

# Thermal Analysis of Second Stage Aero Gas Turbine Blade

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**Abstract** - In this experiment here we are detecting the hot zone the profile of second stage gas turbine blade. On the gas turbine blade various flue gases are affected on blade profile, so here we studied the effect of flue gas. We analyze and detected the heat zones on second stage gas turbine blade. For detecting the heat zones the thermal paint are applied on the surface of second stage gas turbine blade. Non-contact type temperature sensors are used to sense the temperature. By thermal analysis the direction of the temperature flow is known on turbine blade. A structural analysis has been carried out to investigate the stresses, shear stress and displacements of the turbine blade.

**Key Words:** Thermal Paint, Turbine Blade, Non-contact type temperature sensor, Effect of Flue Gas, Hot Zone Detection

## 1. INTRODUCTION

Aerodynamic design techniques of gas turbine compressors have dramatically changed in the last few years. While traditional 2D design procedures are consolidated for preliminary calculations, emerging techniques have been developed and are being used almost routinely within industries and academia. The compressor design still remains a very complex and multidisciplinary task, where aerothermodynamics issues, traditionally considered prevalent, now become part of a more general design approach, where aeromechanical, technological, structural, noise-related concerns and many other matters have to be taken into account simultaneously, thus leading to a very challenging problem for designers. The interesting and alternative options are in and casing treatments for enhanced stall margin and fact available for compressor 3D design, such as new blade shapes for improved on-off design efficiency, end wall contouring many others. For this reason, while experimental activity remains decisive for ultimate assessment of design choices, numerical design optimization techniques, along with Computational Fluid Dynamics (CFD) are assuming more and more importance for the detailed design and concrete evaluation of options.

### 1.1 History

If we throw the light on the history of gas turbine we can observe that, for more than a half-century gas turbine engines pioneered for military jet fighters have hung under the wings of commercial airliners. For nearly as long, manufacturers have built industrial gas turbines to drive

electricity generators and pump oil and gas. Many gas turbines, large and small, are designed specifically for these industrial applications. Aero derivative gas turbines used for these industrial applications are adapted directly from existing aircraft engines. Aero derivative gas turbines emerged in the late 1960s with unique performance attributes in comparison to the existing industrial gas turbines. Aero derivative units could startup more quickly for peak and emergency electricity generation. Also, aero derivative turbines offered lower weight in a smaller footprint, which was ideal for offshore platforms. Furthermore, their higher efficiency, coupled with simplified installation and maintenance, saved money for pipeline operators.

The performance of aero derivative gas turbines is largely enabled by the engineering successes sustained in the lucrative aircraft engine market. The role and impact of industry-government partner ships in advancing aircraft engine technology is widely appreciated and has directly impacted the evolution of aero derivative gas turbines.

## 2. LITERATURE SURVEY

After the study of second stage aero gas turbine, the few things are comes in front that the aero gas turbine operates above the temperature 2000- 3500 degree Celsius. at this much high temperature the gas turbine blade material will not sustain anymore and this is the main problem we have been observe. At this high temperature there may chances of bending of material due to various stresses act on the profile of second stage gas turbine blades. There is also chances of creeping and overheating of blade material. Because of this entire problem there may chances of decreasing life of blade.

### 2.1 Objectives of Study

In the present work CFD analysis is used to examine the heat zone analysis of second stage gas turbine blade. The temperature indicating Paint is a kind of technology which is widely used to measure the surface temperature of high temperature components of gas turbine engine. Analysis of hot zones occupied in the profile of second stage gas turbine blade. The portion where the hot zones are obtained should be replaced by another toughest material for increasing the efficiency of the gas turbine blade.

