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Modelling Of Gas Turbine Rotor Blade with Internal Cooling Passages

Ganesh Cheemanapalle[1], S Praveen Kumar[2], Sreenivasulu Bezawada[3]

[1] *M.Tech Scholar, Department of Mechanical, Madanapalle Institute of Technology & Science, Madanapalle, India*
[2]*Assistant Professor, Department of Mechanical, Madanapalle Institute of Technology & Science, Madanapalle, India*
[3]*Assistant Professor, Department of Mechanical, Madanapalle Institute of Technology & Science, Madanapalle, India*

Abstract: ***Gas turbines are extensively used for land-based power generation, aircraft propulsion and industrial applications. The turbine blade temperature plays a critical role in developing the thermal efficiency and power output and lifetime of gas turbines. The rotor inlet temperature should be below the melting point of the turbine blade material. So the gas turbine blade needs "cooling technologies" to overcome the problem. This paper deals with the modelling and analysis of gas turbine rotor blade with internal cooling passages. The blade coordinate data is imported through the GSD_ExcelSplineLOft excel sheet to the CATIAV5 and modelled. FEA analysis and meshing both are done by using ANSYS. Internal cooling passages provided on blade tip, which passes through the axial length of the turbine blade. The coolant flows through these cooling passages to reduce the temperature distribution on the blade surface. Structural and thermal analyses have to be done to find out the temperature distribution over the surface of the turbine blade after applying coolant.***

Keywords: ***Gas turbine rotor blade, Inlet temperature, cooling technologies, CATIA, ANSYS***

I. INTRODUCTION

The purpose of gas turbine technology is to excerpt the maximum energy from the high temperature, high pressure gases produced by combustor. This could be achieved by improving the thermal efficiency of the gas turbine engine. Attempts were being made to increase the power output and thermal efficiency of a gas turbine engine by operating turbine at elevated temperatures as it is understood that the efficiency of gas turbine is a direct function of turbine inlet temperature. In the turbine section of a gas turbine engine, individual components of turbine blades are attached in circular shape and are accountable to take out energy from the high temperature, the combustor produces high pressure gas. The turbine blades are regularly the controlling component and were considered as the critical components of the gas turbine engines in which failures occurs.

High pressure turbine blades go various types of failures during the service. The failures are time dependent, i.e. longer time, temperature distribution on rotating blades. These turbine blades are subjected to high mechanical stresses, elevated temperatures and operate in aggressive environments. To continue in this tough environment, turbine blades repeatedly made from exotic materials like super alloys. To service at high temperatures, particularly in the hot zones of gas turbine super alloys is metallic materials. Super alloy materials permit the turbine to operate more powerfully by surviving higher temperatures. Since the second quarter of the 20th century super alloy materials were technologically advanced as materials for higher temperature applications and can be divided into three groups:cobalt-base super alloys,nickel-base super alloys, and iron base super alloys. The gas turbine blades mainly made of Nickel-base super alloys. The brilliant thermal stability, tensile and fatigue and thermal strengths, resistance to creep and hot corrosion, tensile and fatigue strength and micro structuralstability, overcome by Nickel-base superalloys extract the material an optimal choice for application in turbine blades. Failures in this turbine blade can have a dramatic effect on the safety and performance of the gas turbine engine. In some studies, it was reported that as many as 42 percentages of the failures in gas turbineengines were only due to bleeding problems. In this regard, an investigation has been made to know the cause of turbine blade failures and thus to improve the service life of turbine blades. The gas turbine industry is seeking to develop the performance of the gas turbine. This is the one of the methods that is increasing the turbine inlet temperature. Due to increase in inlet temperature some huge problems occurred.

The design operating temperature of the turbine blade always above the melting point of the blade Material.The variations in the inlet temperature can create thermal stresses, which leads to failure. To decrease these problems cooling techniques is required. To maintain standard inlet temperature, different methods are used. The methods are used 1) ceramic material 2) cooling of the blade material and 3) thermal barrier coatings. Ceramics are used as structural material for hot section components (blades, nozzles) because of these have superior high-temperature strength and durability.Silicon carbide and silicon nitride materials used for small turbine rotors.The gas turbine blade which runs at higher temperatures. The higher temperatures are insulated by the thermal barrier coatings.These coatings are used in the combustor, turbine blades and on guide vanes. A coating of low thermal conductive material is painted on the surface of the gas turbine blade. The inducing temperature drops across the thickness of the layer.This coating not only reduce the metal temperature of the component and also diminishes the oxidation rate of the coating applied on blade surface and hence delay failure by oxidation. Heat on the turbine blade is dissipated by the coolant; this is the one of cooling technique. The coolant flows at a high rate and by expanding the surface area of the turbine blade the temperature on the blade surface reduced. Adding of ribs or fins to the blade surface, the blade surface area increases. The coolant is fed from the compression system and issued as a coolant to remove the heat from the blade. This process prevents the blade from high temperature. Several types of cooling techniques are used in present generations, which are internal air cooling, external air cooling and liquid spray cooling.

