RESEARCH ARTICLE OPEN ACCESS

Analysis of Turbine Blade under the Effect of Damping with Different Materials

N. Sreenivasa Babu[1] Dr. K. Jayathirtha Rao[2],
Lecturer, Shinas college of Technology, Sultanate of Oman.
IDST consultant, RCI, DRDO Hyderabad

ABSTRACT
Critical operating conditions of turbine blades for its effective life is the present need of the industry. In this aspect a typical analysis is performed on a turbine blade in this research work. In the first stage an analysis is performed taking into account of thermal loading and with combination of mechanical loads for the evaluation of displacements and stresses to locate the critical area in the model. Later in the second stage under the effect of damping factor 0.001 and natural frequencies of blade is investigated using commercial Ansys software with different materials. A solid 185 brick element is chosen for the analysis and the simulated results were analyzed for comparison with materials like Nickel base Alloy and Ti-6 Al-4V.
Key words: Coupled field analysis, Solid 185 brick element, Natural frequencies and Damping factor.
Nomenclature:

I. INTRODUCTION

Aero Engines working under typical operating conditions are subjected to different types of loads such as thermal and mechanical loads as they are otherwise known as gas turbines. These are effected by high temperature and as well as high pressures to give sufficient propulsive force to the space vehicles. Binesh Philip and N. C. Mahendra Babu [2010] explained an analytical procedure to evaluate and quantify the fatigue life of a single stage fan blade. This blade, being at the starting of the engine, is subjected to centrifugal, gas bending and dynamic loads.. Different regions of the blade such as dovetail roots and roots of the aerofoil experience high centrifugal stresses when the blade spins at 10600 rpm along with the gas bending load. Maximum von Mises stress of 1740 MPa is observed at the dovetail root. But the yield strength of the material is only 985 MPa [1]. All the loads are dependent on the speed of the engine and not much focused on the temperature and damping effect of the material. In the same context at the beginning stage, the requirement for improved stress analysis and life predictions techniques which will allow the best usage of the materials. To enable this features D. P. Shepherd, T J Ward, A Wisbey, B Vermeulen and A D Boyd Lee [2004] narrated the different life enhancement techniques by not only reducing the weight but also considering available service life [2]. G. Narendranath and S.Suresh [2012] emphasized the thermal analysis of N155 super alloy with iron based and the results were evaluated with respect to temperature and found no significant change in the temperature from the first 6 mm length from the leading edge and from there to next 36 mm length of blade the temperature is gradually decreasing and reaching to a temperature of 781.548°C [3]. But such turbine blade need more attention about it fatigue life as it is subjected to repeated stresses. This research will concentrate some of the needy features for its fatigue life estimations by introducing an additional concept of damping.

II. Problem Description

In the context of the blade, a typical environment of working conditions are chosen for the turbine blade while the operating pressure from 4 to 10 bar (maximum value of 10 bar chosen for analysis) and the temperature is about 1050°c [5] [2005] were chosen for the analysis in the first stage of static analysis. The same model is performed for its second stage of dynamic analysis to evaluate its natural frequencies with the effect of damping under these working conditions. Materials chosen for this analysis and their properties are as in the table1.

S.No.	Material	Thermal Conductivity(K)[W/mm°C]	Thermal Expansion(α)[1/°C]	Density (ρ) Kg/mm^3	Young's Modulus(E) N/mm^2	Poisson's Ratio (1/m)
1	Nickel base Alloy	19e-3	15e-6	8.19e-6	0.18e5	0.3
2	Ti-6 Al-4V	6.7e-3	8.6e-6	4.43e-6	1.138e5	0.342
3	M246 Alloy	25e-3	10e-6	7.7e-6	2.0e5	0.285
4	N155 Alloy	20e-3	8.5e-6	8.249e-6	2.02e5	0.298

Table: 1 Material properties

III. FEM Model

A section representing the actual dimensions of the turbine blade having airfoil cross-section is modeled using Ansys with solid 185 element having airfoil blade length of 510 mm for the analysis. The total number of elements considered for the analysis is 77,378 to an effective convergence of the solution. At the rim of the blade is fixed by choosing all degrees of freedom arrested and later the thermal environment is superimposed on mechanical loads to evaluate the combined effect on the turbine blade for its deflections and stresses. Later its natural frequencies and forced frequencies are extracted from modal analysis to evaluate material consistency.

