

# Computational Modal Analysis of First stage Gas Turbine Blade

Sushila Rani

Department of Mechanical Engineering, Beant College of Engineering and Technology, Gurdaspur, Punjab, India.

## Article Info

Article history:

Received 25 September 2015

Received in revised form

20 October 2015

Accepted 28 November 2015

Available online 15 December 2015

**Keywords:** Gas Turbine Blade, Computational modal analysis, Mode shape

## Abstract

Modal analysis can be a powerful tool to assist in the identification and elimination of fatigue problems. The most obvious use of modal analysis is in determining the natural frequencies of the turbine blades. Knowledge of these frequencies can be very useful in avoiding excessive excitations and thereby reducing the risk of fatigue failure. A less obvious application of modal analysis is in the validation of computer generated models of the turbine blades. These models can be very useful to investigate turbine and turbine blade properties under running conditions. Finite element models can be used to predict the influence of design changes on the stresses and strains acting on the turbine blade under running conditions.

## 1. Introduction

Modal analysis can be described in terms of its natural characteristics like frequency, damping and mode shape. Generally these are called dynamic properties of structure. Modal data are very useful information that can assist in the design of any structure. Many researchers used modal parameters as the diagnostic tools for structural assessment. Knowledge of modal parameters helps in damage detection in structures and hence used as an assessment tool for structures

Mansour et al.[1] have found structural mode shapes, natural frequencies, and modal dampings of a setar by means of experimental modal analysis and finite element (FE) method. Stehan et al.[2] has performed modal analysis of gas turbine blade and chassis body of car Paolo et al. [3] have performed thermal and mechanical simulation of both Laser and TIG welding. Wilhelm et al.[4] has focused on the remaining benefits of implicit analysis and how a proper combination of ANSYS and LS-DYNA can be used to prepare the transient analysis by common preprocessing and static analysis steps. Joeng et al.[5] performed finite model analysis of bolted joints. Muscia et al. [6] presented a theoretical experimental method for estimating damping capacity of vibrating structures based on modal analysis. Banerjee et al. [7] performed free vibration of a three-layered sandwich beam using dynamic stiffness method and experiment modal analysis. Esfandiari et al. [8] have presented a finite element model updating technique using strain data in the frequency domain. Guy Banwella et al. [9] used experimental modal analysis for validating a finite element model of a tennis racket.

## 2. Computational modal analysis of Turbine Blade

A failed First stage gas turbine blade is shown in Fig [1]. The positioning of First stage gas turbine blade on rotor is shown in Fig. [2]. Finite element model used here for computational modal analysis is developed through three dimensioning scanning of this failed turbine blade. Fig. [3] Shows three dimensional model of first stage gas turbine blade and meshing of this three dimensional model is shown in Fig. [4]. The modeling and post-processing is performed using Finite element based software ANSYS 15.

\*Corresponding Author,

E-mail address: sranidtu@gmail.com

All rights reserved: <http://www.ijari.org>

The finite element model generated has 136468 nodes and 84361 elements. Triangular surface meshes are used and the meshing is performed with the auto meshing features of ANSYS 15. The Material properties and dimensions of IN738 turbine blade are listed in Table 1 and Table 2 respectively.

