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Design and Analysis of Gas Turbine Blade by Potential Flow Approach

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ABSTRACT
The design features of the turbine segment of the gas turbine have been taken from the "preliminary design of a power turbine for maximization of an existing turbojet engine". It was observed that in the above design, after the rotor blades being designed they were analyzed only for the mechanical stresses. As the temperature has a significant effect on the overall stress in the rotor blades, a detailed study is carried out on the temperature effects to have a clear understanding of the combined mechanical and the thermal stresses. The first stage rotor blade of the gas turbine is analyzed for the mechanical axial and centrifugal forces.

Knowing the fluid conditions at exit of the gas turbines, a value of static pressure was assumed at the turbine outlet. From this the corresponding enthalpy drop required in the power turbine is calculated. The peripheral speed of rotor and flows velocities is kept in the reasonable range so to minimize losses.

In which the base profiles available and is analyzed later for flow conditions through any of the theoretical flow analysis methods such as "Potential flow Approach".

Key words: Gas turbine blade, Mechanical and the thermal stresses, mechanical axial and centrifugal forces, Potential flow Approach, Static pressure, enthalpy drop

I. INTRODUCTION

The gas turbine in its most common from is a rotary heat operating by means of series of processes consisting of air taken from the atmosphere, increase of gas temperature by constant pressure combustion of the fuel in the whole process being continuous. It is similar to petrol and diesel engines in working medium and internal combustion but is akin to the steam turbines in its aspect of the steady flow of the working medium.

Today the steam turbine is preeminent as an aircraft power plant with outputs ranging from a few hundreds of Newton if thrust to over 1000 KN. As a shaft unit the smallest in regular service is 5H.P.

The outstanding characteristics of gas turbines, which make them eminent of all turbines, are as follows:

1. It has a very simple mechanism.
2. It runs at higher speed.
3. It is very compact engine compared to other requiring less weight and space.
4. It requires less maintenance cost.
5. Cheaper liquid fuel can be used, as phenomenon of detonation does not exist.
6. It is highly situated for peak load and standby power generation and aircraft propulsion.
7. It works at high operating pressures.
8. It has greater power to weight ration than other engines.
9. It requires less manpower.

II. BLADE MATERIALS:

- Vatallium [Cobalt alloy based at a temperature rating above 760] also called Haynes's stellite21 available in precession cast from with Carbon and Molybdenum as hardening agents.
- Titanium alloys.
- Haynes's series of alloy [Nickel and Cobalt based alloys with temperature ranging between 785-840] with Carbon, Molybdenum as hardening agents available in precession cast from.
- Alloy steels.

III. BLADES MANUFACTURING TECHNIQUES

1. Forging.
2. Casting.
3. Fabrications.
4. Powder metallurgy.

IV. CHALLENGES

The turbine plates are subjected to high temperature which leads to a higher thermal efficiency, higher power to weight ratio and low specific fuel consumption. If a blade is heated rapidly to a high temperature it causes uneven temperature distribution and several thermal stresses are developed with in the material. Beyond certain level of temperature (65-800C) the blade material does not remain elastic and continuous to stretch under applied forces. This is called creep and if this exits for a long time fracture will occur.

V. OPTIONS PROPOSED TO OVERCOME THIS PROBLEM:-

1. A new material may be sought which is capable of operation at high temperatures.
2. By blade cooling which maintains the temperature of the blades at a value low enough to preserve the desired material properties?

BLADE COOLING:- is the most effective way of maintaining high operating temperatures making use of the available material. Blade cooling may be classified based on the cooling medium as

1. Liquid cooling.
2. Air-cooling.

STRUCTURAL ANALYSIS:

The structural analysis is the most common analysis of finite element method, which accomplishes various structures such as bridges, naval, aeronautical, mechanism housing and mechanism components such as possible in ANSYS software.

They are, Static analysis, Modal analysis, Harmonic analysis, Transient dynamic analysis, Spectrum analysis, Buckling analysis, Explicit dynamic analysis, Fractured mechanics, Composites, Fatigue, and P-method.

Out of these 11 analysis options generally we consider the static and modal analysis options only. In the analysis options we have H-method and P-method types of solutions.

VI. STATIC ANALYSIS:

A static analysis calculates the effects of static loads on the structure while ignoring the inertia and damping effects such as those caused by time varying loads but it can accomplish steady inertia loads static equivalent loads. Steady loading and response conditions are assumed. The loads and the structures response are very slow in this analysis.

The types of loads that can be applied in a static analysis include, Externally applied pressures and forces, Steady state internal forces (such as gravitational velocity), Imposed (non-zero) displacements, Fluencies (for nuclear swelling).

