Numerical analysis of effect of thermal performance of gas turbine nozzle guide vane

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Abstract:*The present gas turbine engines requires higher entry turbine entry temperatures as engines are operating at higher thrust and thermal efficiency at the same time by operating a turbine at higher temperature reduces the life of blades or vanes because of thermal stresses. Sometimes, the turbine entry temperatures may nearly equal to melting point turbine blade material. Therefore, it is required to determine the blades or vanes to a temperature which gives need to cool the blades optimal condition. In typical gas turbine engines nozzle guide vanes are (NGV) endure the highest operating temperatures. There exists a great drive in the turbine industry to increase the turbine entry temperature leading to higher thermal efficiency.A thermal analysis has been carried out to investigate the direction of the temperature flow which is been develops due to the thermal loading. The present work aims to determine a temperature distribution on blade surface. Heat transfer analysis has been carried out to find out the performance and thermal distribution on the existing blade without internal cooling on nozzle guide vane by using CFD code ANSYS CFX. In this work, CFD analysis has been carried out using Reynolds average Navier stokes equations. The analysis was done without cooling channel on the Nozzle Guide Vane and average temperature on the nozzle guide vane surface will be estimated.*

Keywords: Gas turbine, Computational fluid dynamics, Heat transfer.

I.INTRODUCTION

A turbine is a rotary mechanical device that extracts energy from a combustion chamber and converts it into useful work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Turbine blades move and impart rotational energy to the rotor. Generally Turbine blades are of two types namely, Rotor and Stator. Rotors are rotational blades and the stators are stationary vanes. Since the turbine gets energy from the combustion chamber, the turbine is exposed to high temperature. For this purpose various types of high temperature materials and alloys are used to withstand the high temperature exposed from the combustion chamber. Generally if the outlet temperature of the engine get increased then the efficiency and the performance of the engine get increased, but increasing the temperature causes the turbine material to get damage and leads to engine malfunction. To overcome this malfunction various high temperature withstanding material and alloy are used. But, presently we employed various heat transfer cooling technique which makes the material to withstand more temperature than its critical temperature and makes the increase in efficiency of the engine.

II. PROBLEM FORMULATION

In typical gas turbine engines nozzle guide vanes are (NGV) endure the highest operating temperatures. There exists a great drive in the turbine industry to increase the turbine entry temperature leading to higher thermal efficiency. This has led to drive to increase turbine blade and vane cooling. The present gas turbine engines Requires higher entry turbine entry temperatures as engines are operating at higher thrust and thermal efficiency at the same time by operating a turbine at higher temperature reduces the life of blades or vanes because of thermal stresses. Sometimes, the turbine entry temperatures may nearly equal to melting point turbine blade material. Therefore, it is required to determine the blades or vanes to a temperature which gives need to cool the blades in optimal condition.

In this work, Conjugate heat transfer analysis will be carried out to find out the performance and thermal distribution on the existing blade without internal cooling on nozzle guide vane by using CFD code ANSYS CFX. Here, CFD analysis will be carried out using Reynolds average Navier-stokes equations. Finally analysis will be carried out without cooling on the Nozzle Guide Vane and average temperature on the nozzle guide vane surface will be estimated. The current work aims at determining a temperature configuration which gives optimal temperature distribution on blade surface.

III. BOUNDARY CONDITION

In this work, Turbine blade without cooling has been computed by applying boundary conditions as follows,

a)Input data

- External gas temperature = 1300 K
- Coolant Inlet temperature = 650 K
- Mass Flow rate of Gas =0.9 kg/s
- Cooling air mass flow rate = 0.045 kg/s

b)Design Data

- Number of blades = 37
- Blade span (Height) = 40 mm
- Blade chord (Length) = 75 mm
- Blade external perimeter = 2.2*chord

IV. METHODOLOGY

1. Problem formulation.
3. Generate the 3-dimentional computer models
4. Prepare 3-D finite element model
5. Pre-process the 3D model for the defined geometry
6. Mesh the geometry model and refine the mesh considering sensitive zones for results accuracy
7. Post process the model for the required evaluation to be carried out
9. Determine the temperature distribution along the blade profile.
10. Finally a post processing is used for the analysis and visualization of the resulting solution.