II. LITERATURE SURVEY

This literature is based on the study of gas turbine blade under different loading conditions, different remedies to increase the efficiency of gas turbine engine and lifetime of the turbine blade. The gas turbine blade made of a nickel based super alloy Inconel-738. The blade goes to failure after service of 73500 h in hot gas conditions (1). To increase the lifetime of the blade “JE CHIN HAN” (2) given a detail study on the turbine blade cooling methods. Operating cost of the turbine engine mostly influenced by durability of hot section components like blade and hub. Coating materials were applied on the blade surface with certain thickness and also provided internal cooling ducts to decrease the temperature distribution on the blade volume (3). Experimental study was done on the blade after applying thermal barrier coating on the blade surface. The coating obstructed the heat not to transfer into the inner face (4).

III. MODELING OF TURBINE ROTOR BLADE

In order to model a turbine blade, we have to choose a particular series of model and their dimensions like diameter of turbine hub and blades, number of blades, and height of blade section.. I have chosen USPATENT journal profile with twisting. The modelling of turbine blade was done in CATIA. Coordinate points are exported by excel with macros command. Use spline command to get splines on the hydrofoil points. And after that by using multi sections surface options in GSD we have to create blade surface points. To provide internal ducts (diameter 10mm), twisting of the blade was removed.

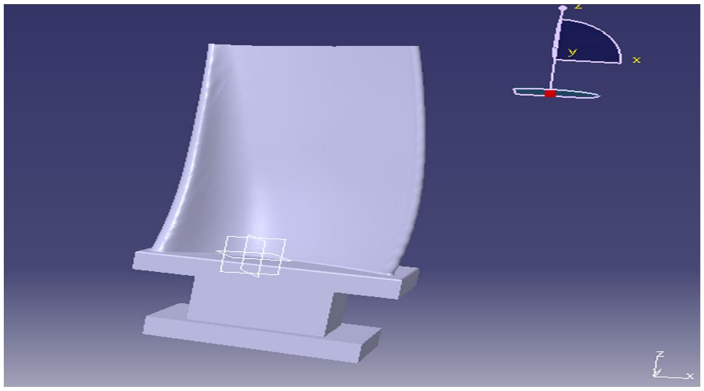


Fig 1 Turbine blade model with twisting

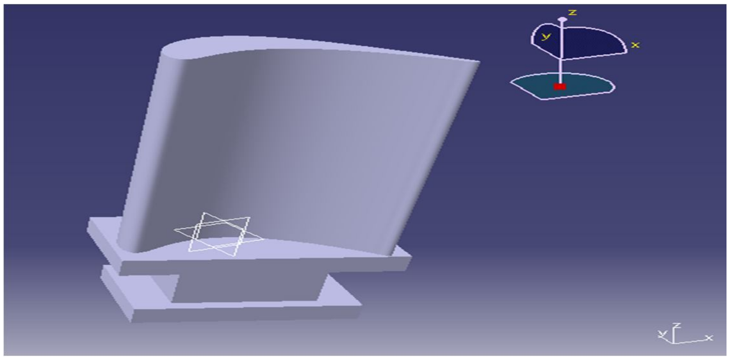


Fig 2: Gas turbine blade without twisting.

