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DESIGN AND ANALYSIS OF TURBINE BLADE BY USING FEM

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ABSTRACT

The first stage rotor blade of a gas turbine has been analyzed for structural, thermal analysis using ANSYS (Finite Element Analysis Software). The material of the blade was specified as INCONEL 718. The thermal boundary conditions on the rotor blade are taken from the reference. The temperature distribution across the blade is obtained. The maximum stress up to which the blade can withstand is known and the stress distributions across the blade are obtained accordingly. The obtained results are compared with N-155, Mild Steel and the most suitable material is discussed. In final the actual fir tree model blade root compared with I-section model blade root, results are tabulated and it is observed that stress distribution less in fir tree model that the I-section model.

KEYWORDS: ANSYS, INCONEL 718, N 155

I. INTRODUCTION

A Gas turbine in general is a prime mover used for power generation and in various fields of mechanical Engineering. A gas turbine is an engine where fuel is continuously burnt with compressed air to produce a stream of hot, fast moving gas. This gas stream is used to power the compressor that supplies the air to the engine as well as providing excess energy that may be used to do other work. A turbine blade is the individual component which makes up the turbine section of a gas turbine. The blades are responsible for extracting energy from the high temperature, high pressure gas produced by the combustor. Turbine blades are subjected to stress from centrifugal force (turbine stages can rotate at tens of thousands of revolutions per minute (RPM)) and fluid forces that can cause fracture, yielding, or creep failures. Additionally, the first stage (the stage directly following the combustor) of a modern turbine faces temperatures around 2,500 °F (1,370 °C), up from temperatures around 1,500 °F (820 °C) in early gas turbines.

Theoretical Analysis of Gas Turbine blades by finite element method by Lawrence and Depanraj [1] published various techniques for cooling of turbine blades. One such technique is to have axial holes along the blade span. T.J Carter in the research about common failures in gas turbine blades [2] stand with the opinion that there are three probable damage mechanisms affect turbine blades, these being mechanical damage through either creep or fatigue and high temperature corrosion. The use of light alloys for the high temperature sections of the engine is not feasible since they cannot generally be design to give acceptable creep properties at the high temperatures needed for efficient turbine operation. A. K. Matta et.al. [3] studied the stress analysis for N – 155 & Inconel 718 material. On solid blades it is reported that Inconel 718 is better suited for high temperature operation. The analysis is carried by comparing to different materials. Goodwin [4] studied root attachment for a Gas Turbine engine Blade, United States Patent. The shape of the root falls within certain closely defined parameters which have been found to give optimum properties to the root.

II. WORKING MODEL

Cross section of gas turbine rotor blade is created in ANSYS Workbench Geometry. The aerofoil blades of a gas turbine, both in the compressors and turbines, are normally carried from a disc or drum or similar rotor structure. The engagement between the blades and the supporting rotor is a crucial part design of any such rotor without failure, and it must be overall as small as possible so as to reduce the size of the blade root and disc rim to a minimum.

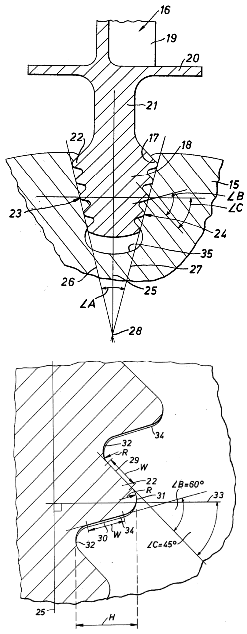

Figure 1: Fir Tree Type Blade Root

The aerofoil section is created by selecting a plane and then marking the key points. After marking the key points these are joined by using splines. The key points are as follows

Table 1: List of Selected Key Points

Key Point Number(Z=0)	Coordinate X	Coordinate Y
1	2.6	17.3
2	5.85	21
3	10	25
4	14.8	26.6
5	22.9	25.3
6	28	22.2
7	33.4	18.5
8	38	14.4
9	42	10.9
10	45.5	5.7
11	6.18	12.4
12	11.2	14.4
13	16.18	15.5
14	21.1	14.9
15	26	13.6

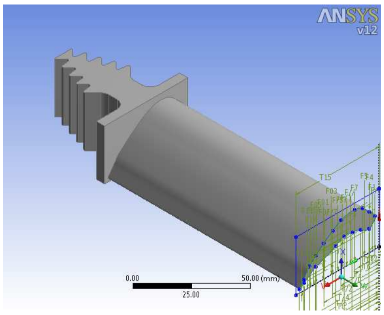

Figure 2: Solid Model of Turbine Blade with Fir-Tree Type Root

III. POST PROCESSING

The first stage rotor blade of the gas turbine is analyzed for the mechanical and radial elongations resulting from the tangential, axial and centrifugal forces. The gas forces namely tangential, axial are determined by constructing velocity triangles at inlet and exist of rotor blades.