V. MODEL FORMULATION

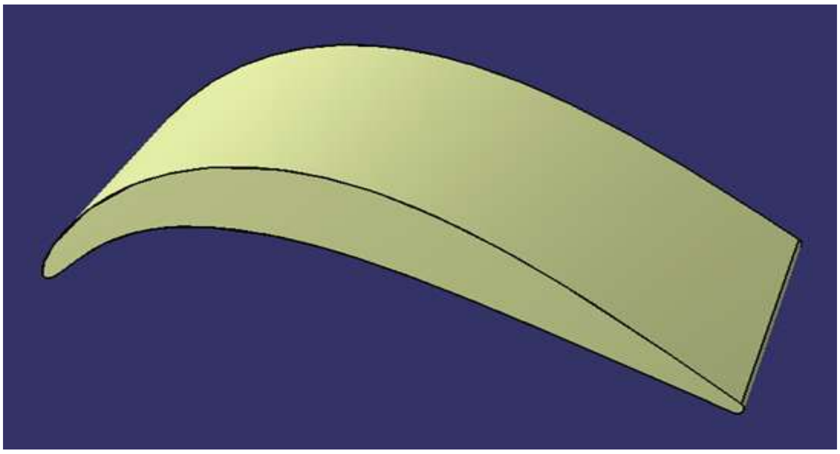


Figure 1:- 3-D Model of Blade profile

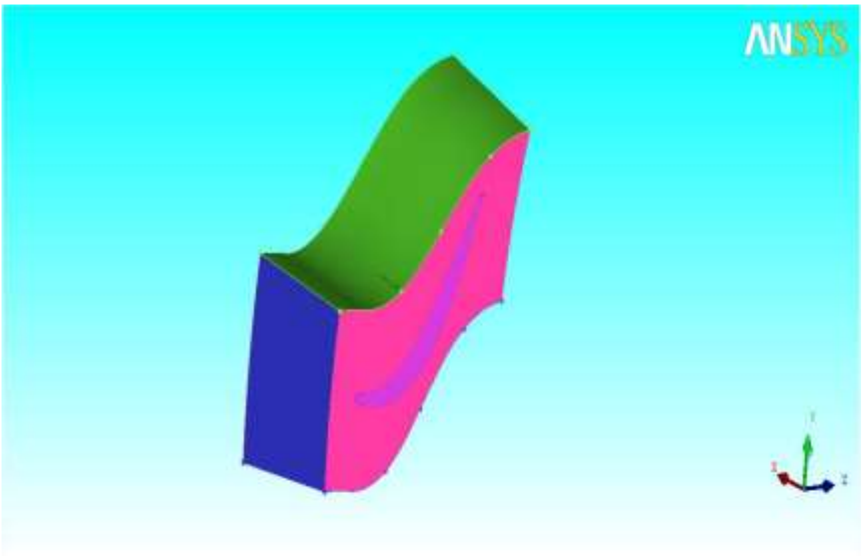


Figure 2:- ICEM CFD model of blade profile

The material of the blade used is Inconel alloy. Inconel alloys are oxidation and corrosion resistant materials, well suited for service in extreme environments subjected to high pressure and kinetic energy. From the literature review, I took computational domain models and boundary conditions as reference and carried out the Solid model with the help of CATIA V5 software package and mesh modelling using ANSYS ICEM CFD. Tetrahedral mesh has been used for the geometry and optimized the mesh for the Turbine Blade.

Table 1:-Number of nodes and elements concept.

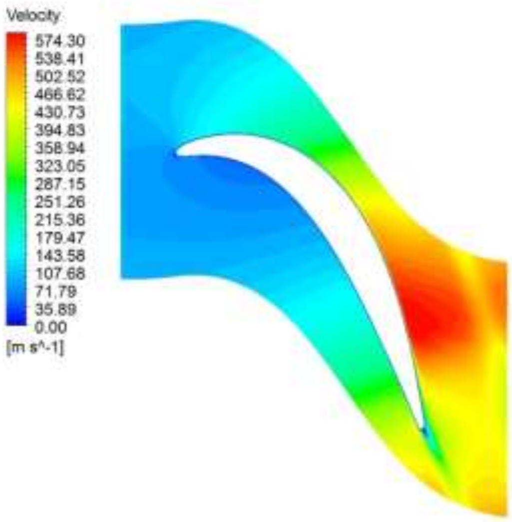
Sl No.	Domain Name	Number of Nodes	Number of Elements	Number of Hexahedrons	Number of Faces
01	NGV	502068	477281	477281	48948
02	Blade	105084	98113	98113	13642
03	Total	607152	575394	575394	62590

VI. RESULTS AND DISCUSSION

Analysis has been carried out for Turbine blade without cooling channel. Here Contour for Temperature has been determined. Finally analysis will be carried out without cooling on the Nozzle Guide Vane and average temperature on the nozzle guide vane surface will be estimated.