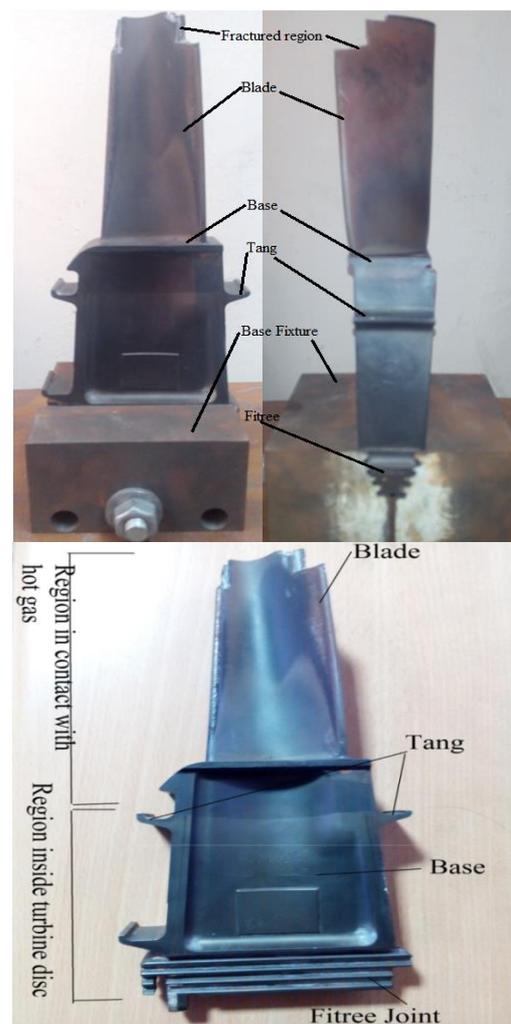
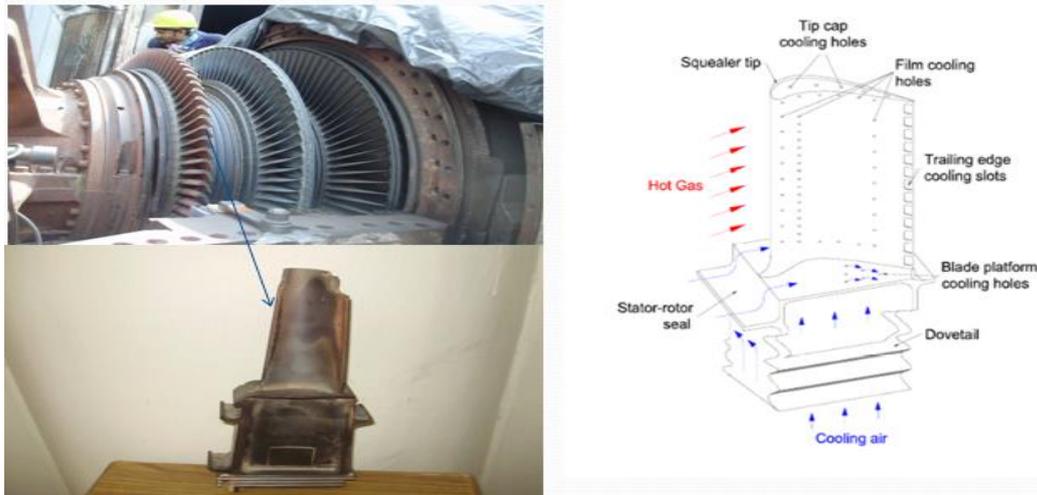
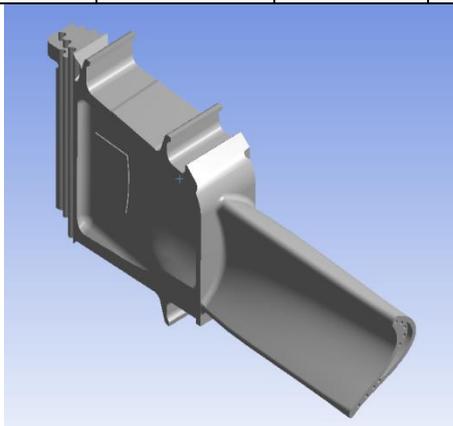