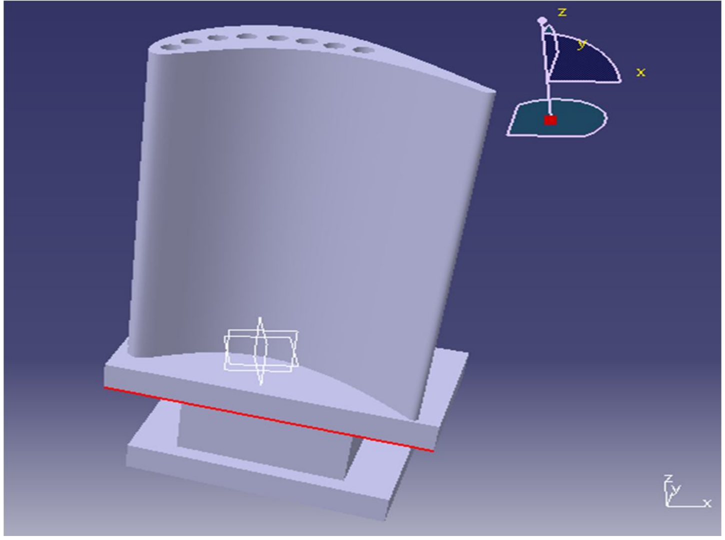


Fig 3: Gas turbine blade with internal cooling ducts

IV. MATERIAL PROPERTIES

Table 1.IN-738 properties

INCONEL-738 ALLOY PROPERTIES	
Property	IN-738
Density(ton/mm3)	8.55e-9
Young's modulus (Mpa)	149000
shear modulus (Mpa)	5.73e10
Poison's ratio	0.30
Yield strength(Mpa)	793

V. BOUNDARY CONDITIONS AND LOADS

A. Centrifugal force

In the rotating component of the gas turbine, the centrifugal force is one of the unfavored loads. In the radial direction which develops tensile stress along the moving blade span length. Centrifugal load depends on two parameters: The distance of each position from rotating axis and The whirling speed of the moving blade.

Whirling speed of the moving blade $w=2\pi N/60$ rad/Sec
=534 rad/Sec. (1)

VI. AERODYNAMIC LOADS

The turbo-machine theory is used to calculate the aerodynamic loads acts on the moving blade surface. The axial force was taken about 226.13 N as the agent of thrust generator and The peripheral component was taken about 1000.6 N as the agent of rotational torque(1). The aerodynamic force was applied on the surface of turbine blade as a distributed pressure.

The root of the turbine was fixed in the turbine hub. Shape of turbine root was designed as per "A Text Book of Gas Turbines by Ganesan".The aerodynamic loads were applied on the surface of the turbine blade and the rotational speed was in the Z-direction. ANSYS software package was used for static structural analysis. More rotational speeds gives more tensile load along the radial direction of moving blades. For the given loading conditions static structural analysis was done on ANSYS software package. Here three designs of gas turbine blades were taken. Separately static structural analyses were done for the three designs. The three designs: 1) Gas turbine blade with twisting 2) Gas turbine blade without twisting 3) Gas turbine blade with internal circular passages. Equivalent (von-mises) stresses were found out for three models. For three models same loading conditions were applied.

VII. RESULTS AND DISCUSSIONS

A. *Static analysis*

The first model was taken from US patent journal (2). The resultant stresses are found for first model was 422.49 Mpa, for second model 304.77 Mpa and for third model 249.69 Mpa. Here we could find the twisted model released more internal stress when compared with another two models. The give below table shows Von-Mises stresses and deformations for three models.

