Thermal and Structural Analysis of Blade using Radial Cooling Holes

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Abstract— **Gas turbines are used for a/c propulsion and industrial applications. The thermal efficiency improved by increasing turbine inlet temperatures. The cooling systems are required for continuous safe operation of gas turbines. Different methods have been suggested for the cooling of the blade and one such technique is to have radial holes to pass high velocity cooling air along the span.**
The turbine blade designed with no holes, six holes and eight holes. The heat transfer analysis is done in CFD software FLUENT (a turbulence reliable k-e model with enhanced wall treatment.) The present used material for blade is Inconel 625, N-155 and Hoste alloy, while comparing these results, Hoste alloy has proved to have better thermal properties and also induces stresses are less than Inconel 625 and N-155.

Keywords— *CFD software fluent, Thermal and Structural analysis, blade materials like Inconel 625, N-155 and Hoste alloy etc.*

I. INTRODUCTION TO TURBINE BLADE

A turbine blade is the individual component which makes up the turbine section of a gas turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. The turbine blades are often the limiting component of gas turbines. To survive in this difficult environment, turbine blades often use exotic materials like super-alloys and many different methods of cooling, such as internal air channels, boundary layer cooling, and thermal barrier coatings.

A. BLADE MATERIALS

1. **Inconel 625:-** Material properties are Young's modulus 150000 MPa, Poisson's ratio 0.31, Density 8400 Kg/m^3, Thermal conductivity 10 W/m.K
2. **N 155:-** Young's modulus 143000 MPa, Poisson's ratio 0.33, Density 8249 Kg/m^3, Thermal conductivity 20 W/m.K
3. **Hoste alloy :-** Material properties are Young's modulus 144000 MPa, Poisson's ratio 0.348, Density 8300 Kg/m^3, Thermal conductivity 20 W/m.K

B. METHODS OF COOLING

Components of the gas turbine blade are cooled by air or liquid cooling. For air cooling the less quantity of air required such as 1.5-3% of main flow and blade temperature can be reduced by 250-300^{0}C.there are many types of cooling used in gas turbine blades.

1. **Internal cooling**
   - Convection cooling
   - Impingement cooling
2. **External cooling**
   - Film cooling
   - Cooling effusion
   - Pin fin cooling

II. LITERATURE SURVEY

Theju V et.al.[1]- the aim of the project is to design and analyze blade.an investigation for the usage of new materials is required. in present work, turbine blade was designed with two different materials (Inconel 718 &Titanium T-6)

K. HariBrahmaiah et.al.[2]- Structural &Thermal analysis done for two different material(Chromium steel & Inconel 718) in ANSYS Software. the better material for the blade analyzed.invastigation is carried out for blade without holes and with no of holes like 5,9 and13 holes.

V. Veeraragavan et.al.[3]- in this project work by using FEA the prediction of the location of possible temperature areas on turbine blade will be done and examine suitable material for the blade of gas turbine engine..

Shridhar Paregouda et.al.[4]- in this work the predictions Reynolds-Averaged Navier-Stokes solution for a baseline Flat film cooling geometry will be the analyzed and compared with experimental data.analysis is carried with software like CFD and FEA. Three film-cooling holes with different hole geometries including a standard cylindrical hole and two holes with a diffuser shaped exit portion (i.e. a fanshaped and a laidback fanshaped hole) will be studied.

III. METHODOLOGY

1. **Types of analysis-**
   - **Structural** analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed.

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- **Vibrational** analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibrational frequency of the material which, in turn, may cause resonance and subsequent failure.
- **Heat Transfer** analysis models the conductivity or thermal fluid dynamics of the material or structure.

2. Basic steps to perform CFD analysis-
I) Preprocessing-
A. 3D Models of Blade
1. Blade without hole
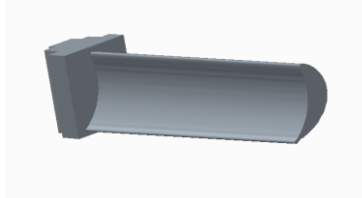
Fig.1 without hole

2. Blade with six holes
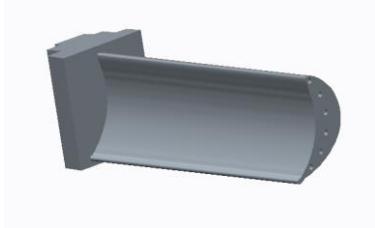
Fig.2 with six holes
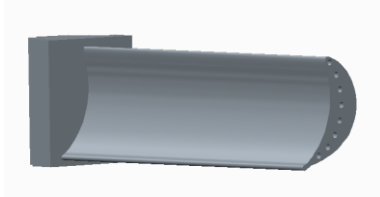
3. Blade with eight holes