Fig.1. Nomenclature of Gas Turbine Blade

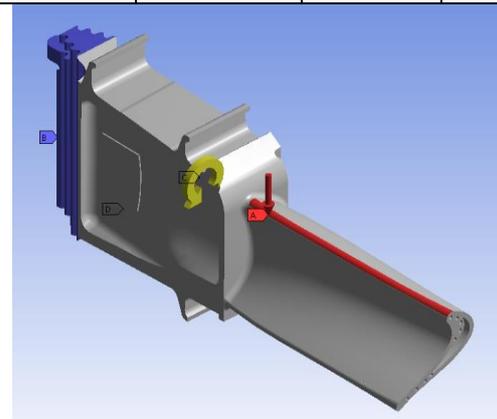


**Fig. 2.**Position of First Stage gas turbine Blade on Rotor  
**Table 1:** Material properties of IN738 Turbine Blade

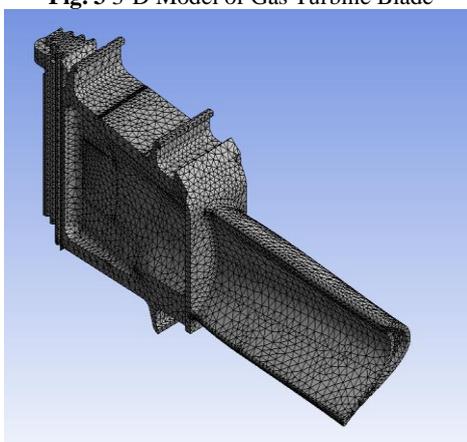
Material	Young's Modulus (N/m <sup>2</sup> )	Poisson's Ratio	Density (kg/m <sup>3</sup> )	Bulk Modulus , (N/m <sup>2</sup> )	Shear Modulus, (N/m <sup>2</sup> )	Tensile Yield Strength	Tensile Ultimate Strength
IN738	1.3996x10 <sup>11</sup>	0.3	8110	1.1664x10 <sup>11</sup>	5.3832x10 <sup>10</sup>	3.4474x10 <sup>8</sup>	4.5505x10 <sup>8</sup>



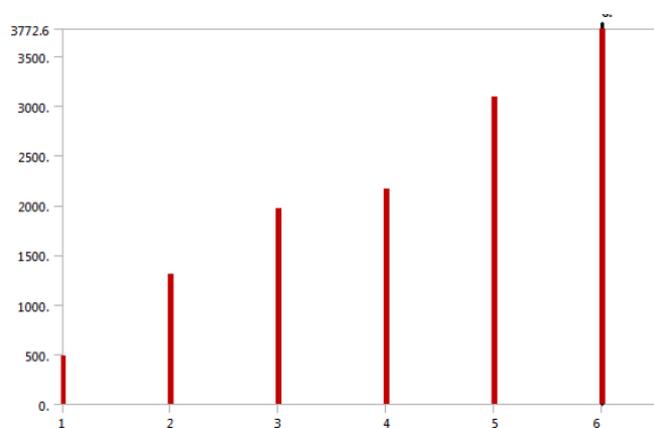
**Fig. 3** 3-D Model of Gas Turbine Blade