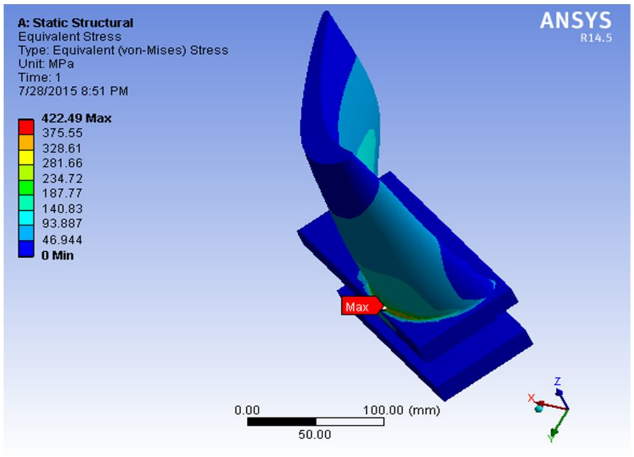


Fig (a): Maximum vonmises stress for model1

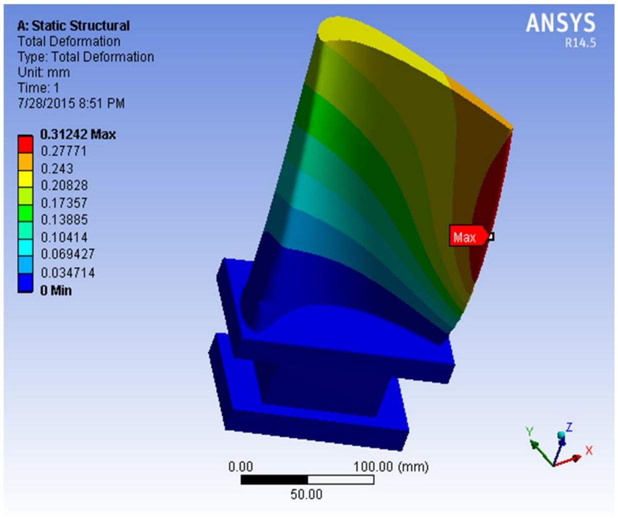


Fig (b): Total deformation for model 1

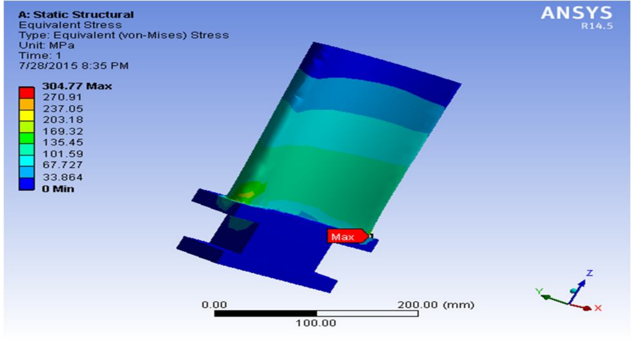


Fig (c): Maximum vonmises stress for model 2

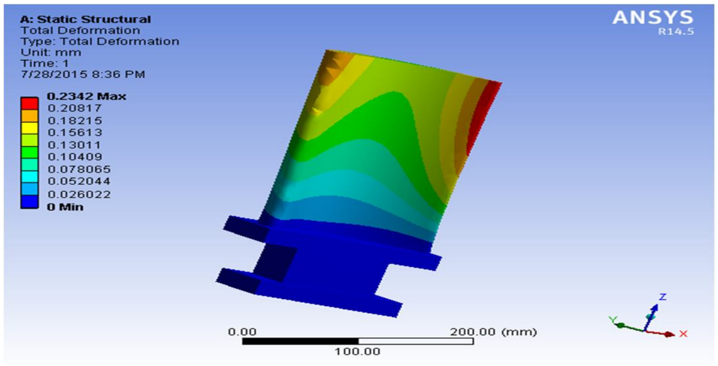


Fig (d): Total deformation for model2

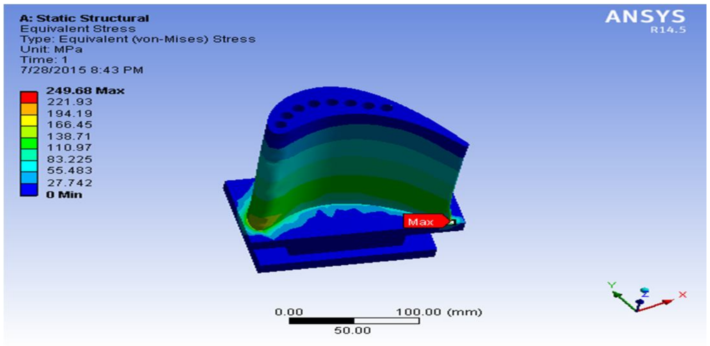


Fig (e): maximum vonmises stress for model3

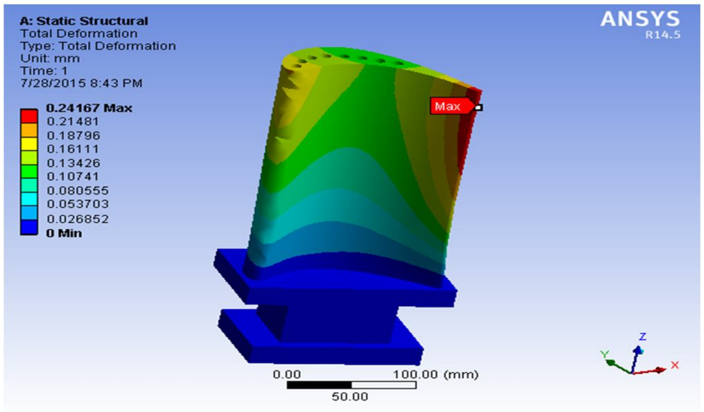


Fig (f): Total deformation for model 3

Table 2

Stresses and deformations for three models

	Deformation in mm				Stress(MPa)
	total	x	y	z	Vonmises
Model1	0.312	0.004	0.005	0.139	422.49
Model2	0.234	0.042	0.151	0.136	304.77
Model3	0.242	0.038	0.136	0.132	249.68

