of heat acting on the gas turbine blade and to come up with an idea to minimize the temperature and increase the life of gas turbine blade. In the present work gas turbine blade has been analysed for static structural, steady state thermal and modal analysis.

III. PROJECT OBJECTIVE AND METHODOLOGY

OBJECTIVES

1. To analyze the effect aerodynamic performance Gas turbine blade
2. To develop a novel approach to enhance the gas turbine blade cooling by innovative cooling duct geometry in the leading edge region.
3. To investigate the effect of grooved passage for effective cooling of turbine blade trailing edge region

METHODOLOGY

1) The geometry was created using commercially available CAD software CATIA V5.
2) The geometry was imported to Design modeller of Ansys Workbench V15.
3) The geometry was meshed using Mechanical of Ansys Workbench V15.
4) The boundary conditions were applied to the turbine blade which was obtained from literature review.

5) Design of the turbine blade was optimised and analysed for different holes with same boundary conditions.

III. GEOMETRY DETAILS

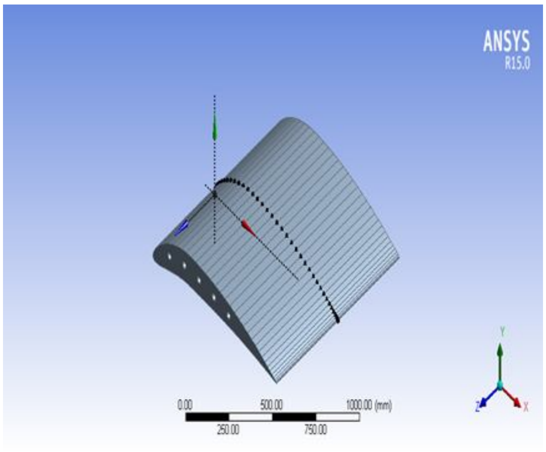
Design of gas turbine blade includes the insertion of circular and hexagonal holes on the turbine blade at the proper positions. By taking RAF 28 coordinates as reference turbine blade profile has been obtained. Using CATIA V5, the required design of turbine blade is created as follows.

For 5 circular holes

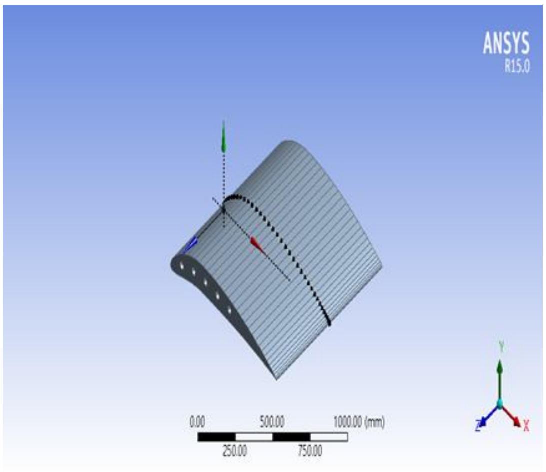
SYMBOLS	DIMENSIONS
D19, D20, D21, D22, D28	25
H30, H31, H32, H33, H34	120
V37, V40, V41	75
V38, V39	95

For 5 hexagonal holes

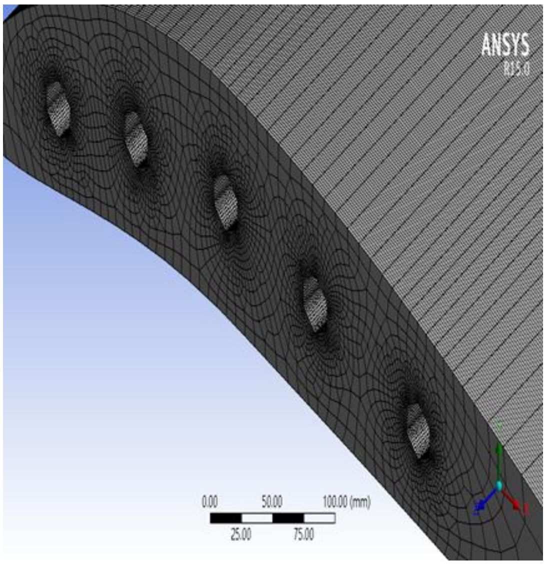
SYMBOLS	DIMENSIONS(mm)
L1, L2, L3, L4, L5	16
H8, H9, H10, H11, H12	85
V13	55
V15	85
V16	95
V17	92
V18	85



