# Fluid Flow Analysis And Velocity Distribution Along A Gas Turbine Blade Profile Using CFD Technique And Tool

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*Abstract*—**Gas turbine blade are designed to operate at high temperature which just below material melting temperature. It always undergoes high temperature and pressures which creates stresses in the gas turbine blade material. Due to this gas turbine mostly fails before its specified time period. It also tends to damage stators in turbine engine. The working environment of gas turbine blade is very hot, aggressive and harsh for blade material. But blade metallurgy and coating always saves the blade material for long period of time. It is observed that gas turbine blade fails due to hot flowing fluid over its profile. Means flowing fluid makes impact on blade working life period and ultimately of course on rotation of blades. The actual flow of hot fluid in gas turbine blade decides the impact in blade. By simulating actual flow of hot fluid on blade can give more information about that environment and we can understand the working phenomenon. If we capable to understand the flow of hot fluid in gas turbine then we can understand root causes of gas turbine blade failure.**

**In this paper we are simulating actual working condition of gas turbine blade by using CFD tool. Further nature of hot fluid flow and its effect on gas turbine blades are discussed. The various parameters are included for exact simulation of fluid flow.**

**Keywords: CFD (Computational Fluid Dynamics)**

## I. INTRODUCTION

Due to high temperature, pressure which is created by hot flowing fluid over a gas turbine blade, it tends to failure after some specific time period. There are several types of failure accurse in gas turbine blade. Few of the failures and investigations are discussed below.

When 150 MW gas turbine examined, it fails with extremely high vibrations, it is observed that all blade including stationary blades were damaged at extremely high level. Blade had completed only 1800 hours of life with intermittent mode running. More important is that there was no damage in other sections. It was pure blade failure and it is due to the crack in the securing pin hole (stress raiser) located at the root of the blade and propagated. [1]

Cooling system is installed on generator because of high increasing temperature. Employing a fan of a cooling system on the generator at the end sides of its rotor is generally preferred. In some cases, due to the fracture of blades short circuit between rotor and stator can accurse and generator tends to fail with huge financial loss. [2]

Most frequent damages in gas turbine blade are creep and stress rupture. These are accurse due to high working temperature and hot flowing fluid. But the working of gas turbine blade is based on microstructure of blade material. During service exploration blade material microstructural degradation can accurse. Hence it is also important to perform detailed microstructural examination of gas turbine blade. For effective microstructural analysis of turbine blades after service exposure, a reliable method should be there. [3]

While designing gas turbine blade by thermal point of view, prediction of stresses and coefficient of heat transfer plays an important role. Some studies are based on an investigation of stresses and heat transfer in blades with circular cooling passages. FVM and FEM commercial codes are used for 3D-numerical conjugated simulations in CFX and ANSYS tools to find out of the heat transfer coefficients distributions along a blade and the stresses, respectively. On the stagnation point of blade leading edge coefficient of heat transfer is more because of incoming gas flow impingement. But lowest on trailing edge at pressure and suction sides because of thermal boundary layer formation. At the trailing edge near the mid-span, the maximum material temperature and the maximum thermal stress occurs. [4]

Nickel base superalloy provides strength at high temperature hence mostly used in certain applications. As blade works at high temperature it suffers service induced degradation. First stage blade of 3 MW gas turbine having material nickel-base alloy Nimonic 80A which is capable to sustain high temperature. Metallographic and microhardness test was done on blades it is tested for microstructure and microhardness with four different blade zones i.e. root, 30%, 60%, and 90% to total hot region height of blade. Creep damage is found on the basis of performed test. Considering peak loading of centrifugal force and surface (aerodynamic) loads Finite element method (FEM) analysis is conducted to predict the life of turbine blades using the Larson–Miller method. Also two heat treatment cycles are suggested and applied. The heat treatments effects on grain size, volume friction of c0 primary phase, and micro hardness are investigated. Detailed analysis results explain the root cause of failure of blade and it is loss of coating resistance at high temperature due to oxidation, corrosion, erosion and inters diffusion of coating-substrate. [5]

As gas turbine blades are subjected to high temperature working conditions cooling of blades is an important factor. There are various methods are available to perform this task, one of them is providing radial holes to high velocity cooling air throughout the blade span. Due to this blade temperature considerably reduces. Steady state thermal & structural performance on blade which has material N155 & Inconel 718 nickel-chromium alloys with four separate models which consisting of solid blade and blades with several holes (i.e. 5, 9 & 13 holes) able to find out optimum number of blades. Also found that Inconel 718 is better suited for high temperature applications. [6]

## II. CAD MODELING OF GAS TURBINE BLADE

CAD modelling of gas turbine blade is an important part of entire project. Because the blade profile is very complex and it will decide the nature of the hot flowing fluid over a blade. The advanced CAD software i.e. CATIA V5R17 is selected for modeling the gas turbine blade.

### *A. Parameters of gas turbine blade*

Various dimensions required to model gas turbine blade are obtained by Reverse Engineering Process. The gas turbine blades are taken for the reference purpose with owners [7] permission. Steel rule, Screw gauge, Micrometer, Vernier caliper etc instruments are used for taking the dimensions from actual blades. CAD model of gas turbine blade is prepared in such a way that it should exactly represent the actual blade virtually and its profile can be taken for the further analysis.