A static analysis can also include linear and non-linear analysis. Non-linearity such as creep, large deformation, plasticity, stress stiffening, contact elements, hyper elastic elements etc can be handled very easily.

The procedure for static analysis consists of three steps includes, Build the model, Apply the loads and obtain the solutions, Review the results.

VII. THERMAL ANALYSIS:

A thermal analysis calculating the thermal variations and related thermal quantities in a system or component such as, The temperature distribution, The amount of heat lost or gained, Thermal gradients, Thermal fluxes.

Thermal analysis plays an important role in the designing of many components such as heat exchangers, turbines, internal combustion engines and piping systems. The thermal analysis is carried out with static analysis to calculate thermal stresses. The basis of thermal analysis is the heat balance equation obtained from the conservation of energy. The thermal analysis can solve all the modes of heat transfer.

Conduction, convection and radiation ANSYS supports 2 type of thermal analysis such as:
Steady-state thermal analysis and transient thermal analysis.

A steady state thermal analysis-loading situation is the one in where heat-storing effects over a period of varying time can be ignored. In some analysis thermal analysis combined with other phenomenon are used as thermal-structural analysis and magnetic –thermal analysis. This is called as steps includes, Build the model, Apply the loads and obtain the solutions, Review the results.

VIII. MAIN PARTICULARS OF BLADE:

The material taken for the blade is Ni-Cr (10% Chromium and 90% Nicke10). Then material properties of the element are as follows:

1.	Density	:	8900 Kg/m2
2.	Modules of elasticity	:	206.84Gpa
3.	Poisson’s ration	:	0.33
4.	Thermal expansion coefficient	:	1.340e-5/k
5.	Heat capacity	:	444 J/Kg-K
6.	Thermal conductivity	:	90.7 W/m-k

The above are the input material properties for the solution option. The above series of operations are performed in the PREPROCESSOR module. After the model is structured the loads are structured the loads are applied in the solution module after defining the analysis option.

IX. SOLUTION PROCESSOR:

The loads are applied in the solution processor after defining the analysis type.

- Static Analysis.
- Coupled-field Analysis.

X. CONSTRUCTION OF TURBINE ROTOR BLADE:

To accomplish the analysis of a structure in ANSYA package steps are to be followed:

1. Build the model.
2. Apply the loads and obtain the results.
3. Review the results.

Here, we are considering the blade for analysis. So we need to define the list of operations with respect to the structuring of the blades.

PREPROCESSOR MODULE:

In this module the following sets of operations are performed. In this module structures to the built.

BUILD THE MODEL:

in modeling the blade a series of operations are to be followed.
The list of operations that are to follows.

1. Create the key points.
2. Create the lines.
3. Create the areas.
4. Meshing.
5. Extrusion.

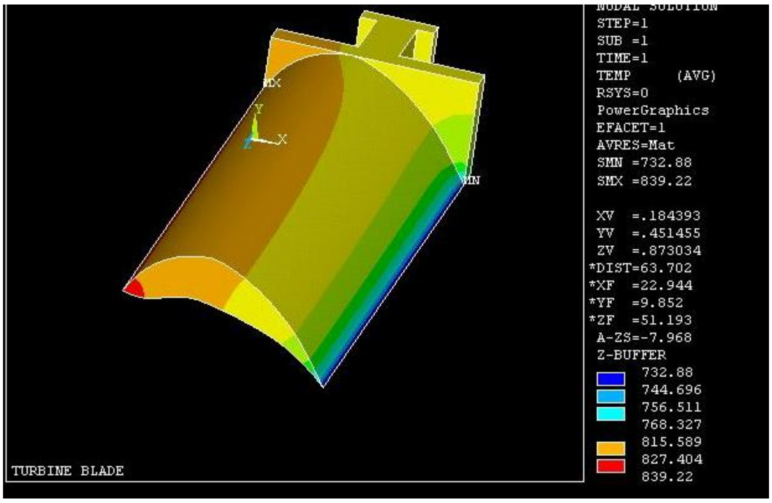
Building the model is the basic step involved in modeling the structure. The list of all the key points through which the basic outline of the structure is obtained is as follows:

LIST OF ALL SELECTED KEYPOINTS: LOCATIONS (Z=0)