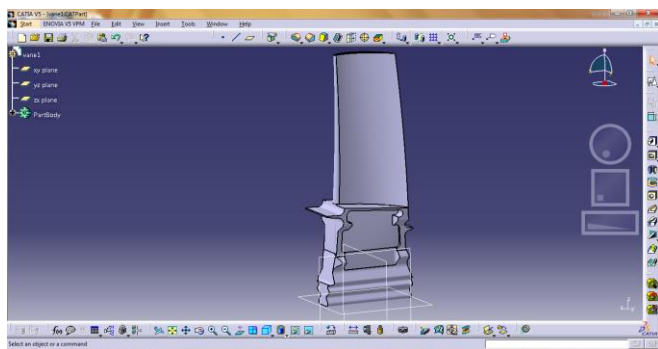
## 2.2 Thermal Analysis of Gas Turbine & It's Need

The physical conditions occurring within the various parts of a turbine engine for a flying vehicle are probably among the harshest environments. The main parameters to describe the physical conditions of a turbine engine are the temperatures, pressures and velocities of the air in the primary gas path, which can be derived from the external conditions (outside air temperature) and from the known laws governing the thermodynamic cycle describing the energy conversion process within the engine. The design of existing engines typically exploits the mechanical and thermal capabilities of the metallic materials like Titanium or Nickel base alloys up to the limits of fracture toughness and life potential. This results in failure of different components of gas turbine such as nozzle guide vanes, turbine blades, turbine rotor, turbine stator, bearing, combustor etc. Therefore thermal analysis of these components is necessary.

## 3. CAD MODLLING OF GAS TURBINE BLADE

CAD modeling 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.

It is one of the leading parametric CAD software we have taken for the modeling of gas turbine blade. Because of its extensive advantages for 3D modeling it is used worldwide. For preparing any 3D model in CATIA simple commands (which have explained further) are given which are user-friendly.



**Figure 1:** Working environment of PART Module in CATIA V5R17

Above figure shows the working environment of part module in CATIA V5R17. There are several modules are given with every CAD software and each one having their own working areas. Such as

- i) Sketcher Module: For 2D sketches which can be converted into 3D.
- ii) Part Module: For development and editing of 3D parts

- iii) Surface Module: For development and editing of various surfaces.
- iv) Assembly Module: For assembling two or more parts.
- v) Drafting Module: For generation on various isometric or orthographic views.
- vi) Simulation Module: For simulation of 3D parts.
- vii) Sheet Metal Module: For performing various surface related advanced work Etc.

Part module is most important for modeling of 3D part and it must be user-friendly so that new users can also able to work with software. Here for modeling gas turbine blade PART model and its commands are used. Some of the Part module commands which are used here and their use are listed below.

### 3.1 PART Module Commands for CATIA V5R17

#### i) Pad Command.

Adding a material in linear direction i.e. with the help of this command we can convert 2D sketch into 3D part by adding material in linear direction.

Multi-pad, Draft Filleted Pad etc. are the subtypes of Pad.

#### ii) Pocket Command.

Removing a material in linear direction i.e. with the help of this command we can remove material in linear direction from any solid body.

#### iii) Groove Command.

Removing material in a revolving path direction i.e. with the help of this command we can remove material in circular direction from any 3D object.

#### iv) Hole Command.

It is used for creating either simple, tapered, counter bored holes.

#### v) Rib Command.

Rib sweeps a profile along Centre curve to create the material. We can do rib with keep angle, Pulling direction, reference surface. Thin Rib, Merge Rib Ends are the subcommands.

#### vi) Slot Command.

Slot removes the material from existing solid by sweeping a profile along a Centre curve.

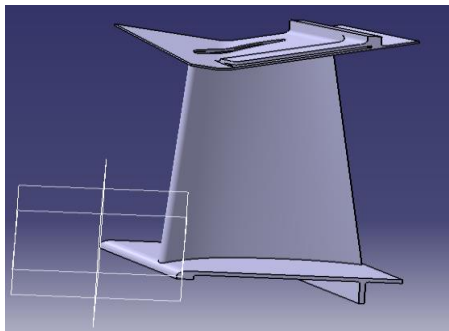
#### vii) Multi Section Solid Commands.

It is a set of commands used for generating a various types of solids along a profile or path specified by the user with various options. It is having Loft, Relimitation etc. subcommands.