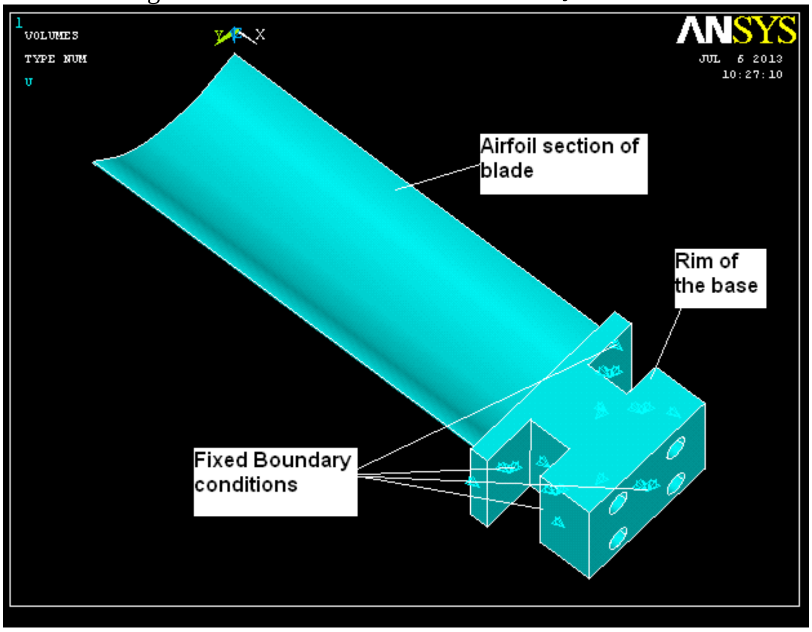

Fig: 1 A typical turbine blade 3-D profile

IV. Results & Discussions

The deflections and the stresses are simulated from the analysis and they are the pre-requisites for calculation of fatigue life of turbine blade for each material. The results are validated from the mathematical models to check the feasibility of the material existence to suite as a best material to the turbine blade.