- **Yellow:** curve attached to a single surface - possibly a hole exists. In some cases this might be desirable for e.g., thin internal walls require at least one curve with single surface attached to it.
- **Red:** curve shared by two surfaces - the usual case.
- **Blue:** curve shared by more than two surfaces.
- **Green:** Unattached Curves - not attached to any surface.

a) Velocity Contours for NGV without cooling Channel



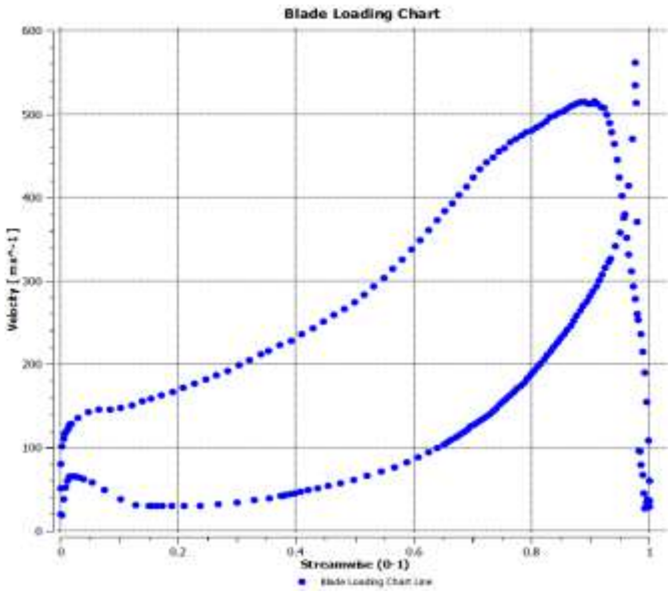


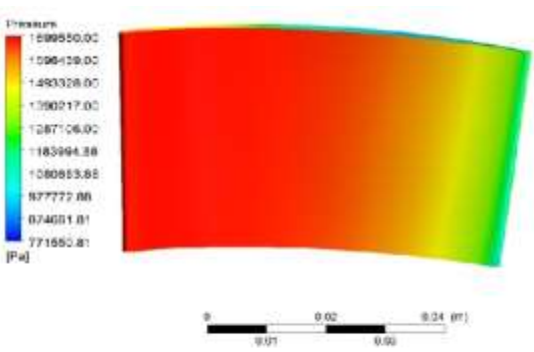
Fig 3:-Velocitycontour for NGV without cooling channel **Fig 4:-**Velocity distribution v/s Span Length on Pressure side &suction side at 0% of Blade Height

Velocity contour for NGV without cooling channel is as shown in fig (3). Mass flow rate of gas decreased continuously from inlet to outlet.

The variation of velocity distribution v/s Span length on Pressure side (lower line) at 0% of Blade Height for turbine blade without cooling channel is as shown in the fig (4). In pressure side mass flow rate of gas willbe increasing with respect to span length. Similarly will get almost near value in 25%, 50%, 75%, and 100% of blade height.

The variation of velocity distribution v/s Span length on suction side (lower line) at 0% of Blade Height for turbine blade without cooling channel is as shown in the fig (4). In suction side velocity increased to about 520 m/s at a span length of 90% and it will goes down with respect to span length. Similarly will get almost near value in 25%, 50%, 75%, and 100% of blade height.

b) Pressure Contours for NGV without cooling Channel



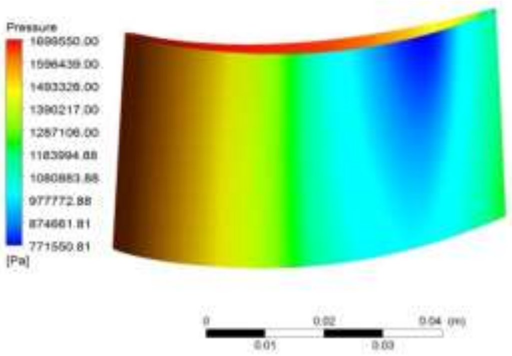
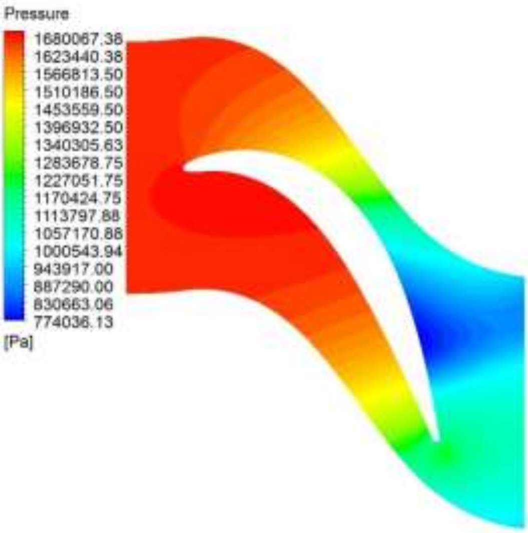