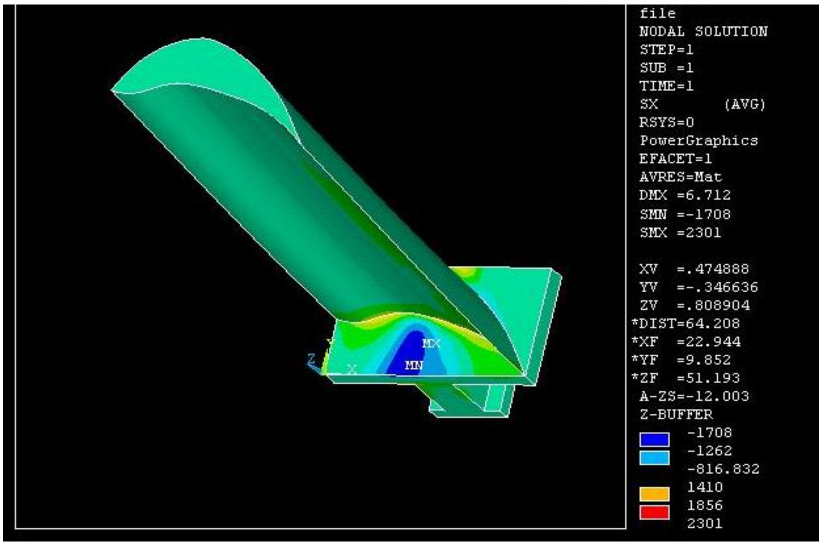
No	**X**	**Y**
1.	1	0
2.	3.25	17.5
3.	5.9	20.95
4.	10.1	24.25
5.	14.65	26.25
6.	23.1	26.25
7.	28.15	23.6
8.	33.4	19.85
9.	38	15.5
10.	42	10.9
11.	45.5	5.7
12.	49	0
13.	6.8	12.9
14.	11.2	14.4
15.	16.18	15.5
16.	21.1	14.9
17.	26	13.6
18.	38.2	8.77
19.	45	3.95
20.	49	27
21.	1	27
22.	19.8	0
23.	1	13.6
24.	29.2	0
25.	29.2	27
26	19.8	27
27.	29.2	12.4902
28.	19.8	15.1288
29.	29.2	22.85

All the areas are MAPPED meshes under PLANE42 with an element size 8 with quadrilaterals element. The areas 2,8,11,12,9,3,4 are extruded in the +Z direction to height of 5mm with element size 2. The areas 10,7,1 are extruded in the +Z direction of height 117mm. Now the areas 11,7,3 are extruded in the –Z direction to a height of 5mm. Now the side areas of this volume are extruded in the +_X direction of 3.8mm. All the extrusion operations are carried under SOLID45element. We obtain a total of 25 volumes, 114 areas, 6042nodes, 98key points and 118areas.

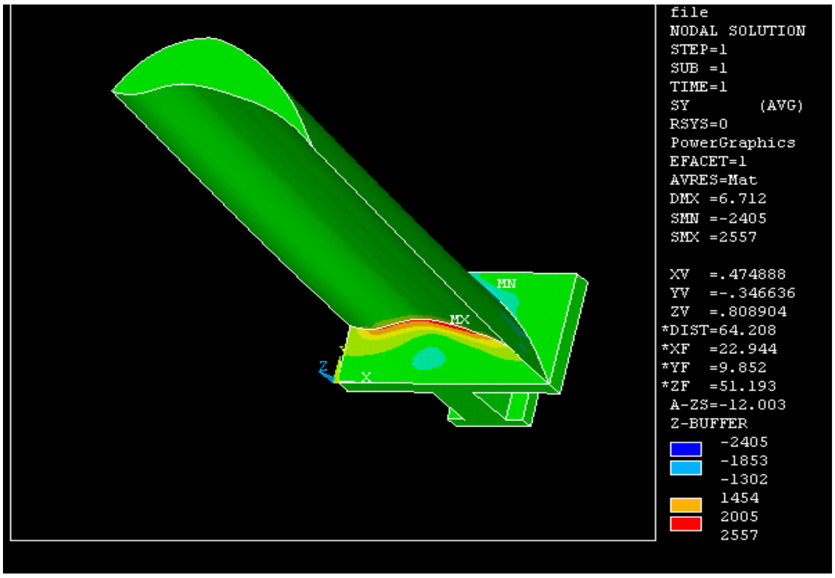
THE POST PROCESSOR MODULE:



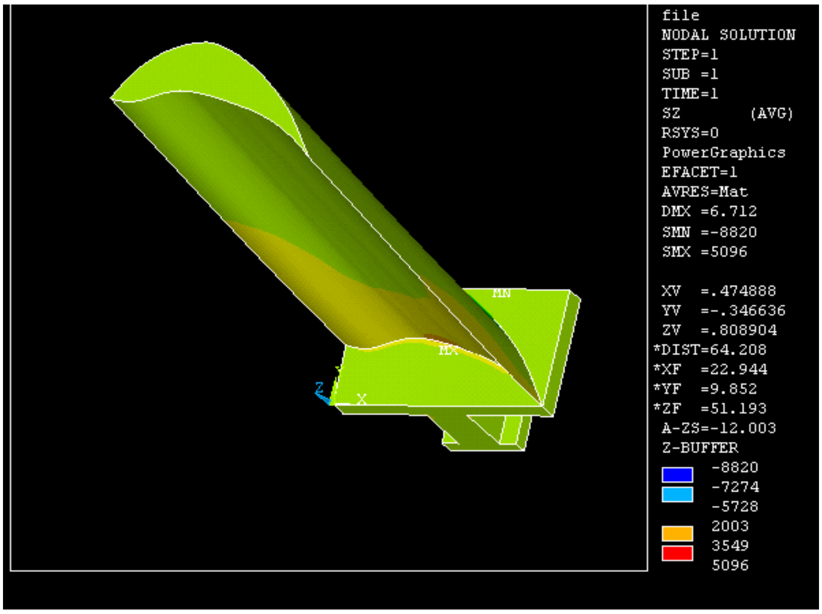
TEMPERATURE



STRESS IN X DIRECTION



STRESS IN Y DIRECTION



STRESS IN Z DIRECTION

ANALYSIS RESULTS:-

SOLUTION	MECHANICAL	THERMAL
DEFORM IN X-DIRECTION	-0.063056 to 2.569	----------------
DEFORM IN Y-DIRECTION	-0.075834 to 6.179	---------------
DEFORM IN Z-DIRECTION	-0.0456091 to 0.75937	----------------
STRESS IN X-DIRECTION	-1708 to 2301	---------------
STRESS IN Y-DIRECTION	-2505 to 2557	----------------
STRESS IN Z-DIRECTION	-8820 to 5096	---------------
VONIMISSES STRESS	46.803 to 317992	------------
VONIMISSES STRAINS	.023e-9 to 1.599	------------
TEMPERATURE	-------------	732.88 to 839.22
TOTAL GRADIENT STRESS	---------------	1.108e-3 to 35.308
TOTAL FLUX STRESS	-----------------	0.100e-3 to -3.202

XI. THE RESULTS ARE REVIEWED AFTER AND IT IS FOUND THAT:

1. The temperature varies between $738.4^0$and 839.28^0.
2. The thermal energy of the structure varies between 0684E-5 to 0.966e10.
3. The heat transfer occurring in the structure varies between –76.765KJ to 86.473KJ.
4. The temperature fluxes and temperature gradients of the structural is found.
5. The stresses and strains in the X, Y and Z directions are found.
6. The strain energy value of the structure is observed.
7. The stress intensity value of the structure is found to be varying between (0.333 to 1852)

It is observed that the temperature is linearly varying inside and irregularly variation on both ends of the flange i.e. suction and exhausts side.

XII. CONCLUSIONS

The finite element analysis of turbine blade and rotor is carried out on brick and isoperimetric elements. The static, modal and thermal analysis is carried out.

- The temperature has a significant effect on the overall stresses in the turbine blade.
- Maximum elongation and temperatures are observed at the blade tip section and minimum elongations and temperature variations at the root of the blade.
- Temperature distribution is almost uniform at the maximum curvature region along the blade profile.
- Temperature is linearly decreasing from the tip of the root of the blade section.
- Maximum thermal stresses are stresses are setup when the temperature difference is maximum from outside to inside.
- The thermal stresses are predominant in the analysis. The order follows thermal, pressure and centrifugal forces.
- Maximum stresses and strain are observed only at blade region in the rotor along the blade length and elongations in Y-direction are gradually varying from the different sections along the rotor axis.

REFERENCES

[1]. Steam & Gas turbines and Power Plant Engineering, VII ed., 2004, Central Publishing House Allahabad.
[2]. Fundamental of Internal combustion Engine by Gill, Smith, Ziurys
[3]. I.C. Engine by Rogowsky
[4]. I.C. Engine Analysis and Practice by E.F. Obert
[5]. Gas Turbine Theory by Cohen and Rogers
[6]. I. C. Engine by V. Ganeshan
[7]. Steam, Gas Turbines in Power plant Engineering, VII Ed. 2004, Central Publishing House Allahabad.
[8]. http://www.energymanagertraining.com/power_plants/Gas_Turbines.html
[9]. http://www.sulzerts.com/desktopdefault.aspx/tabid-1289/?gclid=CKuMvNSy1pkCFcIvpAodLGl_Vw
[10]. http://www.infibeam.com/Books/info/H-I-H-Saravanamuttoo/Gas-Turbine-Theory/013015847X.html