B. Steady-state Thermal analysis

Gas turbine inlet temperature plays important role in power generation of gas turbine. Higher inlet temperatures give higher thermal efficiency; lower inlet temperatures give less thermal efficiency. By applying cooling technologies to the gas turbine rotor blade we can improve the inlet temperature. In this paper internal circular cooling passages are designed in the rotor blade with 5mm diameter. Thermal analysis conducted on three models is 1) gas turbine blade with twisting 2) gas turbine rotor blade without twisting 3) gas turbine rotor blade with internal cooling passages. CATIA models were imported to the ANSYS workbench.

Thermal Boundary conditions of turbine blade

Inlet hot gas temperature $T_{hot\ in}$ =1483 K

Outlet hot gas temperature $T_{hot\ out}$ =1343 K

Blade surface temperature T_{sur} =298 K

Thermal loading conditions for turbine blade model:

At leading edge convective heat transfer coefficient

$h_{convective}$ =193.39 W/m^2K

Heat flux=247072.5 W/m^2

At trailing edge convective heat transfer coefficient

$h_{convective}$=185.71W/m^2 K
Heat flux=194069.39 W/m^2

At pressure side convective heat transfer coefficient

$h_{convective}$ =113.338 W/m^2K
Heat flux=126371.87 W/m^2
At suction side convective heat transfer coefficient
$h_{convective}$ =106.35 W/m^2K

Heat flux=101564.25 W/m^2
Internal cooling gas temperature $T_{cooling}$=342 ^{0}c (3)

Diameter of internal circular cooling passages= 5 mm

Thermal boundary conditions were applied to the surface of the turbine blade. Temperature distribution on the solid part was different in different areas of the blade surface. Maximum temperature distribution occurred on the leading edge of the blade. Convective heat transfer coefficient gradually decreases from leading edge to trailing edge.