Fig 5:-Pressure on Blade Pressure side**Fig 6:-** Pressure on Blade suction side

Pressure on blade pressure side and suction side is as shown in fig (5) & (6). The pressure distribution on pressure side is low compared to suction side as Velocity of the flow in pressure side is more compared to suction side. So, the blade pressure are high on pressure side compared to suction side.



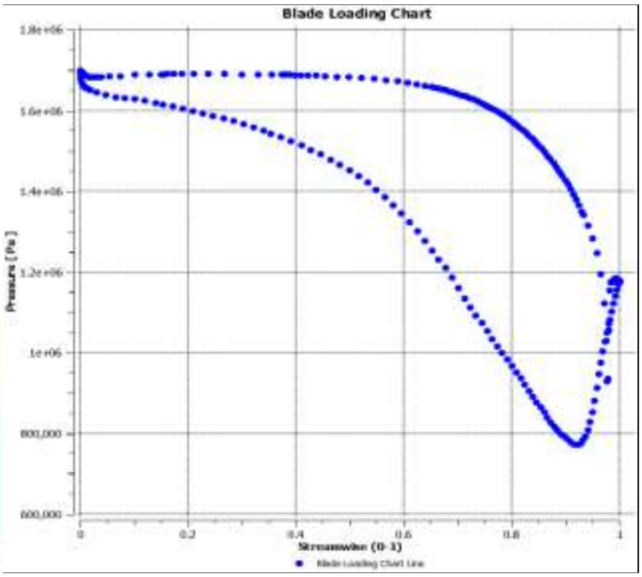


Fig 7:- Pressure contour for NGV without cooling channel

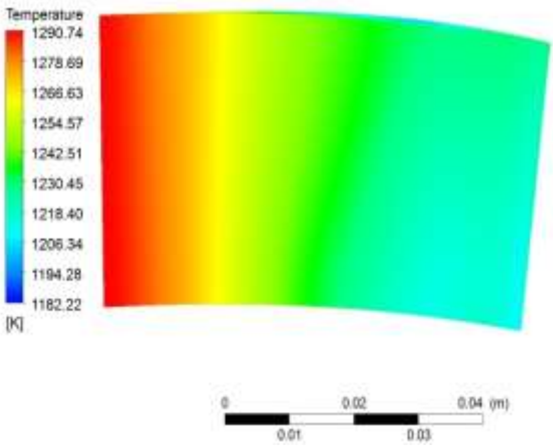
Fig 8:-Pressure distribution v/s Span Length on Pressure side &suction side at 0% of Blade Height

Pressure contour for NGV without cooling channel is as shown in fig (7). Static pressure is decreased continuously from inlet to outlet due to increase in velocity from inlet to outlet.

The variation of pressure distribution v/s Span length on Pressure side (lower line)at 0% of Blade Height for turbine blade without cooling channel is as shown in the fig (8). Pressure falls below 800,000 Pascal at a span length of 90%. From that point, wake formation takes place and pressure goes on increasing with respect to span length. Similarly will get almost near value in 25%, 50%, 75%, and 100% of blade height.

The variation of pressure distribution v/s Span length on suction side (upper line)at 0% of Blade Height for turbine blade without cooling channel is as shown in the fig (8). Here Pressure distribution up to 60 % of span length will same and after that it will be falling down with respect to span length. Similarly will get almost near value in 25%, 50%, 75%, and 100% of blade height.