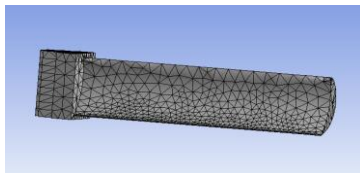

Fig.3 with eight holes

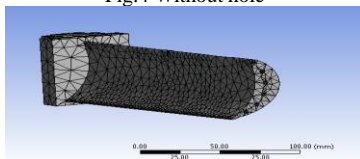### B. Meshing-

Fig.4 Without hole
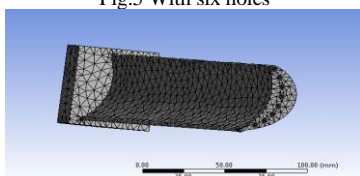

Fig.5 With six holes

Fig.6 With eight holes

II) Solution-
The dataset prepared by the preprocessor is used as input to the finite element

Code itself, which constructs and solves a system of linear or nonlinear algebraic equations are

$$K_{ij}\, u_j = f_i$$

Where u and f are the displacements and externally applied force at the nodal points. The formation of the K matrix is dependent on the type of problem being attacked, and this module will outline the approach for truss and linear elastic stress analyses. Commercial codes may have very large element libraries, with elements appropriate to a wide range of problem types. One of FEA's principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library.

III) Post processing-
This process used for viewing and interpretation of result. The results can be viewed in various animations, graph etc.

IV. RESULT ANALYSIS
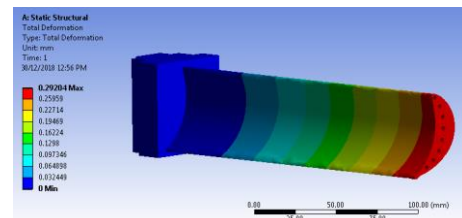### A. Structural Analysis of Blade with 8 holes hoste alloy
1. **Deformation**

Fig.7 Deformation in blade with eight holes hoste alloy

2. **Strain**
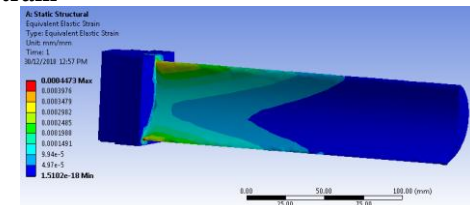

Fig.8 Strain in blade with eight holes hoste alloy
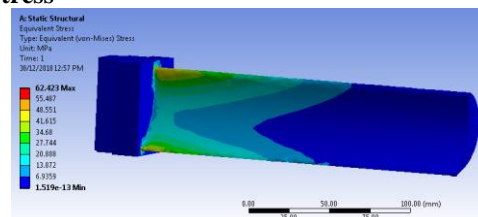
3. **Stress**

Fig.9 Stress in blade with eight holes hoste alloy

B. Thermal Analysis with 8 holes hoste alloy
1. **Temperature**

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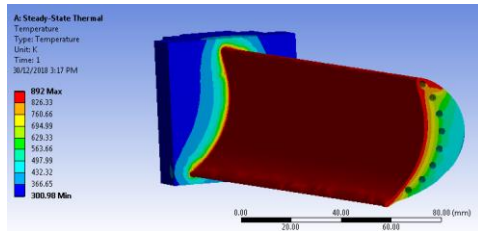**Vol. 8 Issue 12, December-2019**

Fig.10 Temperature distribution profile
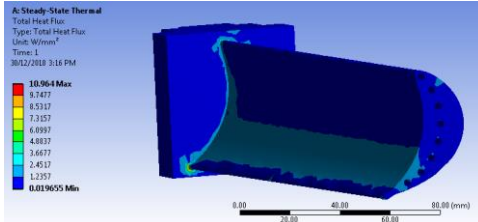
2. Heat Flux

Fig.11 Heat Flux distribution profile

C. Final Results Table
1. CFD Analysis

	Pressure (Pa)	Velocity (m/s)	Temperature (K)	Heat transfer coefficient (W/m² K)
Without holes	6.61e+04	9.16e+02	8.92e+02	1.90e+03
With 6 holes	6.52e+04	9.22e+02	8.92e+02	1.88e+03
With 8 holes	6.36e+04	9.39e+02	8.92e+02	1.82e+03

Table 1: CFD Analysis

2. Structural Analysis

	Deformation (mm)		
	N-155	Hoste alloy	Inconel 625
Without holes	0.26811	0.26609	0.25636
With 6 holes	0.29095	0.28883	0.27836
With 8 holes	0.29418	0.29204	0.28144

Table 2: Deformation Results

	Strain		
	N-155	Hoste alloy	Inconel 625
Without holes	0.00033798	0.00033442	0.00033064
With 6 holes	0.0003875	0.00037300	0.00037300
With 8 holes	0.0004501	0.0004473	0.00042667

Table 3: Strain Results

	Stress (MPa)		
	N-155	Hoste alloy	Inconel 625
Without holes	48.048	47.873	49.341
With 6 holes	55.029	54.956	55.673
With 8 holes	62.356	62.423	61.831

Table 4: Stress Results

3. Thermal Analysis

	Temperature min (k)			Heat Flux (W/mm²)		
	N-155	Hoste alloy	Inconel 625	N-155	Hoste alloy	Inconel 625
Without holes	299.63	302.53	295.92	2.1303	2.5255	1.4554
With 6 holes	298.95	301.48	293.79	2.2145	2.6491	4.1881
With 8 holes	298.6	300.98	279.68	9.1879	10.964	5.2543