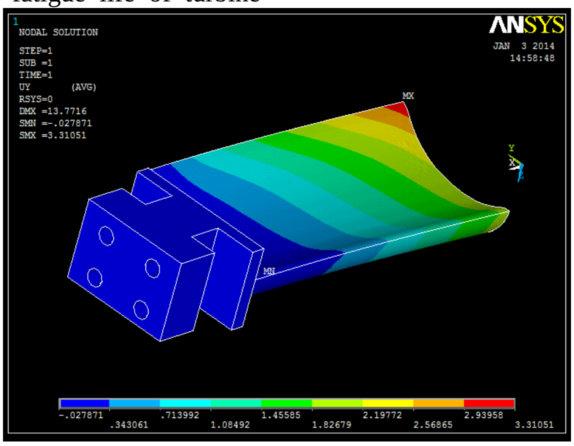

Fig: 2 Static Deflection of Ni based Alloy material blade

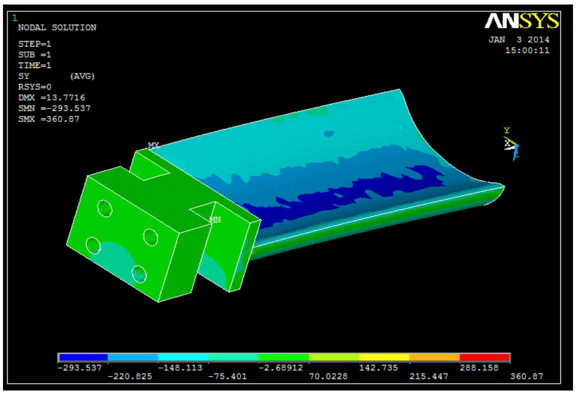

Fig:3 Stress Distributions of Ni based Alloy material blade

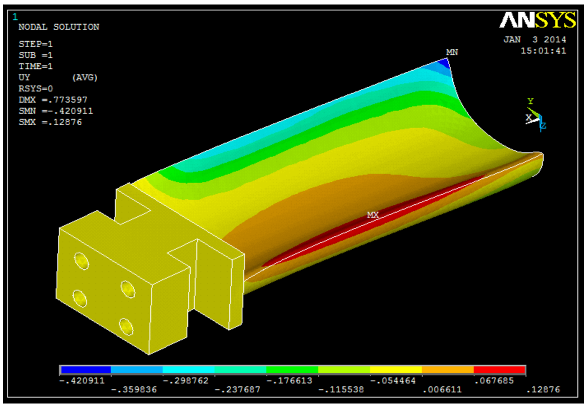

Fig: 4 Static Deflection of Ti-6 Al-4V material blade

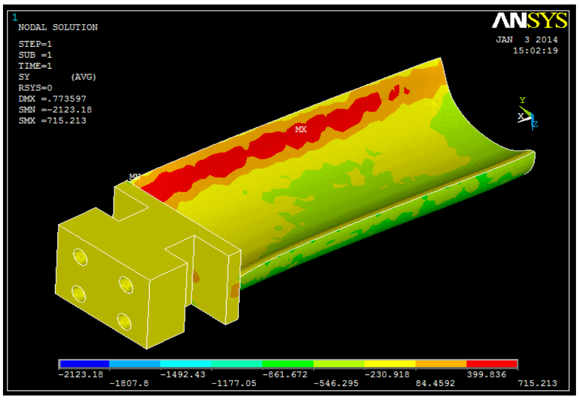

Fig: 5 Stress Distribution of Ti-6 Al-4V material blade

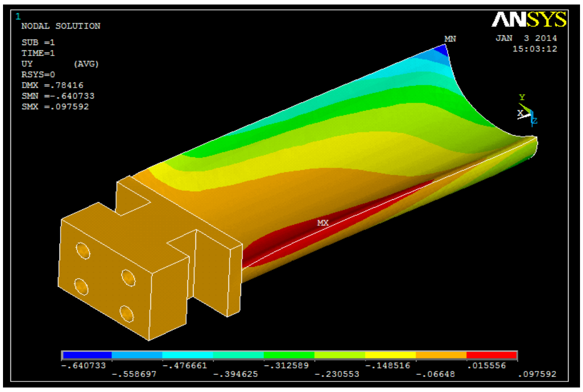

Fig: 6 Static Deflections of M246 Alloy material blade

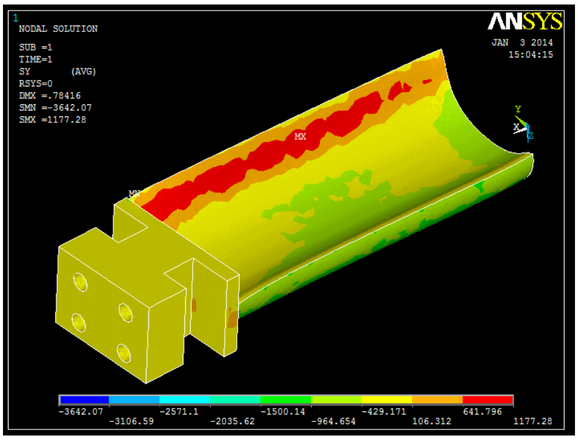

Fig:7 Stress Distributions of M246 Alloy material blade

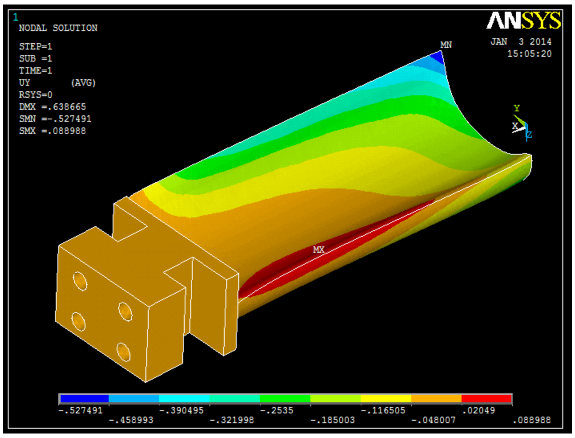

Fig: 8 Static Deflections of N115Alloy material blade

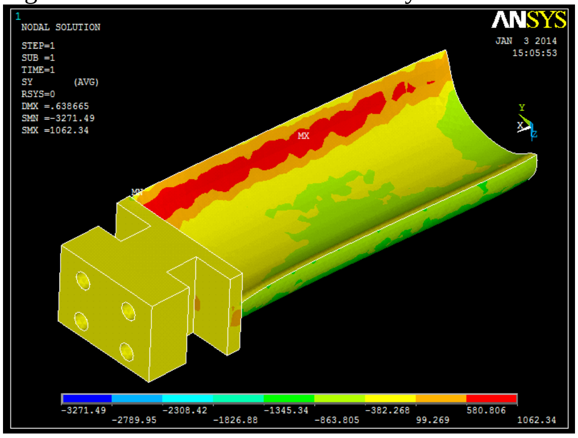

Fig:9 Stress Distributions of N115 Alloy material blade

The deformations, stresses and the frequency levels for each material are tabulated at the value of 0.001 for the damping factor.

Material Name	Deflection in mm	Stress in N/mm^2
Ni based alloy	3.31051	360.87
Ti-6 Al-4V alloy	0.12876	715.213
M246 Alloy	0.09759	1177.28
N115 Alloy	0.08000	1062.34

Table: 2 Stresses and deflections at 1 N/mm^2 pressure and 1050°C temperature

Material Name	Frequency levels at 1 N/mm^2 pressure and 1050°C temperature
Ni based alloy	8.01
Ti-6 Al-4V alloy	27.53
M246 Alloy	27.42
N115 Alloy	26.72

Table: 3 Frequencies at 1 N/mm^2 pressure and 1050°C temperature

V. Conclusions