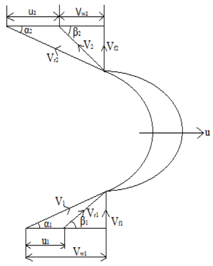

Figure 3: Velocity Triangle

F_a = Mass flow rate of gas × (V_{w1}+V_{w2})

F_a = 257.53 N

F_t = Mass flow rate of gas × (V_{f1}-V_{f2})

F_t = 38.13 N

IV. EXPERIMENT AND RESULT

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools. Modal analysis is the study of the dynamic properties of structures under vibration excitation. Modal analysis is the field of measuring and analysing the dynamic response of structures and or fluids when excited by an input. A thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The finite element solution you perform via ANSYS calculates nodal Temperatures, then uses the nodal temperatures to obtain other thermal quantities.

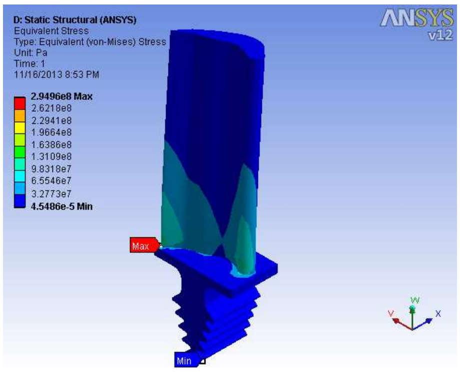

Figure 4: Von-Mises Stress of Mild Steel

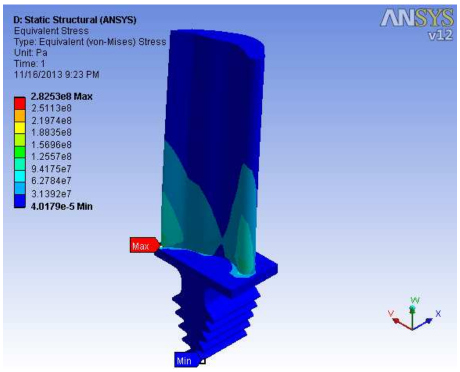

Figure 5: Von-Mises Stress of ICONEL 718

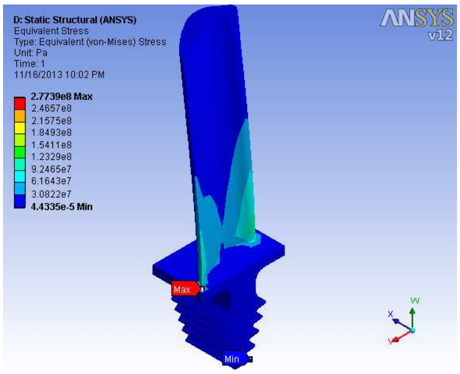

Figure 6: Von-Mises Stress of N 155

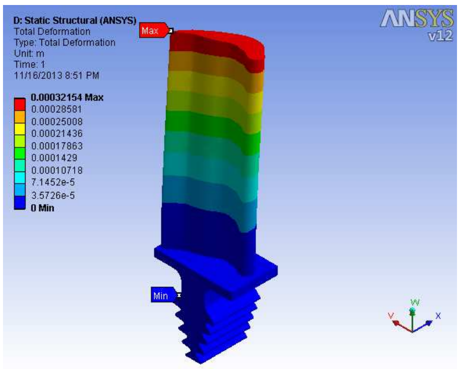

Figure 7: Deformation of Mild Steel

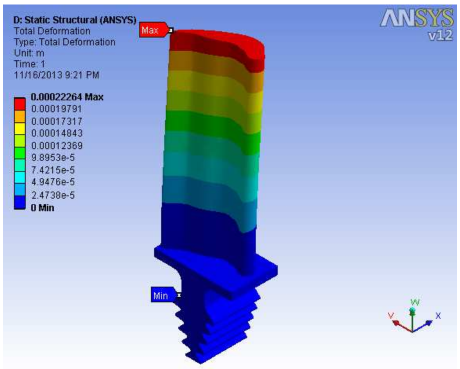

Figure 8: Deformation of ICONEL 718

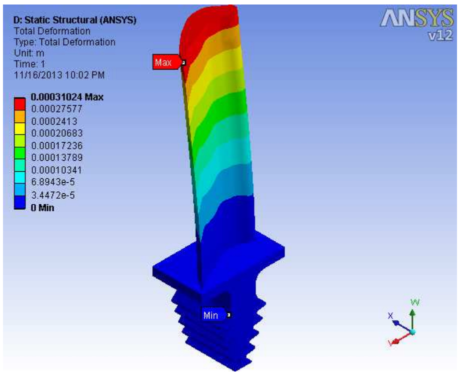