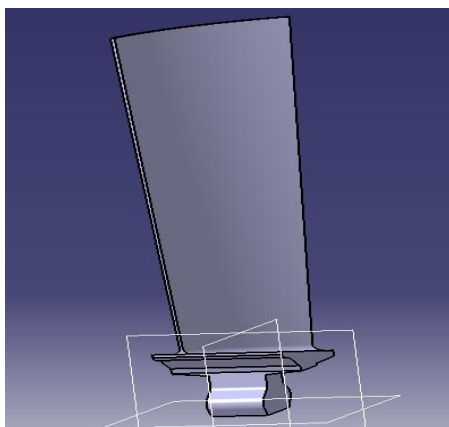
**viii) Remove Multi Section Commands.**

It is exact command of multi section solid command. Only the difference is, it removes the material along a profile with defined closed curve.

Also some dressed up features like Edge Fillet, trim Ribbons, Blend Corner etc. have used while creating CAD model of gas turbine blade.



**Figure 2:** Vane of Gas Turbine



**Figure 3:** Second Stage Blade

**3.2 Conversion of CAD files into IGES Format**

After creating model of gas turbine blade we need to convert it into suitable Neutral File Format. To perform analysis on blade FEA software can't work directly on CAD file. So we have convert CAD file into IGES (neutral file) format.

**4. COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYSIS**

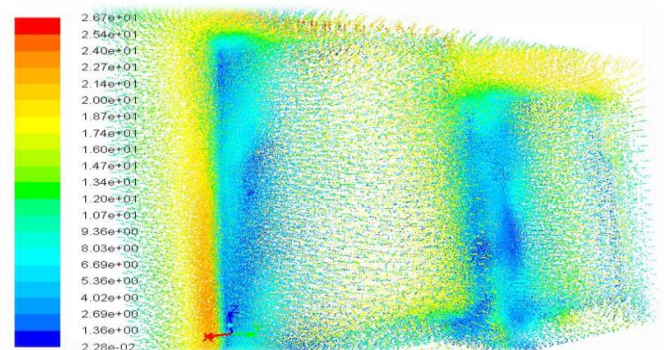
The CFD analysis has been carried out with the help of ansys 14.0 software. Fluent enables engineers and designers to simulate fluid flow, heat and mass transfer, and a host of related phenomena involving turbulent, reacting, and multiphase flow. The broad physical modelling capabilities of Fluent have been applied to industrial applications

ranging from airflow over an aircraft wing to combustion in a furnace, from bubble columns to glass production, from blood flow to semiconductor manufacturing, from clean room design to wastewater treatment plants. The ability of the software to model in-cylinder engines, aero acoustics, turbo machinery, and multiphase systems has served to broaden its reach. Advanced solver technology provides fast, accurate CFD results, flexible moving and deforming meshes, and superior parallel scalability. User-defined functions allow the implementation of new user models and the extensive customization of existing ones. Effluent's interactive solver setup, solution, and post-processing make it easy to pause a calculation, examine results with integrated post-processing, change any setting, and then continue the calculation within a single application.

In this practically experimental set up of second stage aero gas turbine blade, the thermal paint are applied on the profile of second stage gas turbine blade and the exact front side of the blade the two flame burner are fixed. The purpose of that two flame burner is that to emits the flame at profile of second stage gas turbine blade because of this the temperature of second stage gas turbine blade is get increases and after reaching at certain temperature (at 250-300 degree Celsius). The thermal paint which are applied on the profile of second stage gas turbine blade get change its color and the hot zones get detected on the profile of second stage gas turbine blade and the detected hot zones should be match the hot zones which we detected on theoretical experimental set up and do the analysis of the hot zones.

Following figurer shows the velocity counters on blade profile as well as temperature counters on the blade profile.