- The deflections are varying up to 3.31051mm for Ni based Alloy blade, 0.12876mm for Ti-6 Al-4V blade, 0.097592 mm M246 Alloy blade and 0.08mm for N155 Alloy blade material indicating that Ni based material is deflecting more from the other materials for the same loading conditions.
- The stresses are varying up to 360.87 N/mm^2 for Ni based Alloy blade, 715.28 N/mm^2 for Ti-6 Al-4V blade, up to 1177.28 N/mm^2 for M246 Alloy blade and up to 1062.34 N/mm^2 for N155 Alloy blade material. Proving that Ti-6 Al-4V material stresses are in good understanding with the safe limit.
- No significant change observed in the natural frequency level to the forced frequency level and proving that the structure is stable even at typical loading conditions.
- Betterment can also be made by providing thermal barrier coating system for the blade material is the future scope for the researches.

References

[1] Binesh Philip and N. C. Mahendra Babu, "Numerical Estimation of Fatigue Life of Aero Engine
Fan Blades", SAS Tech Journal, Volume 9, Issue 2, September 2010.

[2] D. P. Shepherd, T J Ward, A Wisbey, B Vermeulen and A D Boyd Lee, "Life Extension Methods in Aero Engines", OMMI, Vol.3, Iissue 1, 2004.

[3] Yaşar Kahraman and Imdat Taymaz, " Lifetime Assessment and Shock Behavior of TBC in Gas Turbine Blades: Experimental and Numerical Investigations", 13th International Conference on Plasma Surface Engineering, Germany, 2012.

[4] www.Ansys.com

[5] Rybnikov A.I., Getsov L.B. and Leontiev S.A., "Failure Analysis of Gas Turbine Blades", Microscopy Society of America, Microsc Microanal 11(Suppl 2), 2005.

[6] www.wikipedia.com

[7] www.hightempmetals.com