

SIMULATION BASED INVESTIGATION ON HEAT DISSIPATION IN VENTILATED GAS TURBINE BLADE

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Abstract: In this work a typical gas turbine blade is considered and studied using different vent configurations. Here the temperature rise in cooling fluid is considered as a scale of better heat transfer from the blade surface. Inconel 718 is taken as blade material and air and steam are considered as cooling fluids at three different temperatures 100°C, 200°C and 300°C for better study. All the results and observations are discussed briefly in the conclusion. To carry out this work CATIA V5 is used for modeling and ANSYS 15.0 is used for simulation.

INTRODUCTION

A device which absorbs a portion of the energy of the fluid in motion, and convert this energy into mechanical work, rotating output, on a shaft, is called turbine. The fluids used are typically air (wind), steam and water. Gas turbine engines are the one which use combusted products of compressed air and fuel to drive its turbine.

It is highly desired that the gas turbine to have highest efficiency within the operational parameters. One way to achieve this state is to raise the temperature of the gases entering the turbine section, because higher temperature, higher the velocity of the fluids. However the degree to which this temperature can be raised is dependent on the ability of the turbine material to maintain these temperatures without deterioration. Most commonly used materials can barely withstand 1300°C. Thus, to increase the inlet temperatures to the maximum we need to make use of modern alloys and ceramics, thermal barrier coating and blade cooling technology.

There are many ways to achieve cooling of the turbine blade; they are broadly classified into two categories: internal cooling and external cooling. One such method is to have holes made radially from hub to the tip of the blade, through these holes the cooling air is passed out with high velocity. The temperature of the blade is reduced by heat transfer via forced convection between blade and the cooling fluid, to remain in the allowable range.

LITERATURE REVIEW

K. Hari Brahmaiah et.al.[1]- blade models without holes, with holes of dimension 5, 9 and 13 units were made. They were analysed for total heat transfer rate and temperature distribution, with materials chromium steel and inconel718. The optimum model is the one with 13 holes. In the result inconel718 was found to have less induced stress and overall better thermal properties.

R. D. V. Prasad et.al.[2]- finite element analysis was done on four models, one solid body and others with holes of 5, 9 and 13 units to examine steady state thermal and structural aptitude of N155 and inconel718 alloys. This was done to find number of cooling holes which were optimal. For high temperature application inconel718 was found to be better. The graph for temperature distribution, von-mises stresses and deflection were studied and it was conclude that the blade with 13 holes is optimal, because of low induced stresses and blade temperature close to required temperature 800°C.

B. Deepanraj et.al.[3]- finite element analysis of thermal and structural performance of six models with number of holes 7, 8, 9, 10, 11 and 12 with material properties of Titanium – Aluminium alloy were carried out to find optimal number of holes. First a thermal analysis then a structural analysis is carried out. Temperature distribution graph were plotted. It was found that with the increase in number of holes from optimal number the distribution of temperature decreases. For this study model with 8 holes was found to be optimal

FORMULAS

Specific heat

$$C_p(T) = A_1 + A_2.T + A_3.T^2 + \dots + A_n.T^{n-1}$$

Thermal conductivity

$$\lambda(T) = \lambda_n + \frac{\lambda_{n+1} - \lambda_n}{T_{n+1} - T_n} \cdot (T - T_n)$$

Viscosity

$$\mu = \mu_o \cdot \left(\frac{T}{T_o}\right)^n$$

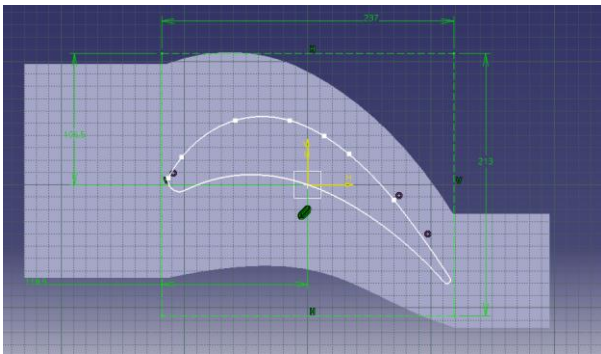
MODELING

DESIGN OF THE PRODUCT THROUGH CATIA:

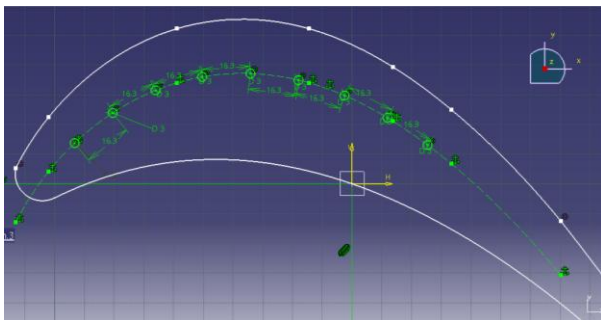
There are different modules in CATIA using which a model with required specifications can be designed. Most of the components designed using CATIA are sketched placed and derived figures. Unlike a sketched feature, the placed feature is created without drawing a sketch that defines the shape of the sketched feature. The sketcher workbench provides space and tools for drawing sketches of the solid model.

The manufacturing industries need to consider the demands of customer and thereby the market while manufacturing a product. In order to meet these requirements in an accurate way, synthesis and analysis of the performance of product must be studied prior to its manufacture. Synthesis is crucial to design an analysis. A financial estimate to transform the idea of conceived product into reality is also made with the help of synthesis. Various mechanical properties and functionality of the designed model can be predicted accurately during analysis process. By synthesis of the product virtually, it becomes easier for the manufacturers to get a better idea of the product to be manufactured.

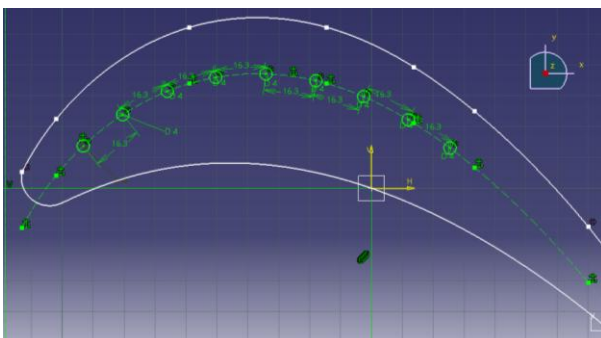
Model 1 blade without vents



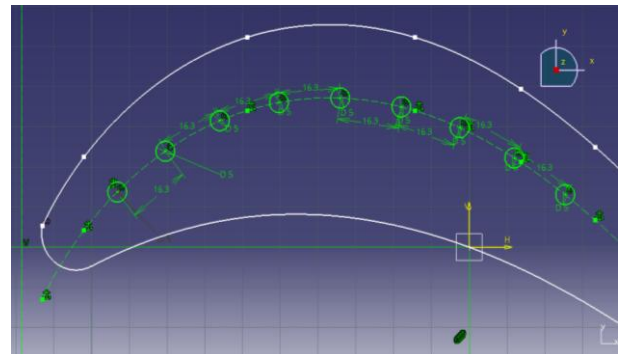
Model 2 with circular vents (3mm Diameter)



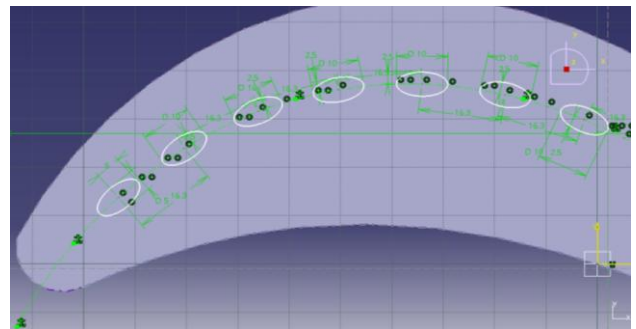
Model 3 with circular vents (4mm Diameter)