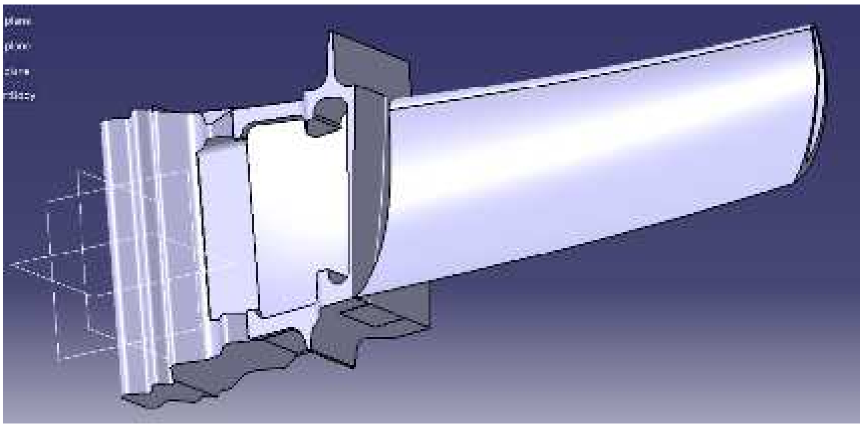

Figure 1. CAD model of first stage gas turbine Blade

*B. IGES (Neutral File) format.*

After creating model of gas turbine blade we need to convert it into suitable Neutral File Format. Now to perform analysis on gas turbine blade, it must be imported in FEA software. But FEA software can’t work directly on CAD file. Hence the universal accepted format for exchanging such data is used which is called as neutral file format.

It is also called vendor-neutral standard format. The IGES (Initial Graphics Exchange Specification) is used to exchange geometric models between various CAD and CAE softwares. But it is able to import partial files which contain dimensions and geometry related data. We are also able to import multiple files into the same model. [8]

## III. COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYSIS

Here the blade assembly is considered for simulating hot fluid flow over a profile. Specific domain for this purpose is set and by applying boundary condition required results can be obtained. The prepared domain for CFD analysis is shown below figure.

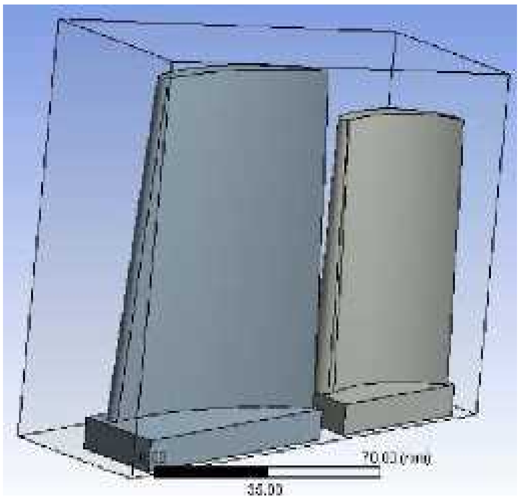


Figure 2. Blade assembly domain for CFD analysis

### *A. CFD Analysis.*

We are using ANSYS 14.0 Fluent CFD tool for performing this analysis. [8]

Following figure shows the meshed view of considered domain. The overall domain is under the influence of hat fluid. So such kind of fluid properties is applied and behavior of fluid is checked out.

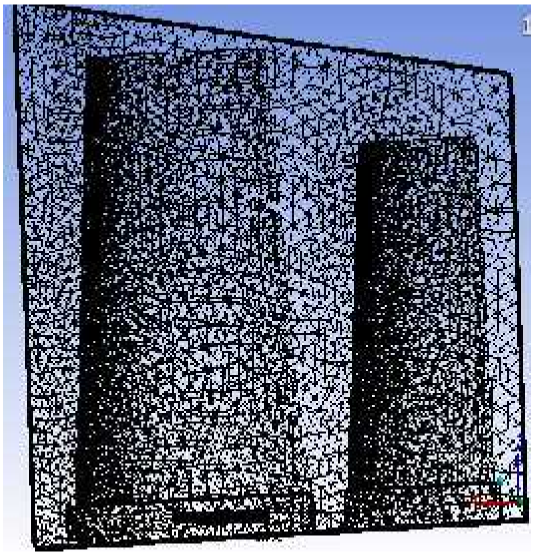

Figure 3. Meshed view of blade and vane assembly

## IV. RESULTS OF CFD ANALYSIS

In this step, we will display the results of the simulation, Results calculated by performing CFD analysis are shown below.