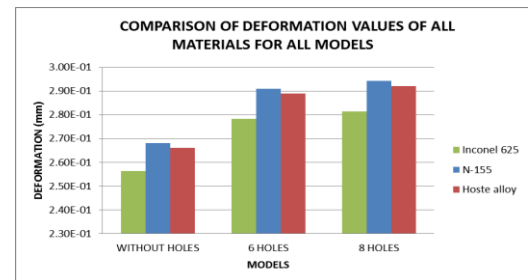Table 2: Thermal Analysis

4. Comparison Analysis Graphs

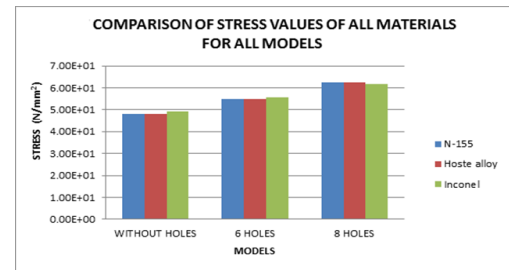Fig.12 Graph for deformation vs models

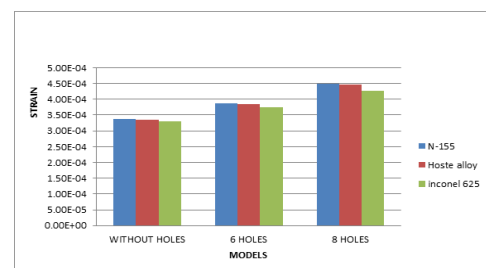Fig.12 Graph for stress vs models
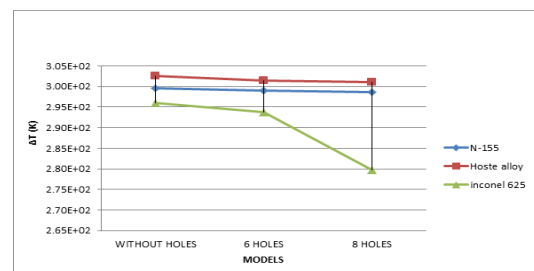

Fig.12 Graph for strain vs models

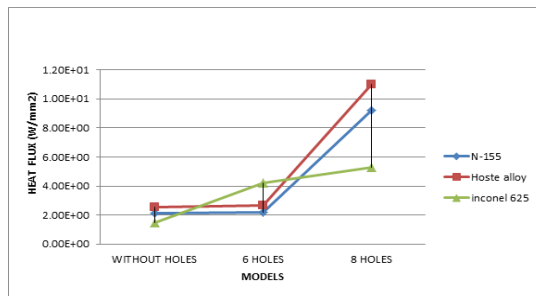Fig.13 Graph for temperature difference vs models

Fig.12 Graph for heat flux vs models

V. CONCLUSION

The turbine blade is designed with no holes, 6 holes and 8 holes for blade cooling purpose with materials like N-155, Inconel 625, Hoste alloy respectively. By observing the structural analysis results, the stresses are increasing with increase of number of holes. By comparing the results, they are less for material Inconel 625. The stress values for all materials are less than the respective yield stress values. So using all the 3 materials is safe under given load conditions. Similarly by observing the thermal analysis results, the heat transfer rate is increasing by increasing the no. of holes and it is more for Hoste alloy. So from the above two analysis it can be concluded that providing 8 holes for Hoste alloy is better.

REFERENCES:

[1] Theju V, Uday P S , PLV Gopinath Reddy, C.J.Manjunath, Design and Analysis of Gas Turbine Blade, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 6, June 2014

[2] K. HariBrahmaiah, M. Lava Kumar, Heat Transfer Analysis of Gas Turbine Blade Through Cooling Holes, ISSN (e): 2250 – 3005 || Vol, 04 || Issue, 7 || July – 2014 ||International Journal of Computational Engineering Research (IJCER)

[3] V.Veeraragavan, Effect Of Temperature Distribution In 10c4/60c50 Gas Turbine Blade Model Using Finite Element Analysis, International Journal of Engineering Research & Technology, Vol.1 - Issue 10 (December - 2012), e-ISSN: 2278-0181

[4] K. Takeishi, S. Aoki, T. Sato and K. Tsukagoshi, Film Cooling on a Gas Turbine Rotor Blade, J. Turbomach 114(4), 828-834 (Oct 01, 1992) (7 pages), doi:10.1115/1.2928036

[5] M. Y. Jabbari, K. C. Marston, E. R. G. Eckert and R. J. Goldstein, Film Cooling of the Gas Turbine Endwall, J. Turbomach 118(2), 278-284 (Apr 01, 1996) (7 pages), doi:10.1115/1.2836637

[6] A. Immarigeon, Discrete-Hole Injection by An advanced impingement/film cooling scheme for gas turbines – numerical study, International Journal of Numerical Methods for Heat & Fluid Flow, Vol. 16 No. 4, 2006, pp. 470-493