**Fig.5.** Fixing of all contact points at Fitter part



**Fig. 4.** Meshing of Gas Turbine Blade



**Fig.6.** Natural Frequencies of Gas Turbine Blade

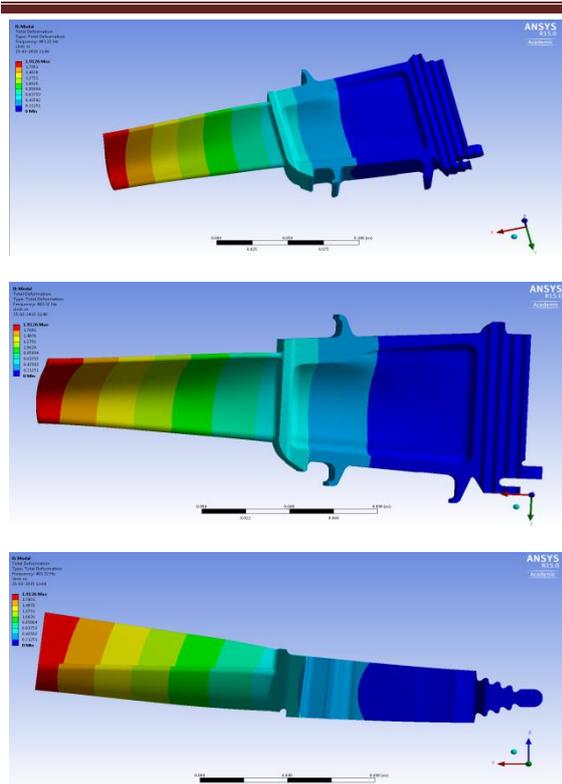


Fig.7. Mode 1 at frequency 483.32 Hz

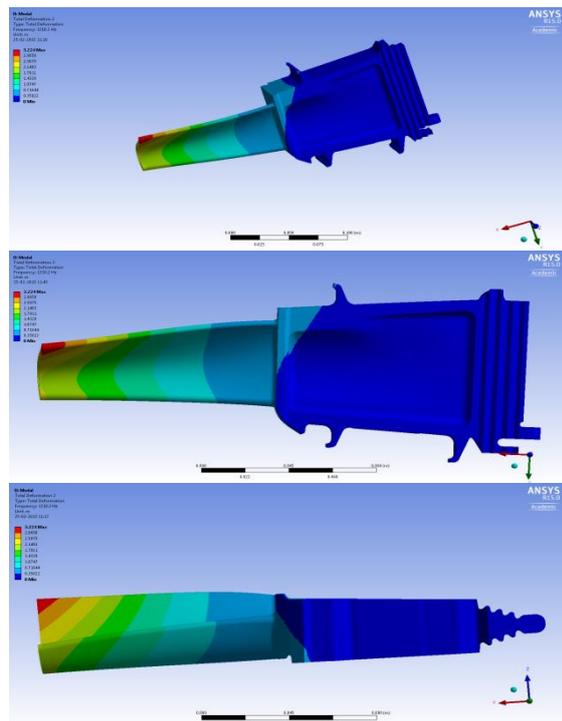


Fig.8 Mode 2 at frequency 1310.2 Hz

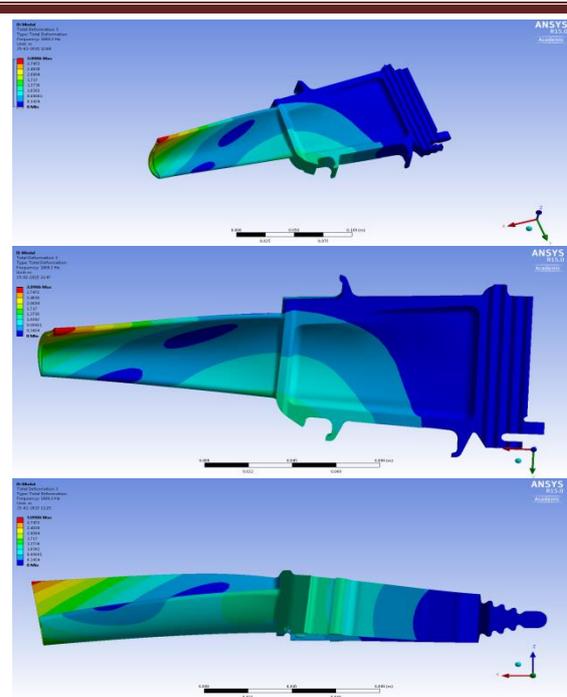


Fig.9 Mode shape at frequency 1969.3 Hz