Figure 9: Deformation of N 155

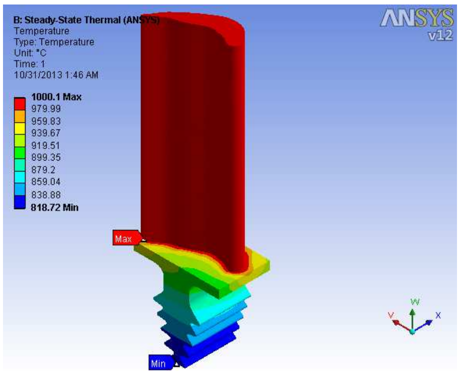

Figure 10: Temperature Distribution of Mild Steel

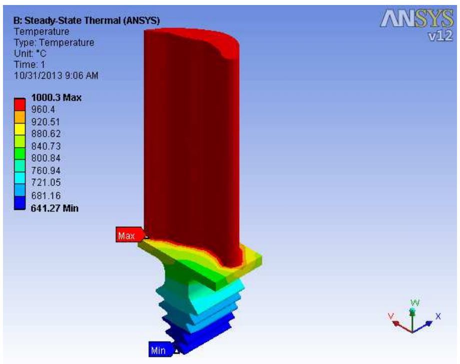

Figure 11: Temperature Distribution of ICONEL 718

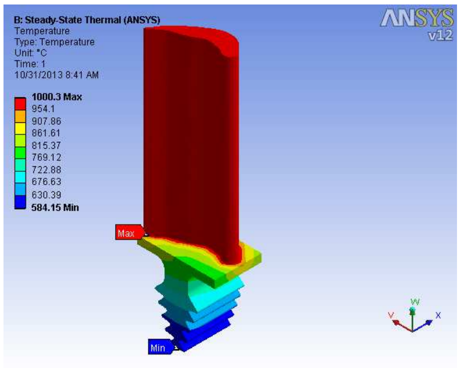

Figure 12: Temperature Distribution of N 155

Table 2: Comparison of Results

Property	MILD STEEL	INCONEL 718	N-155
Von-Mises Stress (MPa)	282.5	277.39	294.96
Max. Principal Stress (MPa)	296.83	291.37	309.68
Total Deformation (10^{-4}× m)	2.2264	3.1024	3.2154
Equivalent Elastic Strain(10^{-3})	1.4126	1.8617	2.0626

Table 2 represents analysis has been carried on three different materials i.e. Mild steel, N-155, INCONEL 718. From structural analysis, we have found that displacement is less for INCONEL 718 i.e. 0.00031024 on comparison with MILD STEEL and N- 155. The maximum operational Von-Misses Stresses are within the yield strength of the material and the deformation is comparatively less for material INCONEL 718.

Table 3 shows the fir tree model blade root compared with I-section model blade root, results are tabulated and it is observed that stress distribution less in fir tree model that the I-section model.