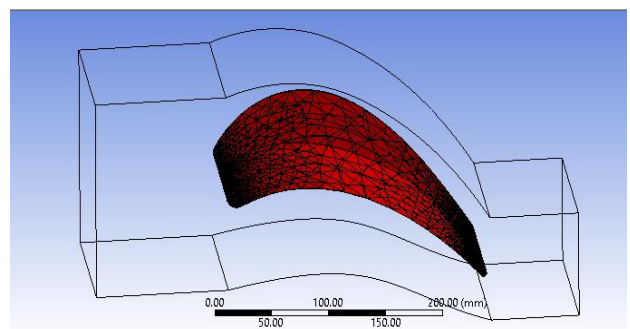
Model 4 with circular vents (5mm Diameter)



Model 5 with elliptical vents

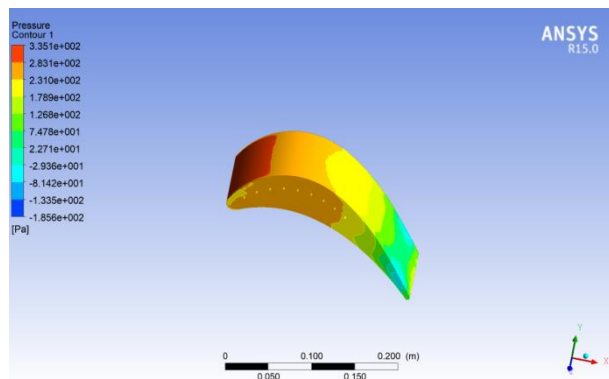


Blade mesh surface inside flow volume



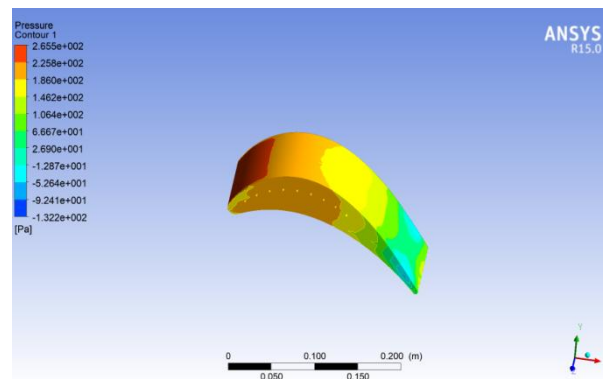
ANALYSIS

Case 7 results for model 2 with air at 100° C.

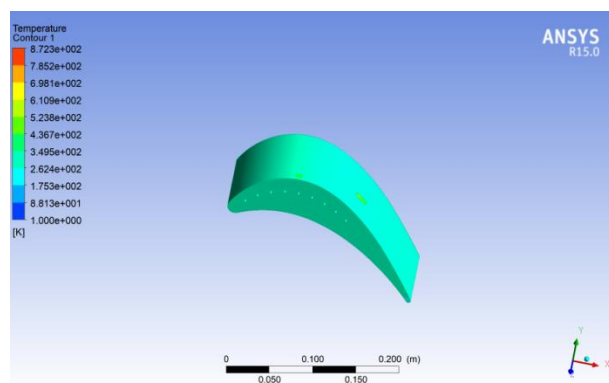


Picture Representing pressure of model 2 with air at 100° C.

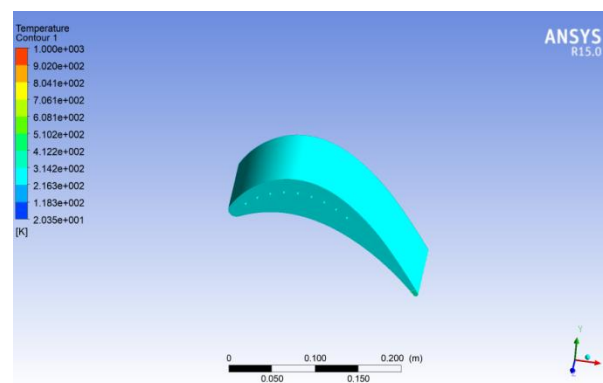
Case 8 results for model 2 with air at 200° C.