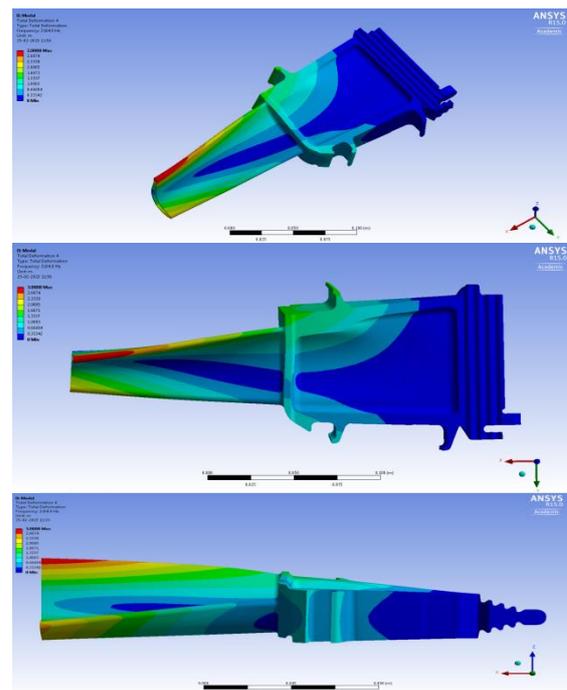


Fig. 10 Mode 4 at frequency 2164.9 Hz

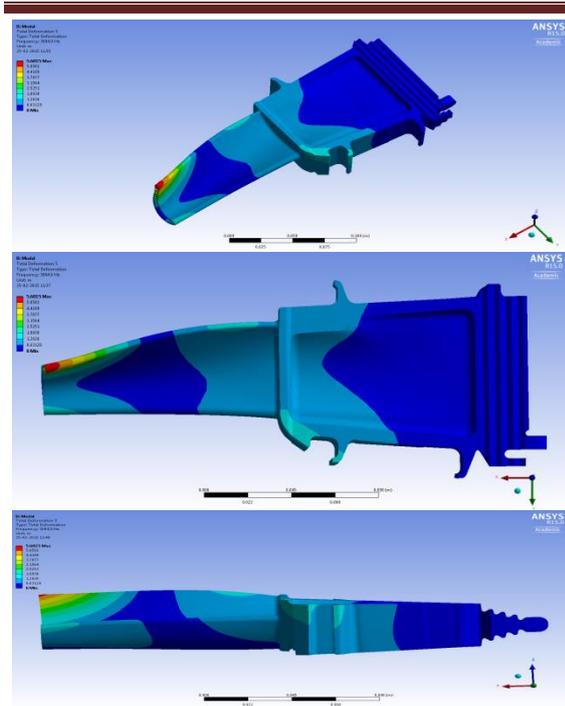


Fig .11 Mode shape at frequency 3094.9 Hz

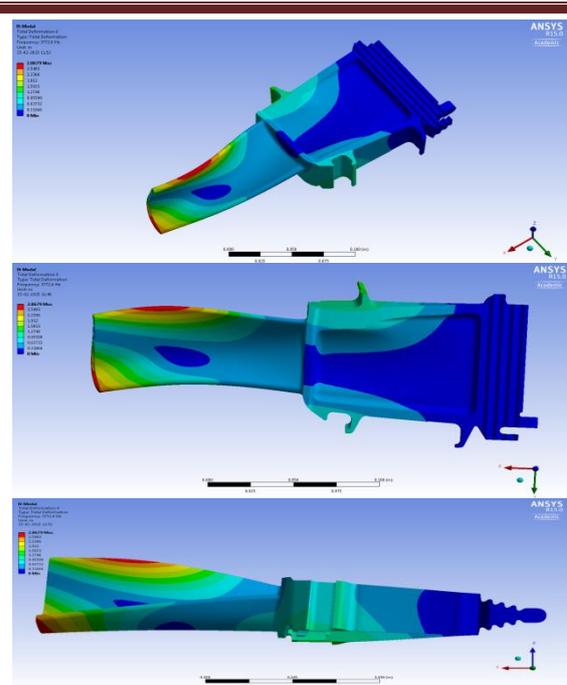
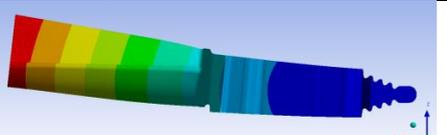
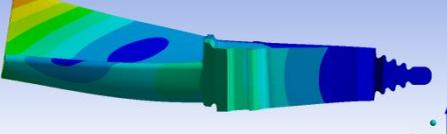
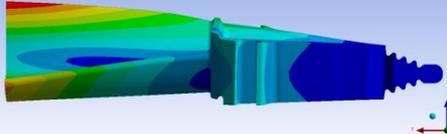
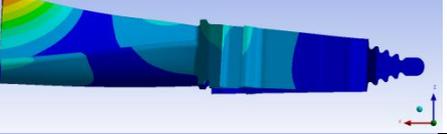
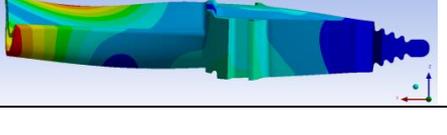