### *A. Velocity Distribution along a blade profile.*

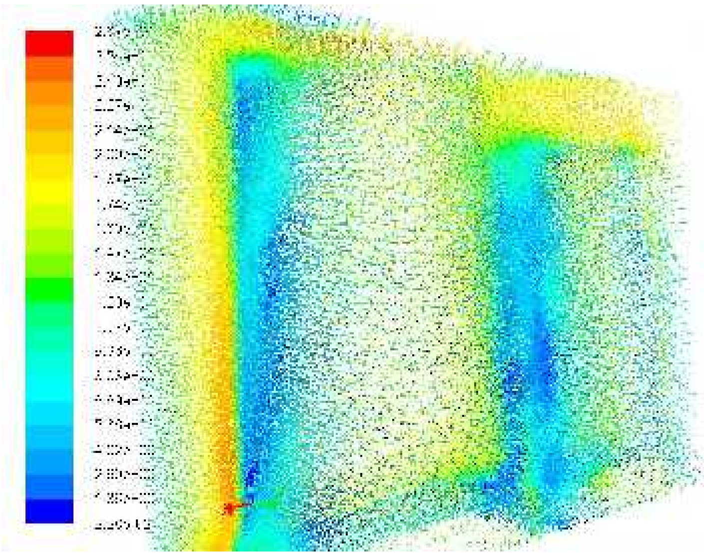

Figure 4. Velocity Counters on Blade profile.

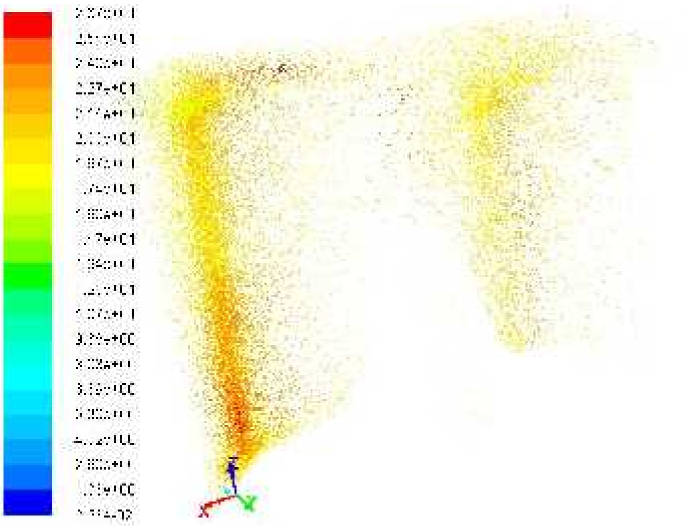

Figure 5. High Velocity points on Blade profile.

### *B. Temperature Distribution along a blade profile*

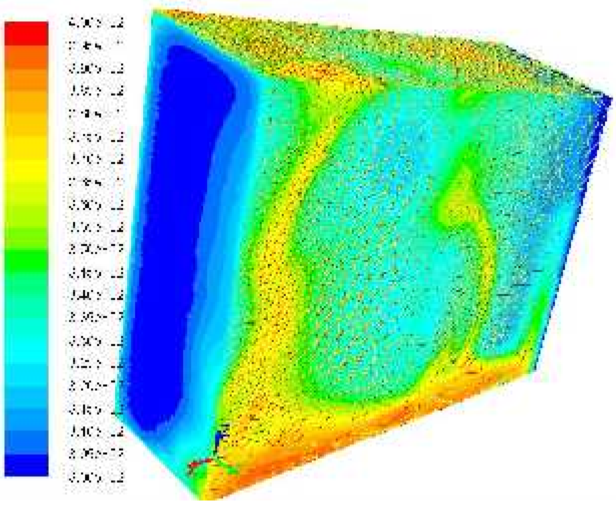

Figure 6. Temperature Counters on Blade profile

Above figures illustrates the nature of fluid flow, temperature distribution, Velocity vectors etc. By studying these results we can understand where the possible defects may accurse. The behavior of blade material at high temperature can be examined.

Following summerised results also help for studying flow of hot fluid on blade.

TABLE1 RESULTS OBTAINED BY PERFORMING CFD ANALYSIS.

| Sr No | Properties | Minimum Value | Maximum Value |
|---|---|---|---|
| 1 | Velocity | 0 m/s | 25.69 m/s |
| 2 | Temperature | 1000C | 8000C |
| 3 | Pressure | -996.20 Pa | 20.66 pa |
| 4 | Density | 1.22 kg/m3 | 1.22 kg/m3 |
| 5 | Turbulence | 0.0037 m2/s2 | 175.36 m2/s2 |
| 5 | Heat Transfer Rate | 153 w | 153 w |

## V. CONCLUSIONS

Based on the CFD analysis it is to be state that, the root cause of failure of gas turbine blade is high working temperature with high pressure difference. Results show the temperature counters on blade profile which illustrate the possible damage due to overheating.

Conducting thermal mapping CFD tool provides extensive information about failure of gas turbine blade. It gives better approximate solutions with material saving. It can be implemented where the direct contact thermal mapping techniques cannot be applied. The following observations can also conclude accordingly.

- Due to high temperature at middle and top of the blade there is always possibility of failure.
- Pressure difference affects the blade material at high temperature.
- Turbulence in hot fluid is due to pressure difference.
- CFD tools are best for thermal mapping of gas turbine blade and are also reliable.

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[8] http://www.ansys.com
Ansys 14.0 workbench and Ansys 14.0 APDL Help