Velocity Distribution along a blade profile



**Figure 4:** Velocity counters on blade profile.



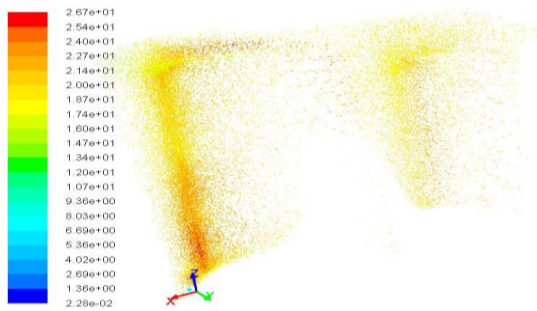


Figure 5: High Velocity points on Blade profile

Temperature Distribution along a blade profile

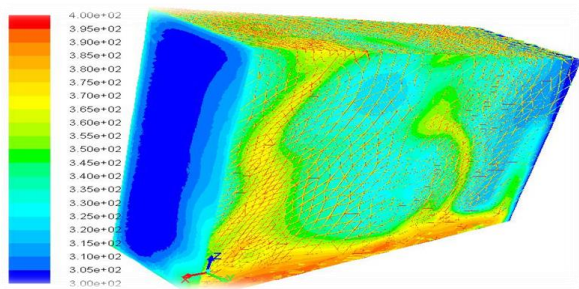


Figure 6: Temperature counters on blade profile

### 5. RESULT FROM CFD ANALYSIS

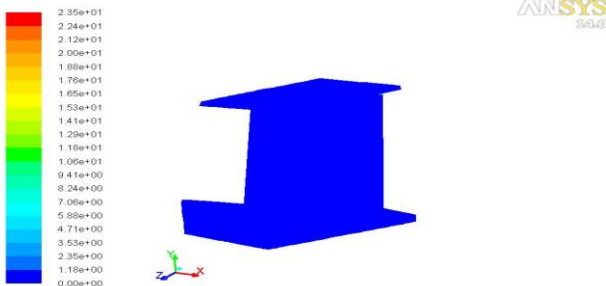


Figure 7: Velocity profile on blade

The blue colour indicated that the blade having zero velocity. The blade profile is at rest and the flue gases are passed over them. The blade is in steady condition so the velocity of the blade zero.

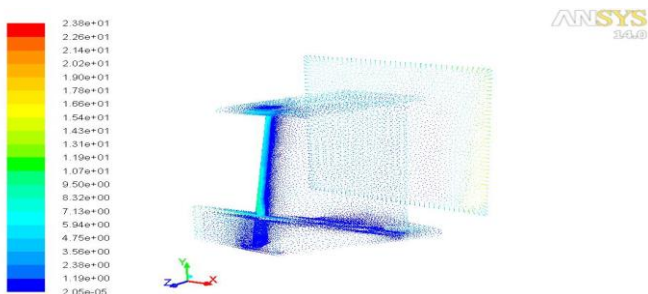


Figure 8: Counters of velocity magnitude on second stage blade

Above figure shows the velocity counters on blade profile. At the leading edge velocity of the blade is maximum. The flue gases are initially strikes on the leading edge of the blade, so the velocity of blade maximum. After striking the velocity gets reduces when the flue gases passed over the blade.

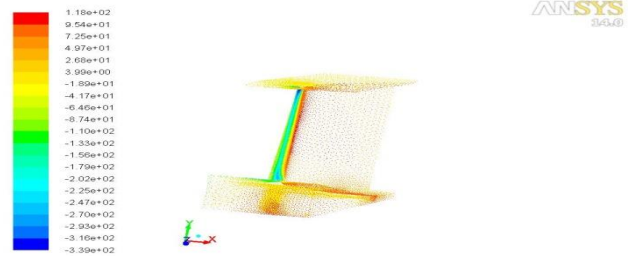


Figure 9: Temperature contours on second stage gas turbine blade

The above figure shows that on the leading edge temperature is lesser than the trailing edge temperature. The temperature at the trailing edge the temperature is maximum. The maximum temperature is 2073 Kelvin and minimum temperature is 250 Kelvin.