c) Temperature Contours for NGV without cooling Channel



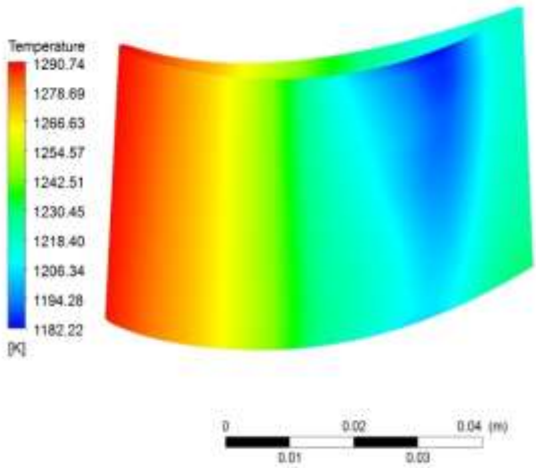
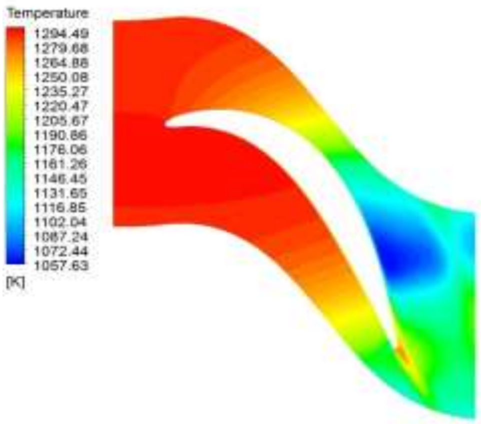


Fig 9:-Temperature on Blade Pressure side **Fig 10:-**Temperature on Blade Suction side

Temperature on blade pressure side and suction side is as shown in fig (9) & (10). The heat transfer co-efficient on pressure side is low compared to suction side as Velocity of the flow in pressure side is more compared to suction side. So, the blade temperature are high on pressure side compared to suction side.



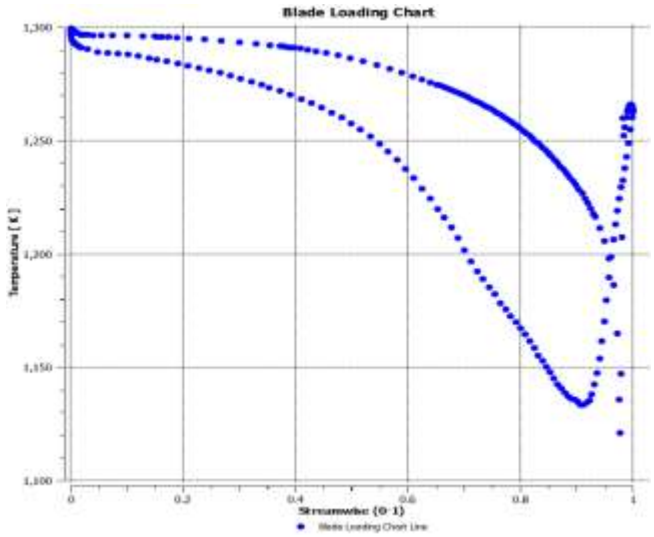


Fig 11:- Temperature contour for NGV without coolingchannel

Fig 12:-Temperature distribution v/s Span Length on Pressure side & suction side at 0% of Blade Height

Temperature contour for NGV without cooling channel is as shown in fig (11). Static temperature is decreased continuously from inlet to outlet due to increase in velocity from inlet to outlet.

The variation of temperature distribution v/s Span length on Pressure side (lower line) at 0% of Blade Height for turbine blade without cooling channel is as shown in the fig (12). Temperature falls below 1150 K at a span length of 90%. From that point, wake formation takes place and temperature goes on increasing with respect to span length. Similarly will get almost near value in 25%, 50%, 75%, and 100% of blade height.

The variation of temperature distribution v/s Span length on suction side (upper line) at 0% of Blade Height for turbine blade without cooling channel is as shown in the fig (12). Here temperature will falling down from 1300 K with respect to span length. Similarly will get almost near value in 25%, 50%, 75%, and 100% of blade height.

Table 2:- Average temperature values on Blade surface.

Average Temerature [K] on Blade Pressure side						
% of	**% of Blade Chord (Length)**					
Blade Height	**0**	**20**	**40**	**60**	**80**	**100**
0,25,50,75 & 100	1295.3	1282.45	1270.67	1240.87	1200.64	1235.91

Average Temerature [K] on Blade Suction side						
% of	**% of Blade Chord (Length)**					
Blade Height	**0**	**20**	**40**	**60**	**80**	**100**
0,25,50,75 & 100	1295.9	1295.16	1290.38	1280.67	1265.19	1230.68

VII. CONCLUSION

- The present work aims to determine a temperature distribution on blade surface.
- From the results, it is revealed that the turbine blade average temperatureof the blade without cooling is tabulated in table 2.
- In pressure side thetemperature has come down to 1200.64 K from this point wake formation takes place and it will be increasing with respect to span length.
- In suction side the temperature will be decreasing continuously with respect to span length.
- From the results, it is revealed that the turbine blade temperature which gives required to cool the turbine blade to reduce the melting point of turbine blade material.

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