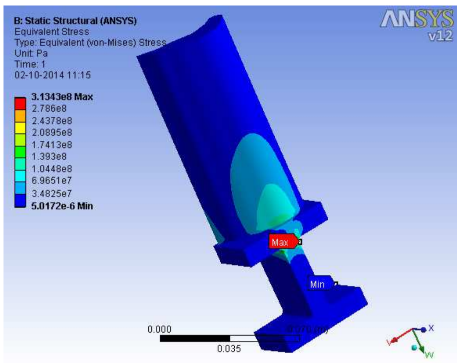

Figure 13: Stress Distribution in the I-Section of Material Mild Steel

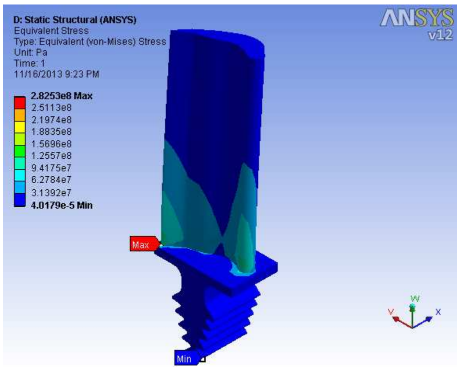

Figure 14: Stress Distribution in the Fir Tree Section of Material Mild Steel

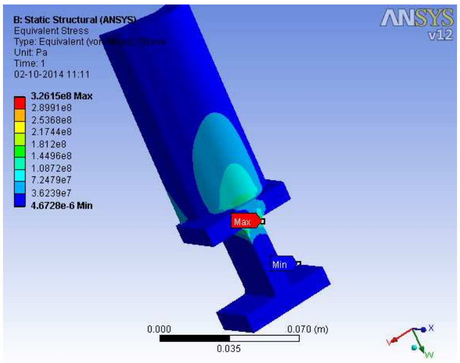

Figure 15: Stress Distribution in the I-Section of Material INCONEL 718

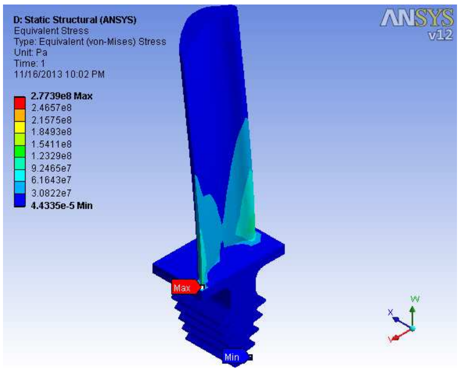

Figure 16: Stress Distribution in the Fir Tree Section of Material INCONEL 718

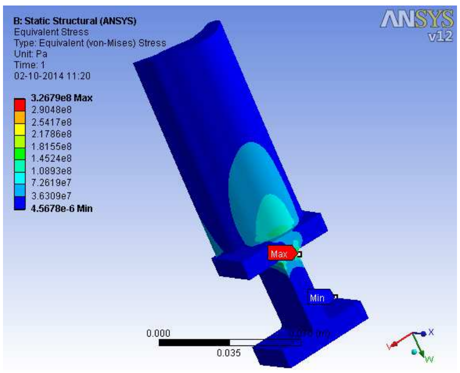

Figure 17: Stress Distribution in the I-Section of Material N 155

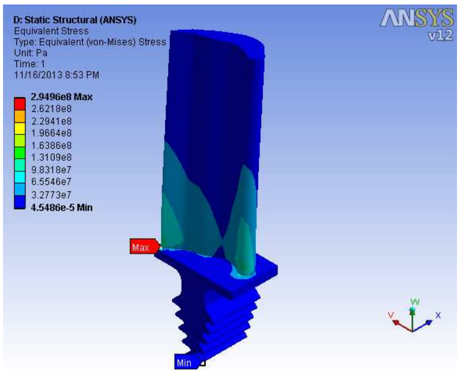

Figure 18: Stress Distribution in the Fir Tree Section of Material N 155

Table 3: Comparison of Results

S. No	Material	Results	Fir-Tree Model Blade Root	I-Section Model Blade Root
1	Mild Steel	Von-Misses stress(MPa)	282.5	313.43
2	INCONEL 718	Von-Misses stress(MPa)	277.39	326.15
3	N 155	Von-Misses stress(MPa)	294.96	326.79

V. CONCLUSIONS

From the above results we can conclude that using INCONEL 718 is more beneficial than previous materials, due to low stress displacement, good thermal strength and low cost and it is observed that stress distribution less in fir tree model that the I-section model.

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