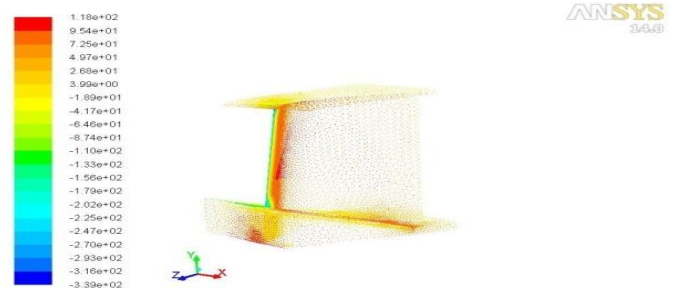


Figure 10: Pressure contours on second stage gas turbine blade

The pressure contours of the blade profile, at the initial condition, the air enters the domain strikes on the leading edge of the blade at the top and starts striking on the throughout the blade profile, so pressure at blade profile is maximum.

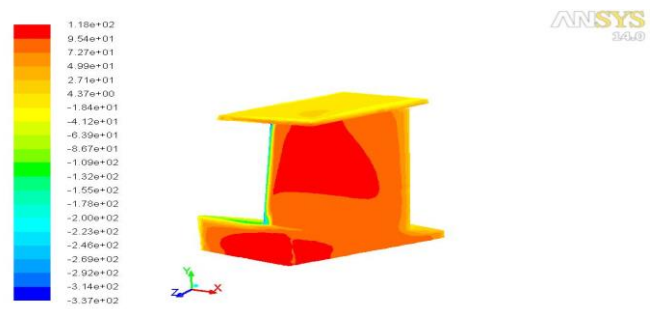


Figure 11: contours of static pressure on second stage gas turbine blade

The above figure shows that, the pressure distribution on blade profile. The various colours show the pressure variation on the blade profile. The green colour shows the minimum pressure at the leading edge of the blade and the pressure at this edge is -109 Pascal. At the top of the blade the pressure is increased shown by yellow colour and the pressure range is -18.4 Pascal. At the base of the blade the red coloured shows the maximum pressure ranged to 118 Pascal. The flue gases passed over the blade profile the pressure increased up to certain area on blade profile which shown by red colour. This red colour indicated the maximum pressure on the blade profile. The orange colour indicates pressure is reduced when the gases are nearer to the tailing edge.

### 6. COMPARISON OF EXPERIMENTAL RESULTS

By doing the theoretically and practically experiment of second stage gas turbine blade it is found that the hot zones are comes on the edges of the second stage gas turbine blade. It means that the temperature of that second stage gas turbine blade increases at the edges.

#### 6.1 Theoretical Result

The experimental results obtain on the second stage gas turbine blade. It is found that the hot zone occur on edges of turbine blade. It means the temperature at the edge of blade is increases. To increases the efficiency of second stage gas turbine blade uses the toughest material.



Figure 12: Result obtain on turbine blade

#### 6.2 Analysis Result

The analysis result obtain is same as the theoretical result. The hot zones are obtain on the second stage gas turbine blade are came on the leading edge and the tailing edges of the second stage gas turbine blade and the same result are found on the CFD analysis.

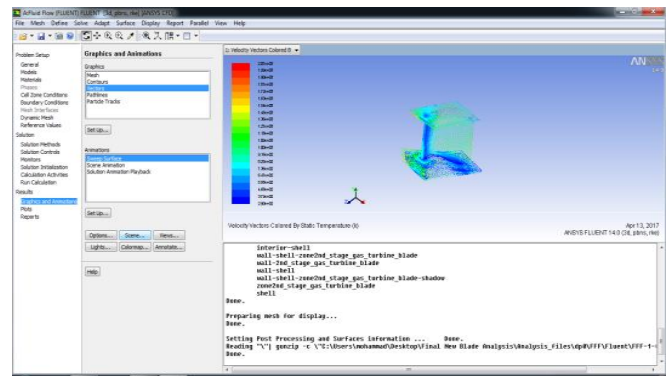


Figure 13: Analysis of result

### 7. CONCLUSIONS

The temperature has a significant effect on the overall stresses in the second stage turbine blades. Maximum temperatures are observed at the leading edge and the tailing edges of the second stage gas turbine blade.

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