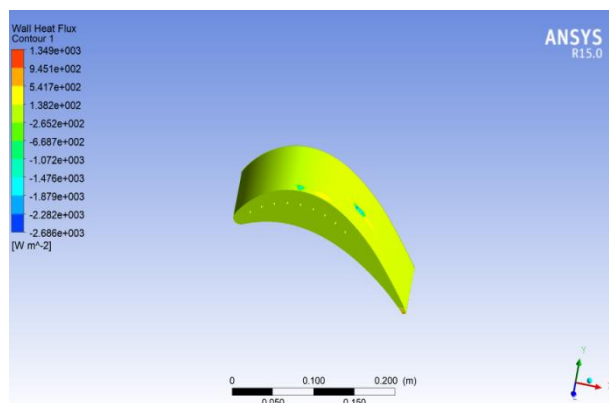
Picture Representing pressure of model 2 with air at 200° C.



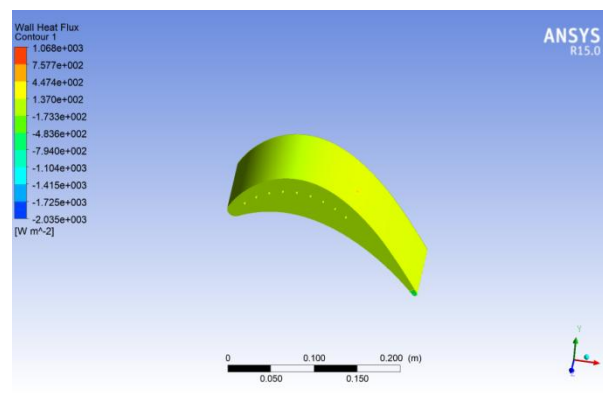
Picture Representing temperature of model 2 with air at 100° C.



Picture Representing temperature of model 2 with air at 200° C.

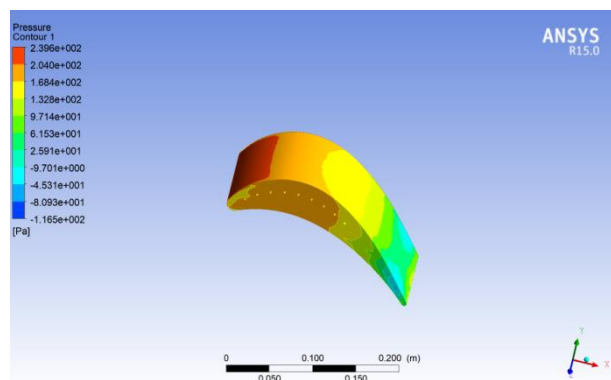


Picture Representing wall heat flux of model 2 with air at 100° C.

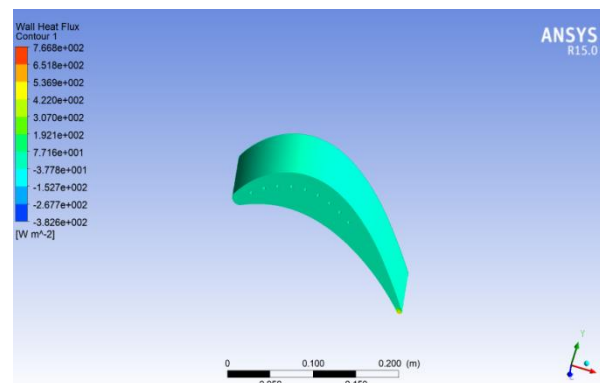


Picture Representing wall heat flux of model 2 with air at 200° C.

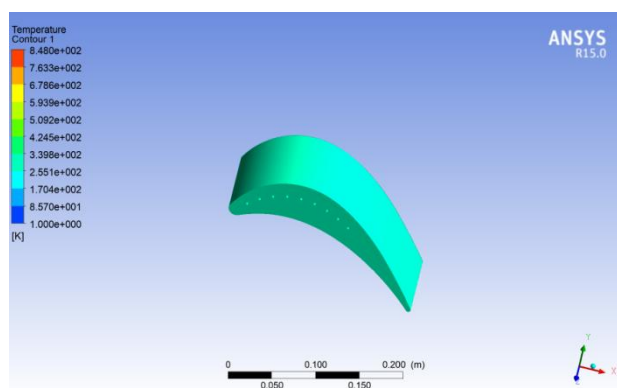
Case 9 results for model 2 with air at 300° C.



