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Optimization of Twisted Aero-Foil Blade Angle of a Structural Gas Turbine Assembly

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Abstract

The present work describes about the optimization of pre-twisted blade angle of a gas turbine. The minimization is done for the best blade structure due to low velocity, high drag force and frictional force. The previous research work brought a comprehensive knowledge about the pre-twisted blade where the angle is about 14.5^0. The modeling of gas turbine structural assembly is done in CATIA-V5 and the prototype is stored in IGES format. The Assembly consists of shaft, blade(twisted) and hub(disc).The prototypes (pre-twisted blades) of different angles of 15^0, 18^0, 21^0 and 25^0 are subjected to Finite element analysis packages like ANSYS like 15.0 version and these prototypes are made of INCONEL 718 material which is a super-alloy. The ANSYS is operated for analyzing the static structure of the gas turbine integral unit to find the natural frequency at different conditions to avoid resonance of the gas turbine assembly unit. Similarly, an experimental analysis is done on the FFT instrument where DEWE software is used to find the natural frequency of the assembly in working condition. The comparisons has been made between experimental and the simulation for the static structural assembly.

Keywords: ANSYS, Static structure, pre-twisted blade, INCONEL, CATIA-V5, Resonance

INTRODUCTION

Gas turbine assembly unit is used in power generation industry as it withstands high temperature, mechanical strength. The present research work is done to analyze the structural assembly of a gas turbine using a three dimensional model using the FEA software package for optimization. It has become important to minimize the weight, size of any structure in present day assemblies. In this case, it is to optimize the pre-twisted blade angle of the integral unit of turbine system by using finite element analysis until is good solution is achieved. The geometrical configurations are used for the solution to obtain. This optimization of pre-twisted blades can also occur in air-craft, jet engines propulsion etc. Bladed Disc initiates for non-linear vibrations that can be responsible for severe problems. This method offers good design for turbine gas model which is critical point to ensure blade angle optimization by using ANSYS. This involves FEM package which finds the natural frequency by solving in order to improve the performance. In this study, we mainly focus on specific engineering field of component mode where the design synthesis is made from both experimental and simulation methods. The results and comparison were made. The experimental method is based on DEWE software which uses the fast Fourier transform. The simulation was made in ansys at all angles of pre-twisted blade of the turbine assembly.

LITERATURE REVIEW

1. Ravi Ranjan Kumar and K.M. Pandey Journal of Basic Applied Engineering Research P.ISSN 2350-0077, e -ISSN 2350-0255, Vol.3, Issue 3. are done static structural Analysis of Gas turbine blade - they used solid works to create modela nd ANSY work bench to do static structural analysis, they took three materials such as Nimonic alloy 80A, super alloy x, Inconel 625, they concluded Inconel 625 can be a suitable for manufacturing of gas turbine blades.
2. Meghna vora, Rowena etl (2) are intend to study two configurations of a rotor blade, that is untwisted and pretwisted blade, modelling of blade can be done by CATIA and static structural analysis will be carried out in ANSYS 15.0. Pre twist angles 4^o and 6^o analyzed.
3. P.R. Surve. R.V.Shitole etal (3) are done structural analysis of Gas turbine blade, they are done analysis to know the mechanical stress and defination

experienced by the Gas turbine rotor blade. Solid model of blade created by using solid works 20 and turbine blade is analyzed for its structural performance due to loading condition for its structural performance due to loading condition using ANSYS 16.2 version, they study blade of materials namely aluminium alloy, titanium alloy and magnesium alloy, they concluded titanium alloy is best among three.

4. Nagesh R, Apoora et. al (4) are present, the work on optimization of material among INCONCL-718 and ceramics to sustain fatigue loading and creep rupture which helps the life assessment of blade increases, they are created solid model by using CATIA V5 R21 and it static structural analysis can be carried out in ANSYS R15, hence they concluded Inconel is stronger than ceramics.

5. J.S. Rao [7] introduce a numerical measure to estimate the natural frequency of flexural vibration of pretwisted beams of rectangular cross section and by applying Galerkin technique with the same twisting in both XZ and YZ planes and experiment results can be compared with caregies measures in previous work by him.

6. J.S. Rao and N.S. Vyas [8] used the analytical equation to calculate the resonant stress of blade during vibrations take place under function of rotor speed frequencies investigating gives reasonable resonance prediction.

