Computational Modal Analysis of First stage Gas Turbine Blade

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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. Stephan 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.

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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

<table>
<thead>
<tr>
<th>Material</th>
<th>Young’s Modulus (N/m²)</th>
<th>Poisson’s Ratio</th>
<th>Density (kg/m³)</th>
<th>Bulk Modulus (N/m²)</th>
<th>Shear Modulus (N/m²)</th>
<th>Tensile Yield Strength</th>
<th>Tensile Ultimate Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN738</td>
<td>1.3996x10¹¹</td>
<td>0.3</td>
<td>8110</td>
<td>1.1664x10¹¹</td>
<td>5.3832x10¹⁰</td>
<td>3.4474x10⁸</td>
<td>4.5505x10⁸</td>
</tr>
</tbody>
</table>

Fig. 3 3-D Model of Gas Turbine Blade

Fig. 4. Meshing of Gas Turbine Blade

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

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

<table>
<thead>
<tr>
<th>Modal Parameters</th>
<th>Natural Frequency</th>
<th>Damping Factor</th>
<th>Mode shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode 1</td>
<td>483.32 Hz</td>
<td>Bending</td>
<td><img src="image1" alt="Mode 1 Mode Shape" /></td>
</tr>
<tr>
<td>Mode 2</td>
<td>1310.2 Hz</td>
<td>Bending</td>
<td><img src="image2" alt="Mode 2 Mode Shape" /></td>
</tr>
<tr>
<td>Mode 3</td>
<td>1969.3 Hz</td>
<td>Twisting</td>
<td><img src="image3" alt="Mode 3 Mode Shape" /></td>
</tr>
<tr>
<td>Mode 4</td>
<td>2164.9 Hz</td>
<td>Twisting</td>
<td><img src="image4" alt="Mode 4 Mode Shape" /></td>
</tr>
<tr>
<td>Mode 5</td>
<td>3094.9 Hz</td>
<td>Bending + Twisting</td>
<td><img src="image5" alt="Mode 5 Mode Shape" /></td>
</tr>
<tr>
<td>Mode 6</td>
<td>3772.6 Hz</td>
<td>Bending + Twisting</td>
<td><img src="image6" alt="Mode 6 Mode Shape" /></td>
</tr>
</tbody>
</table>
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 fitree 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
[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(2–6), 2003, 227–244