Picture Representing pressure of model 2 with air at 300° C.



Picture Representing wall heat flux of model 2 with air at 300° C.



Picture Representing temperature of model 2 with air at 300° C.

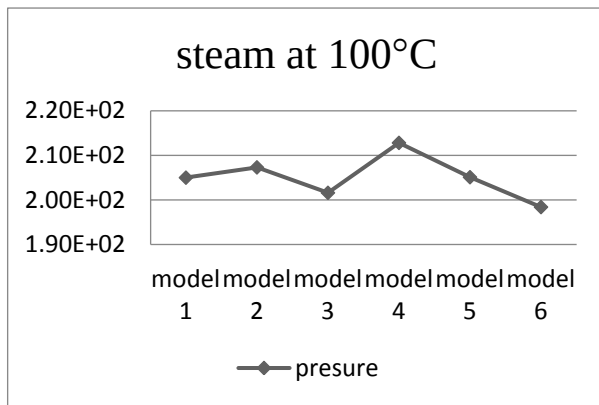
REPORT

1. Table containing values of various models with air at 100° C as coolant.

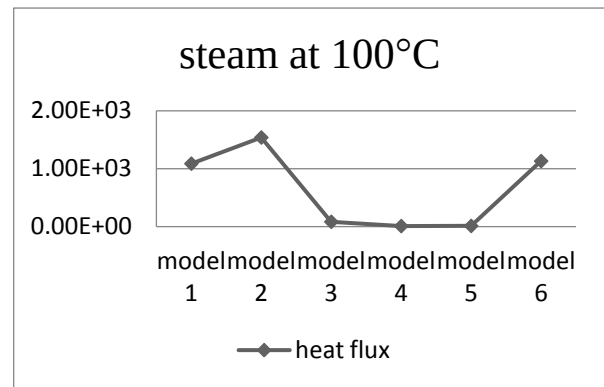
Air at 100°C	Pressure		Temperature		Heat flux	
	min	max	min	max	min	max
model 1	-1.54E+02	3.32E+02	1.79E+02	5.97E+02	-2.95E+03	1.15E+03
model 2	-1.86E+02	3.35E+02	1.00E+00	8.72E+02	-2.69E+03	1.35E+03
model 3	-1.62E+02	3.28E+02	2.51E+02	6.95E+02	-3.22E+01	6.87E+01
model 4	-1.55E+02	3.99E+02	2.00E+02	5.00E+02	-9.02E+00	1.28E+04
model 5	-1.01E+03	1.74E+02	3.00E+02	5.00E+02	-1.31E-02	1.33E-02
model 6	-1.73E+02	3.25E+02	1.32E+02	9.18E+02	-1.54E+02	1.04E+03

2. Table containing values of various models with steam at 100° C as coolant.

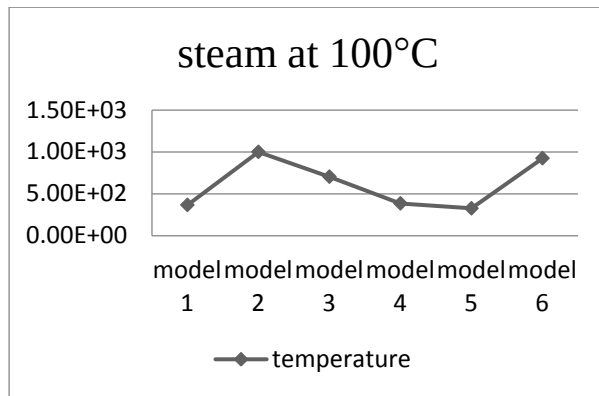
Steam at 100°C	Pressure		Temperature		Heat flux	
	min	max	min	max	min	max
model 1	-1.16E+02	2.05E+02	1.73E+02	3.67E+02	-2.95E+03	1.09E+03
model 2	-1.20E+02	2.07E+02	1.00E+00	1.00E+03	-3.12E+03	1.54E+03
model 3	-1.28E+02	2.02E+02	2.42E+02	7.04E+02	-2.78E+01	8.21E+01
model 4	-8.43E+01	2.13E+02	2.08E+02	3.86E+02	-2.54E+01	7.64E+00
model 5	-1.19E+02	2.05E+02	1.62E+02	3.27E+02	-2.55E+01	1.06E+01
model 6	-1.09E+02	1.98E+02	1.18E+02	9.24E+02	-4.70E+02	1.13E+03