7. J.S. Rao [11] discusses the turbine blading excitation and vibration characteristics he explains that an advancement in investigation of torsional vibrations is due to the trends in field of power generation application the disc blade interactions should be carefully metered to avoid unbalanced vibrations effects the increment in aspect ratio twist angle rotation and structure stability mode shapes are considered during blade design. In designing selection of optimized parameters is essential to respond to competitiveness and increased demand to produce power generation.

8. J.S. Rao [12] is use an extensive survey of tabular approach is also facilitated in formation there he introduced highly focus for various vibration affecting parameters dimensional (or) geometrical parameters to reduce errors he uses Galerkin approach to solve the differential equations and get natural frequencies to avoid resonance.

9. J.S. Rao [13] presents general flexural vibrations relations of a turbine blades on staggered the natural frequency ot vibration tendency, He is used Galerkin technique to evaluate natural frequencies by solving ordinary differential eq. Of beam.

10. J.S. Rao and W.Carnegie [16] was applied collocation method to fracture mechanics & accounting problems in turbine blades. Rao was presented nobel techniques for modelling the ordinary differential equation of torsional vibration of pretwisted tapered beams.

11. J.S. Rao [18] actually uses the reversal routh technique to calculate natural frequency from blade structure reversal routh tabular procedure has been used by them to determine the natural frequencies of longitudinal and torsional oscillations of fixed-fixed systems.

12. Kamalerh purohit, Manish bhandari [19] user the bases of finite element technique to solving the differential equation in time/frequency domain on a blade was described by them the extensive survey of the application of this method is also available there.

13. Finite element technique has been to identify and isolate the dominant vibration problems in gas turbine blade structure by S.C.Mohanty & J.S. Rao [20] they have been used finite element technique to determine the natural frequencies of beam during free vibration analysis.

14. N.S. Vyas and J.S. Rao [26] was determine the blade stresses under constant speed but these approach is not helpful in many applications they are determine resonant stress under transient conditions they are used iteration technique as numerical.

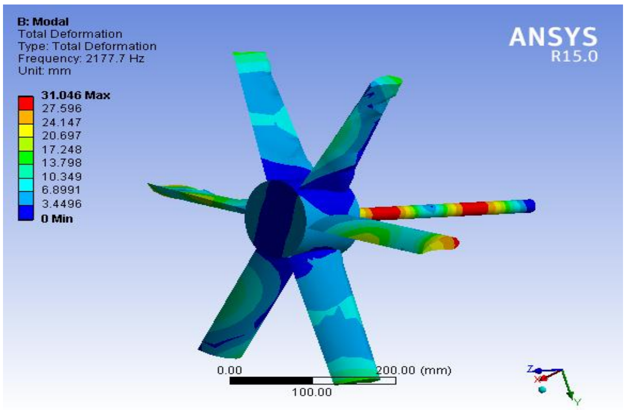
15. J.S. Rao & K. Gupta [27] was developed which involves the novel transformations of uniform blades to twisted and tapered blades. Investigation for highly non-linear applications areas accurate modelling of the underlying dynamics in any physical system is a challenging task and it is crucial to evaluate data during practical applications both from the point of view of aspect ratio as well as fol rapid adoption to twisting the investigating of dynamic characteristics. In this tracking of highly non-linear problems are reviewed with explore on Ritz averaging process.

METHODOLOGY

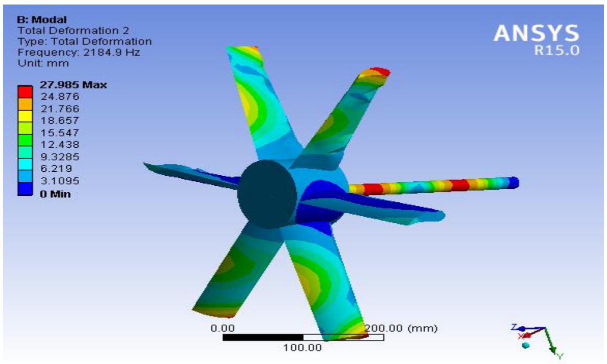
1) Graphical Representation of Simulation

The input parameters given are the pre-twisted blade angle, type of material (INCONEL) and the dimensions of the turbine. The performance is based on the optimization of these input parameters and response of the system. The output is to measure the natural frequency of the operating assembly at different angles. The significance is to pick-up the best angle from one another. The procedure is load a model drawn in CATIA (IGES format) to ANSYS. The features of ANSYS like preferences, preprocessing, solution, and general post processing are used to simulate the model. The results while following these procedure were obtained at different angles as:

At 15^0:



The above image is showing natural frequency value at mode-1



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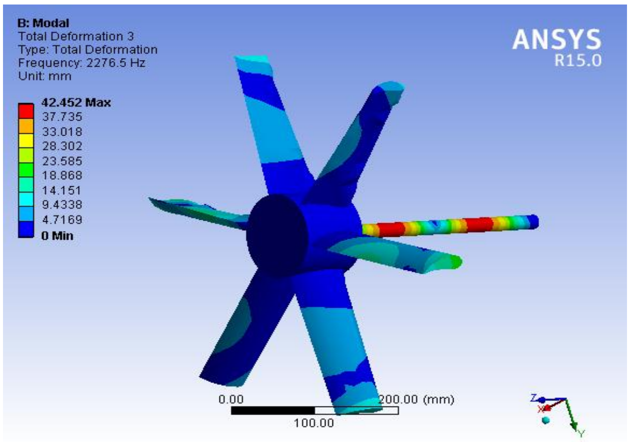

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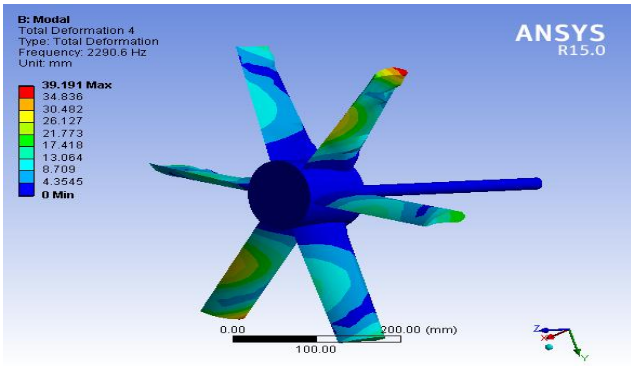
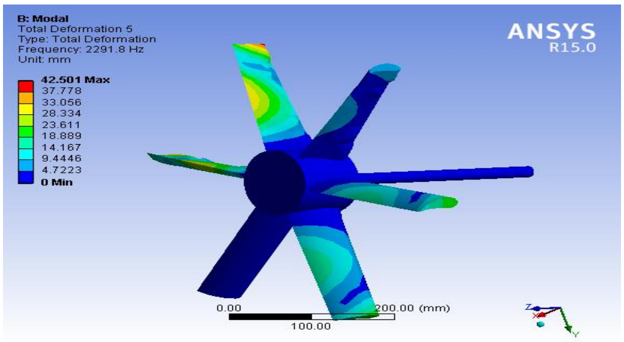


The above image is showing natural frequency value at mode-4



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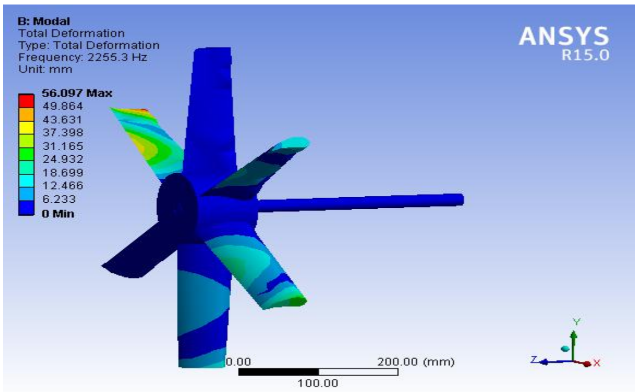
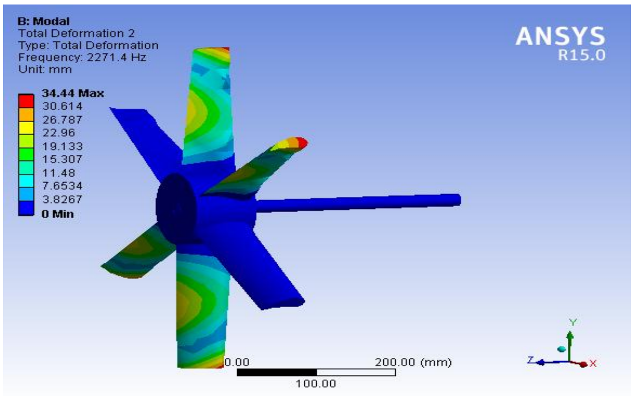
At 18^0:



The above image is showing natural frequency value at mode-1



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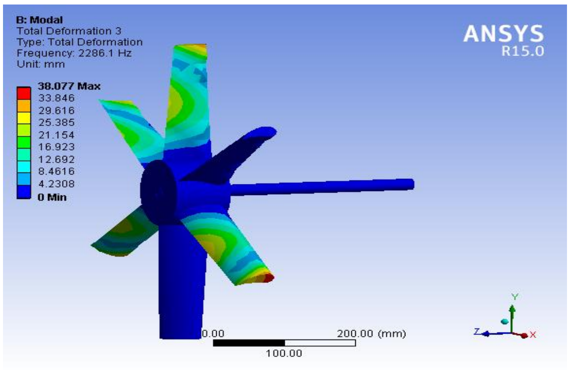
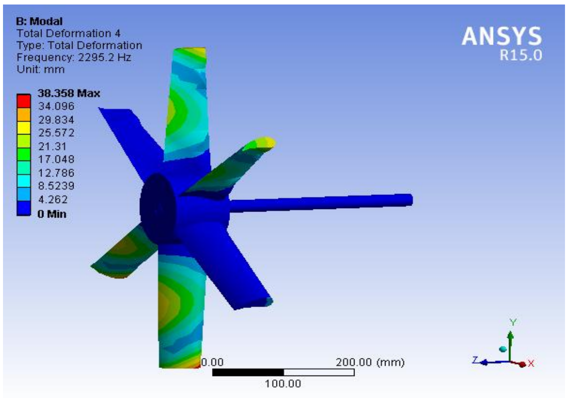


The above image is showing natural frequency value at mode-3



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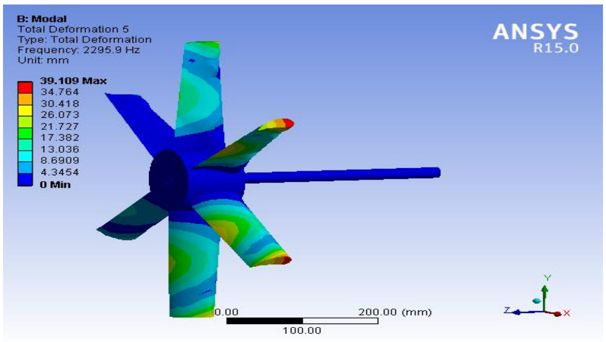

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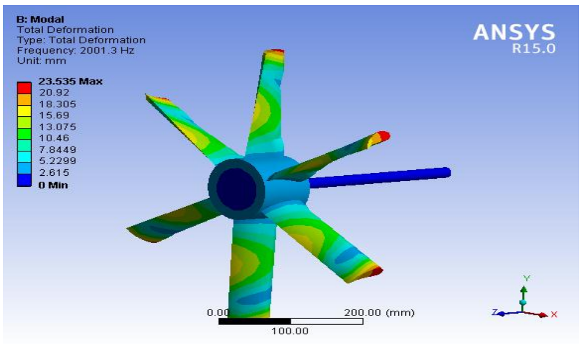
At 21^0:



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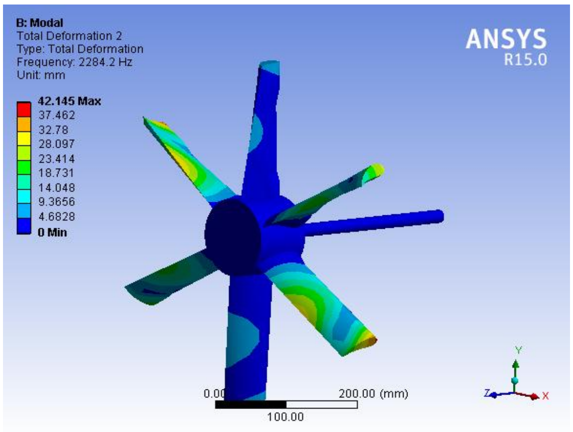

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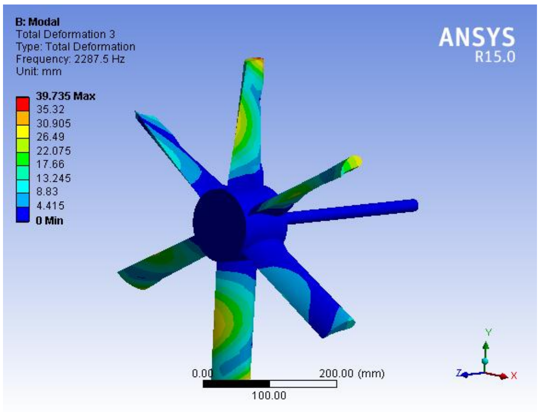