Turbine blade with 5 circular holes



Turbine blade with 5 hexagonal holes



Meshed view of turbine blade

Statistics	
Nodes	3371
Elements	3255

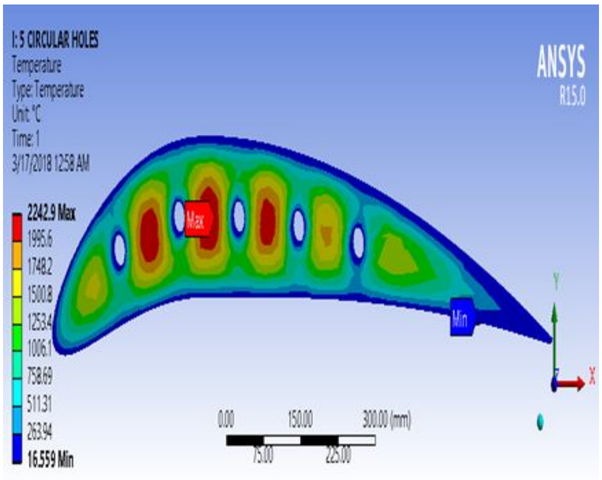
IV. BOUNDARY CONDITIONS

Boundary conditions were set to simulate the flow around turbine blade : on the inlet boundary, velocity components of uniform stream with the given inflow speed were imposed; on the exit boundary the other variables were extrapolated; on the outer boundary, the symmetry boundary condition was imposed; on the blade and hub surface, the no-slip condition was imposed. The inlet is specified as 'velocity inlet', with the velocity normal to the wall, the velocity and the rate of revolution for various load condition

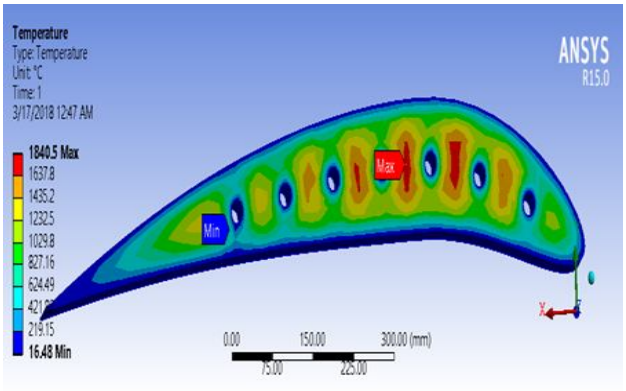
1. Constant temperature throughout the blade
2. Forced convection at the velocity of 60kmph=16.66ms-1 Laminar flow is assumed
3. Atmospheric pressure is been assumed
4. Nickel or Titanium material is considered as it has low oxidation affinity and high temperature stability
5. The turbine blade is assumed to be isolated and only 2 Dimensional analysis has been undergone
6. For 3-D analysis, the material is Titanium and its different properties are
   Density = 4620 kg/m3, Young's modulus = 9.6E+10Pa, Poison's ratio= 0.36.