Fig.12. Mode shape at frequency 3772.6 Hz

Table 1: Computational Modal Analysis Results OF First Stage Gas Turbine Blade

Modal Parameters	Natural Frequency	Damping Factor	Mode shape
Mode 1	483.32 Hz	Bending	
Mode 2	1310.2 Hz	Bending	
Mode 3	1969.3 Hz	Twisting	
Mode 4	2164.9 Hz	Twisting	
Mode 5	3094.9 Hz	Bending + Twisting	
Mode 6	3772.6 Hz	Bending + Twisting	

Modal analysis of Turbine Blade has been performed using Finite Element based software Ansys 15. The boundary conditions in the finite element model are based on turbine blade clamp. In the finite element model boundary conditions are simulated by fixing all contact points in all directions at free part shown in Fig.[5]. The first six natural frequencies of turbine blade are represents in Fig. [6]. Six modes shapes of Turbine Blade are shown from Fig.7-12.

### 3. Results and Discussions

Table.3 represents computational modal Analysis results in tabular form. It is found that first two modes are bending. Mode 3 and mode 4 are twisting and Mode 5 and Mode 6 are combined twisting and bending.

### 4. Conclusion

Modal analysis is described in terms of its natural characteristics like frequency, and mode shape. Generally these are called dynamic properties of structure. In this research work modal analysis of first stage gas turbine blade has been conducted. First six modal shapes at first six natural frequencies have been achieved. Knowledge of these frequencies can be very useful in avoiding excessive excitations and thereby reducing the risk of fatigue failure.

### References

- [1.] Mansour H, Modal Analysis of the Setar: A Numerical–Experimental Comparison, *Journal of Vibration and Acoustics*, ASME 37(6), 2015, 061006-1 to 061006-7
- [2.] Stefan R, Jean-Daniel B, Siddhartha M. Probabilistic finite element analysis using ANSYS, *Journal of Structural Safety* 28, 2006, 17–43.
- [3.] F. Paolo, Multipurpose ANSYS FE procedure for welding processes simulation, *Journal of Fusion Engineering and Design*, 84(2–6), 2009, 546–553
- [4.] R. Wilhelm, Finite element limit load analysis of thin-walled structures by ANSYS (implicit), LS-DYNA (explicit) and in combination, *Journal of thin walled structures*, 41(2–3), 2003, 227–244
- [5.] Joeng K, Yoon J. Finite element analysis and modeling of structure with bolted joints, *Journal of Applied Mathematical Modeling*, 315, 2007, 895–911
- [6.] Muscia, R, A theoretical experimental method based on modal analysis for estimating the damping capacity of vibrating structures, *Journal of Mechanical Systems and Signal Processing*, 5(6), 1991, 475- 499.
- [7.] Banerjee, JR, Cheung, CW. Free vibration of a three-layered sandwic beam using dynamic stiffness method and experiment, *International Journal of Solids and Structures*, 44, 22-23, 2007, 7543 7563.
- [8.] A, Sanayei M, Bakhtiari-Nejad F. Rahai A. Finite element Model Updating Using Frequency Response Function of Incomplete Strain Data, *AIAA Journal*, 48 (7), 2010, 1420-1433.
- [9.] Banwella G, Mohrb S, Rothberga S, Roberts J. Using experimental modal analysis to validate a finite element model of a tennis racket, 9th Conference of the International Sports Engineering Association (ISEA), *Procedia Engineering* 34, 2012, 688 – 693.