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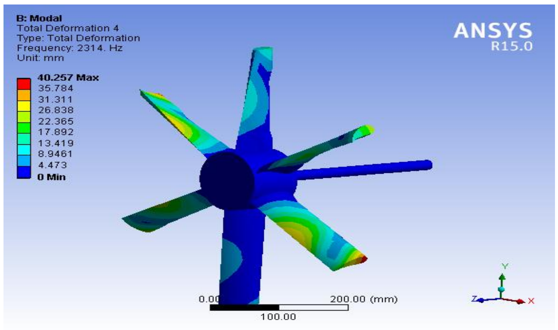

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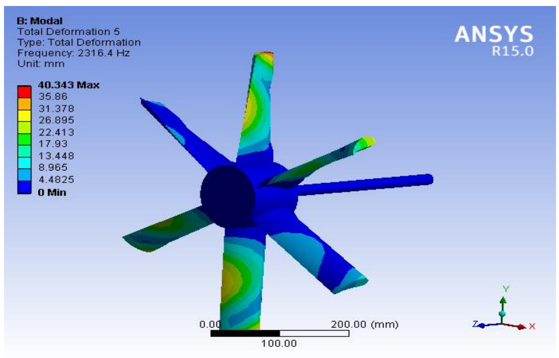

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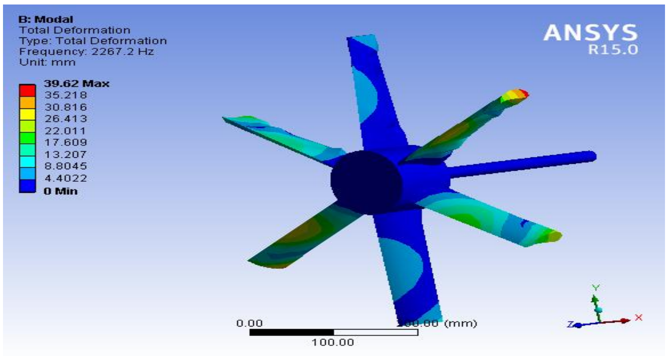
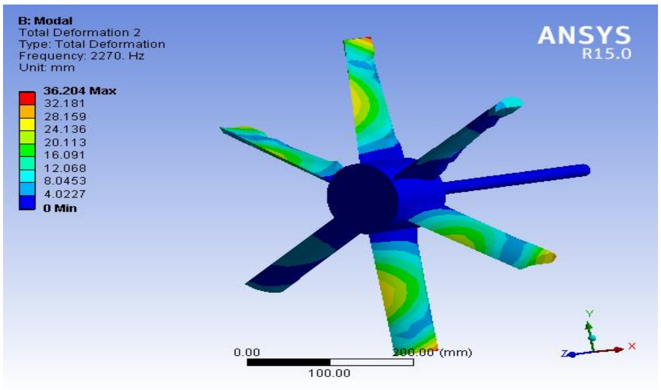
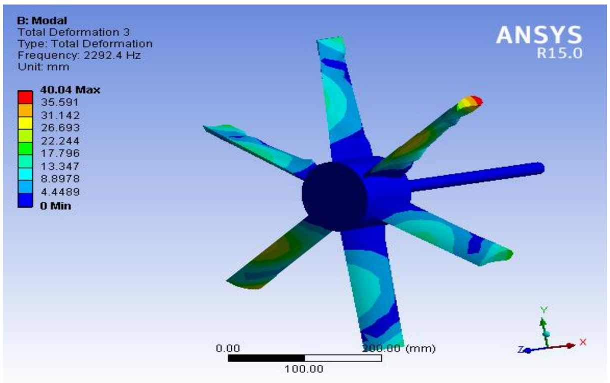
At 25^0:



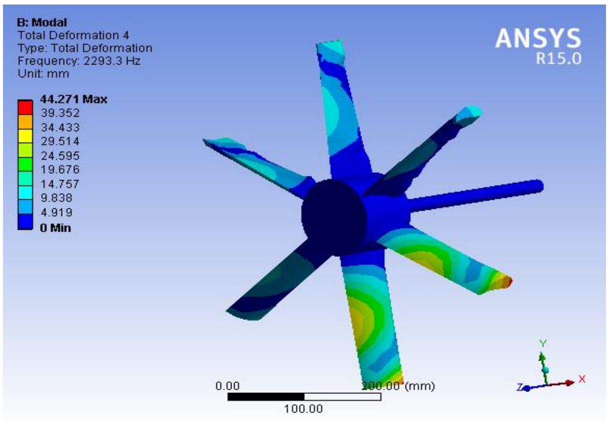
The above image is showing natural frequency value at mode-1