V. RESULTS AND DISCUSSIONS

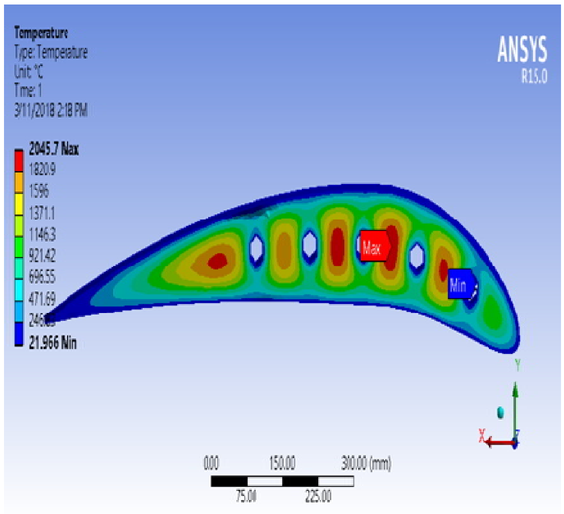
Below figures clearly shows the temperature distribution between turbine blade with circular and hexagonal holes. It shows that blade with hexagonal holes has better cooling effect than turbine blade with circular holes.



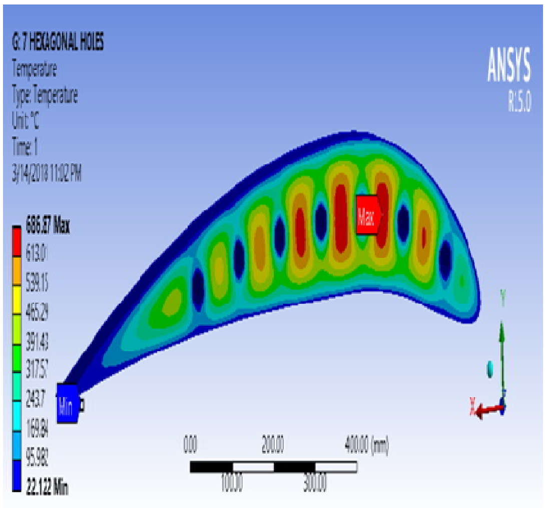
Temperature distribution for blade with 5 circular holes



Temperature distribution for blade with 7 circular holes



Temperature distribution for blade with 5 hexagonal holes



Temperature distribution for blade with 7 hexagonal holes

VI. CONCLUSION

The simulations are ran for RAF 28 airfoil without holes with considering Temperatures. Simulations are ran for turbine blades without holes in the combination with and without considering Temperatures.Temperature distribution over the turbines for without holes clearly shows the heat transfer rate in between the blades. Furthermore studies is required for the advancements of the turbine.

From the 3-D analysis the temperature distribution between turbine blade with 5 circular and 5 hexagonal holes has been observed. It shows that blade with hexagonal holes has better cooling effect than turbine blade with circular holes. Similarly in case of blades with 7 holes.

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REFERENCES

[1] Webb, R.L.et al.,int.j.heat mass transfer, 14(4), 1971

[2] Han, J.C.et al.,int.j.heat mass transfer, 21, 1143, 1978

[3] Gee, D.L. and Webb, R.L.,int.j.heat mass transfer, 23, 1127, 1980

[4] Sang Woo Lee ,Seon Ung Kim, KyoungHoon, Aerodynamic performance of winglets covering the tip gap inlet in a turbine cascade International Journal of Heat and Fluid Flow 34 (2012) 36–46

[5] Heeyoon Chung, Jun Su Park, Ho-SeongSohn, Dong-Ho Rhee, HyungHee Cho. Trailing edge cooling of a gas turbine blade with perforated blockages with inclined holes International Journal of Heat and Mass Transfer 73 (2014) 9–20

[6] M. Papa,R.J. Goldstein, F. Gori. Numerical heat transfer predictions and mass/heat transfer measurements in a linear turbine cascade Applied Thermal Engineering 27 (2007) 771–778

[7] Yao Yu , Zhang Jing-zhou, TanXiao-ming, Numerical study of film cooling from converging slot-hole on a gas turbine blade suction side ,International Communications in Heat and Mass Transfer 52 (2014) 61–72

[8] HMohammad H. Albeirutty, Abdullah S. Alghamdi, Yousef S. Najjar., Heat transfer analysis for a multistage gas turbine using different blade-cooling schemes ,Applied Thermal Engineering 24 (2004) 563–577