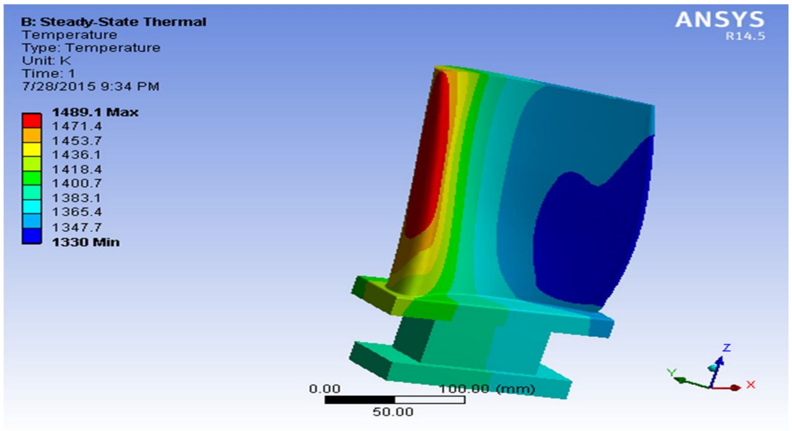


Fig (g): Temperature distribution for model 1

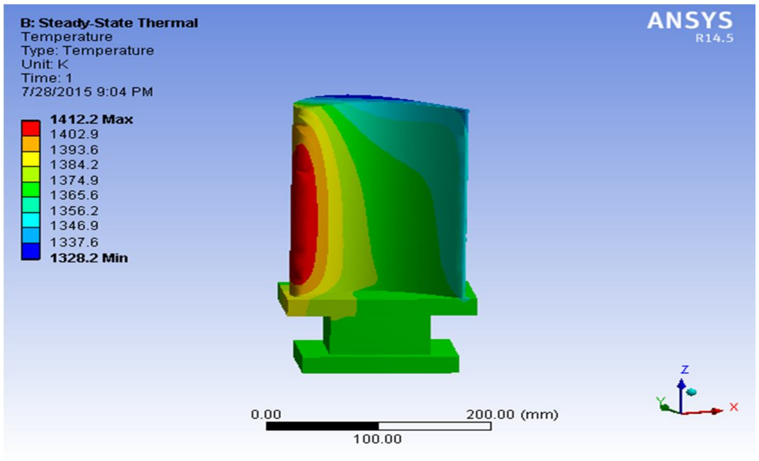


Fig (h): Temperature distribution for model 2\

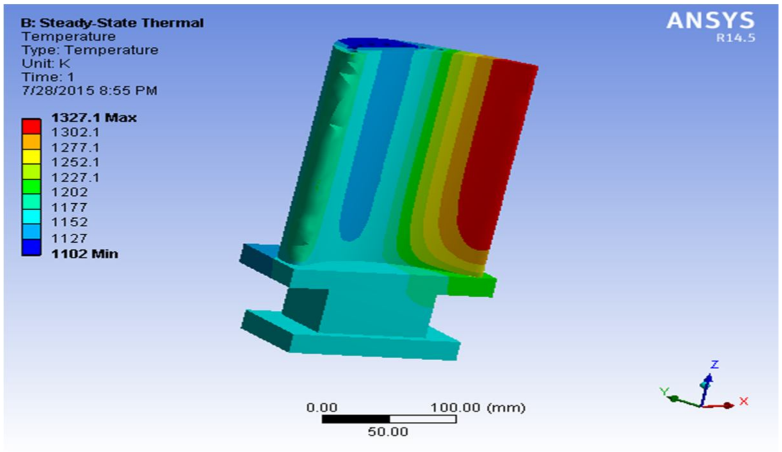


Fig (h): Temperature distribution for model

Table 3: Temperature distribution on three models

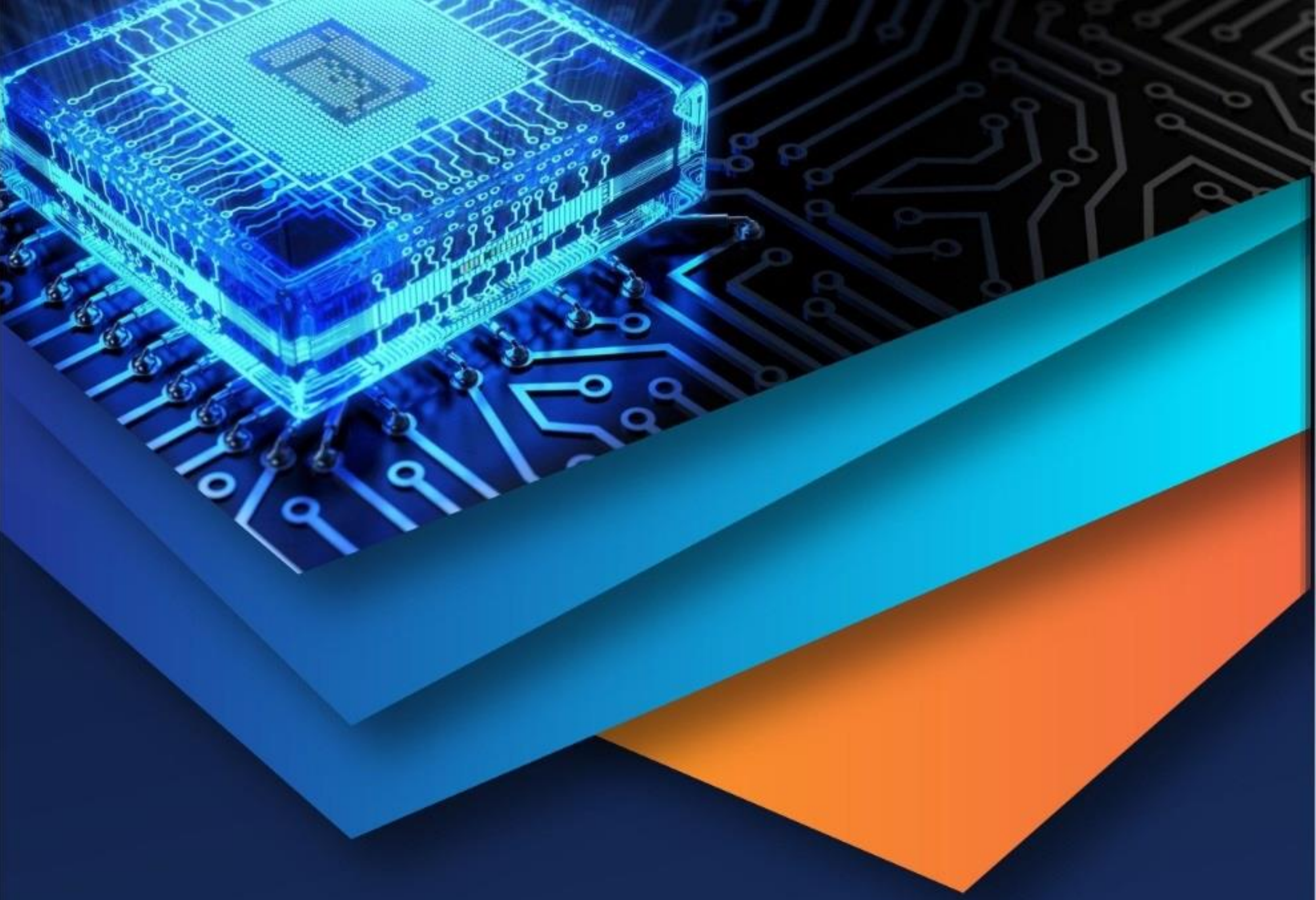
Model type	Model1	Model2	Model3
Max temperature(K)	1489.1	1412.2	1327.1
Min temperature(K)	1330	1328.2	1102
Total heat flux(W/mm^2)	0.07	0.025	0.089