Graph Representing pressure of various models with steam at 100⁰ C as coolant



Graph Representing heat flux of various models with steam at 100⁰ C as coolant



Graph Representing temperature of various models with steam at 100⁰ C as coolant

3. Table containing values of various models with air at 200⁰ C as coolant.

Air at 200°C	Pressure		Temperature		Heat flux	
	min	max	min	max	min	max
model 1	-1.55E+02	2.59E+02	4.06E+01	6.01E+02	-2.82E+03	2.79E+03
model 2	-1.32E+02	2.66E+02	2.04E+01	1.00E+03	-2.04E+03	1.07E+03
model 3	-1.15E+02	2.63E+02	2.61E+02	6.71E+02	-2.06E+01	6.47E+01
model 4	-1.09E+02	2.70E+02	3.00E+02	3.00E+02	-8.18E-03	1.27E-02
model 5	-1.10E+02	2.72E+02	1.72E+02	3.18E+02	-3.99E+01	3.78E+00
model 6	-1.33E+02	2.59E+02	1.47E+02	9.17E+02	-8.13E+01	8.64E+02

4. Table containing values of various models with steam at 200⁰ C as coolant.

Steam at 200°C	Pressure		Temperature		Heat flux	
	min	max	min	max	min	max
model 1	-1.50E+03	2.65E+03	1.39E+02	3.72E+02	-3.13E+03	1.19E+03
model 2	-1.55E+03	2.66E+03	1.00E+00	1.00E+03	-3.20E+04	8.22E+02
model 3	-1.67E+03	2.61E+03	9.09E+01	6.93E+02	-8.96E+02	8.91E+01
model 4	-1.08E+03	2.74E+03	3.00E+02	5.00E+02	-6.54E-03	1.41E-02
model 5	-1.58E+03	2.66E+03	3.00E+02	3.27E+02	-1.19E-02	1.17E-02
model 6	-2.90E+03	5.08E+03	3.00E+02	9.18E+02	-2.18E-02	1.94E-02

5. Table containing values of various models with air at 300° C as coolant.

Air at 300°C	Pressure		Temperature		Heat flux	
	min	max	min	max	min	max
model 1	-1.30E+02	2.15E+02	2.43E+02	3.52E+02	-2.68E+02	5.03E+02
model 2	-1.17E+02	2.40E+02	1.00E+00	8.48E+02	-3.83E+02	7.67E+02
model 3	-1.01E+02	2.16E+02	2.77E+02	6.44E+02	-2.11E+01	4.97E+01
model 4	-9.29E+01	2.25E+02	3.00E+02	3.00E+02	-8.50E-03	8.31E-03
model 5	-9.07E+01	2.24E+02	3.00E+02	3.56E+02	-4.67E+01	2.09E-02
model 6	-1.07E+02	2.14E+02	1.58E+02	9.10E+02	-1.23E+02	6.29E+02

6. Table containing values of various models with steam at 300° C as coolant.

Steam at 300°C	Pressure		Temperature		Heat flux	
	min	max	min	max	min	max
model 1	-2.34E+01	5.45E+00	3.00E+02	6.01E+02	-6.38E-03	6.41E-03
model 2	-1.70E+04	2.67E+03	3.00E+02	1.00E+03	-1.70E-02	1.57E-02
model 3	-1.63E+04	2.70E+03	3.00E+02	6.71E+02	-1.03E-02	1.05E-02
model 4	-1.68E+04	2.61E+03	3.00E+02	3.00E+02	-1.18E-02	8.23E-03
model 5	-3.27E+03	4.95E+03	3.00E+02	3.27E+02	-1.57E-02	1.88E-02
model 6	-2.90E+03	5.08E+03	3.00E+02	9.24E+02	-2.18E-02	1.94E-02