VII. CONCLUSIONS

Three types of turbine blade models are designed and analysis is carried out through CATIA and ANSYS respectively. The gas turbine blade with twisting gives more von-miss stress (422.49 MPa) when compared with the other two models without twisting. The turbine blade without twist develops less stress internally while applying static loads. After designing internal circular passages, the blade gives extra deformation (0.242 mm) when compared with a second model.More temperature distribution (1489 K) occurs on the first model of gas turbine blade. Maximum temperature distribution occurred on the leading edge because of hot gas strikes first in this area. The coolant temperature (342 ^{0} c) properties were applied on ducts surface. ANSYS Software was used to find temperature distribution on a total area of the blade. After providing cooling temperature distribution decreased 89^{0}c when compared with a secondmodel. The temperature distribution for second model and third model are 1412.2 K and 1327 K respectively.

REFERENCES

[1] Failure analysis of a second stage blade in a gas turbine engine E. Persuade, M. Aieneravaie, M.R. Muhammad a Department of Mechanical Engineering, Zanjan University, Zanjan, Iran IPPR Research Lab, Iran Power Plant Repairs Co, P.O. Box 31585-381, Karaj, Iran
[2] Recent Studies in Turbine Blade Cooling∗Je-Chin Han, Department of Mechanical Engineering, Texas A&M University, College Station, Texas, USA.
[3] Heat transfer analysis for a multistage gas turbine using different blade-cooling schemes, Mohammad H. Albeirutty, Abdullah S. Alghamdi, Youssef S. Najjar, Department of Mechanical Engineering, King Abdul-Aziz University, P.O.Box80204,Jeddah 21589, Saudi Arabia Department of Mechanical Engineering, Jordan University for Science and Technology, P.O. Box 3030,Irbid, 22110 Jordan.
[4] Design of Internal Cooling Passages:Investigation of Thermal Performance of Serpentine Passages,WaseemSiddique,Doctoral Thesis 2011Division of Heat and Power Technology Department of Energy Technological Institute of Technology Stockholm, Sweden.
[5] Internal Cooling of Blades and Vanes on Gas TurbineChenglongWangDept. Of Energy Sciences, Faculty of Engineering, Lund University, Box 118, 22100 Lund, Sweden.
[6] A text book of turbine compressors and fans by S M YAMHYA.
[7] A decoupled CHT procedure: application and validation on a gas turbine vane with different cooling configurationsLuca Andreia, Antonio Andreinia, Bruno Facchinia, Lorenzo Winchlera, Department of Industrial Engineering, University of Florence, via DI Santa Marta 3 - 50139, Florence, Italy).
[8] Advanced Materials used for different components of Gas Turbine.Shailendra Kumar Bohidar1, RaviDewangan2, Prof.Kalpit Kaurase3.



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