CONCLUSIONS

The observations made during the study are discussed below. The behaviour of cooling fluid is estimated by the maximum temperatures and heat fluxes recorded in the simulation, in total 36 cases are done. 6 different models are studied in which 5 are ventilated and one is a solid model, all the models are taken in an assumed flow volume, two cooling fluids are considered one is air and the other is steam. The temperatures of the cooling fluids are varied as 100°C, 200°C, 300°C.

1. The maintenance of heat in case of ventilated models is better when compared with base model.
2. In solid model the temperature of the flow volume is raised very less, even the fluxes are high.
3. There is significant pickup in temperature of the flow volume of the blade by introduction of the vents.
4. The performance of the vents is diminishing with increase of diameter of the vent from 3mm to 5mm
5. Introduction of elliptical vents in the model doesn't show much improvement in heat dissipation but it may help in maintaining the structural strength
6. Introduction of elliptical vent with serpentine profile improvised the dissipation significantly.

FUTURE SCOPE

This project is a pure simulation based project. This work can be carried forward by studying the heat dissipation behaviour for various materials of the blade, changing the numbers of the vents and changing the position of the vents for further optimising the model.

REFERENCES

- [1] K. Hari Brahmaiah, M. Lava Kumar, "Heat transfer analysis of gas turbine blade through cooling holes". International journal of computational engineering research (IJCER) Vol. 04, Issue 7, July-2014.
- [2] R. D. V. Prasad, G. Narasa Raju, M. S. S. Srinivasa Rao, N. Vasudeva Rao "Steady state thermal & structural analysis of gas turbine blade cooling system". International journal of engineering research & technology (IJERT) Vol. 2, issue 1, January-2013.
- [3] B. Deepanraj, P. Lawrence and G. Sankaranarayanan "Theoretical analysis of gas turbine blade by finite element method" scientific world. Vol. 9 no 9, July 2011.
- [4] G. Narendranath, S. Suresh "Thermal analysis of a gas turbine rotor blade by using ansys" International journal of engineering research and applications (IJERA) Vol. 2, issue 5, Sep-Oct 2012.
- [5] V. Vijaya kumar, R. Lalitha Narayana, CH. Srinivas "Design and analysis of gas turbine blade by potential flow approach" V. Vijaya kumar et al Int. Journal of Engineering Research and Application, Vol. 4, Issue 1 (Version 1), January 2014.

- [6] 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, ISSN: 2319-8753.
- [7] V. Naga Bushana Rao,N. Niranjana Kumar, N. Madhulata,A. Abhijeet, — Mechanical Analysis Of 1st Stage Marine Gas Turbine Blade, International Journal Of Advanced Science And Technology Vol.68(2014).pp.57-64.
- [8] K. Hari Brahmaiah, M lava Kumar, Heat Transfer Analysis of Gas Turbine Blade through Cooling holes, International Journal of Computational Engineering Research, ISSN: 2250-3005.
- [9] Aqeel Jomma Athab, Dr. Naga Sarada, CFD Analysis Of A Gas Turbine Blade Cooling In The Presence Of Holes, International Journal And Magazine Of Engineering, Technology, Management And Research, ISSN: 2348-4845.
- [10] Amjed Ahmed Jassim, A. L. Luhaibi, Mohammad Tariq — Thermal Analysis Of Cooling Effect On Gas Turbine Blade, International Journal Of Research in Engineering And Technology, ISSN:2319-1163.
- [11] L. Umamaheswararao, Dr. K. Mallikarjunarao. “Design and analysis of a gas turbine blade by using FEM”, ISSN: 2278-621X, Vol. 4 Issue 4, November 2014 published by International Journal of Latest Trends in Engineering and Technology (IJLTET).