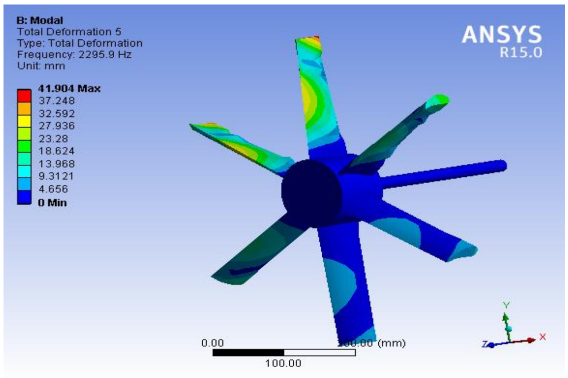
The above image is showing natural frequency value at mode-2



The above image is showing natural frequency value at mode-3



The above image is showing natural frequency value at mode-4



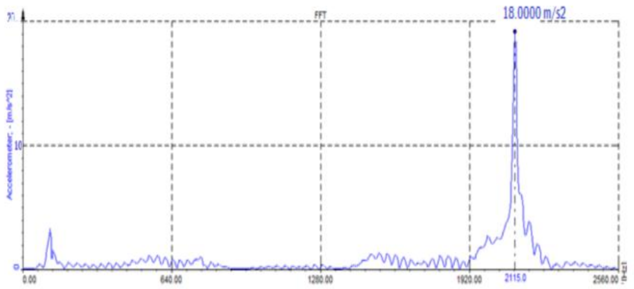
The above image is showing natural frequency value at mode-5

Twisted Angle	First Natural frequency (Hz)	Second Natural frequency (Hz)	Third Natural frequency (Hz)	Fourth Natural frequency (Hz)	Fifth Natural frequency (Hz)
15^0	2177.7	2184.9	2276.5	2290.6	2291.8
18^0	2255.3	2271.4	2286.1	2295.2	2295.9
21^0	2001.3	2284.2	2287.5	2314	2316.4
25^0	2267.2	2270	2292.4	2293.3	2295.9

From the above table, it is clearly showing that the good results were obtained at 15^0 rather than the other angles. The frequency observed was very low which shows a great response for the performance of the gas turbine structural assembly. This procedure was repeated for 4-5 times to obtain best accurate results.

2) Experimental Work

The blade is fixed at the end of FFT equipment which looks like a cantilever set-up exactly and length of blade is known. An accelerometer is fixed at the center on the face of the Hub opposite to the face of the blade. The connections have been as required to connect accelerometer, impact hammer, PC and others with the help of cables and wires. The vibration analysis and experimental modal analysis is processed by switching on AC power supply of computer with the help of software packages installed. Here the four channel analyzer is DEWE software. The adjustment of X-axis for acceleration and Y-axis for frequency is made for the accurate set-up before starting the experiment. The impact hammer provides impact at the tip of the blade on the cantilever one by one. The vibration analyzer receives the corresponding signals from accelerometer and impact hammer, which will be compared and analyzed using the software package. The natural frequencies can be obtained from the frequency function response curves. This graph will give us the first natural frequency. The damping factor is calculated from the logarithmic decrement formulae. By following this procedure, we obtained the natural frequency as 2115hz which can be seen from the graph below.



Graph between natural frequency and the accelerometer

F_n = 2115Hz.

RESULTS AND DISCUSSIONS

- The gas turbine model is created by CATIA-V5(IGES format) and finally loaded and analyzed in ANSYS 15.0 software packages. The structural and modal analysis can be employed in ANSYS.
- This research work is more emphasizing to investigate parameters of vibration such as natural frequency.
- The experimental and simulation results have been compared for best pre-twisted blade angle of a gas turbine assembly unit.
- The first five modes of natural frequencies have been found at different angles of 15^0, 18^0, 21^0 and 25^0 with varying operating conditions.
- The best angle is 15^0 for pre-twisted blade to be attached to gas turbine assembly for better performance to be obtained by optimization of parameters(blade angle).
- The experimental solution is nearly same as that obtained in simulation of structural assembly of turbine model at an angle of 15^0 by comparing them.

CONCLUSIONS

- The previous researcher's work concerned with the pre-twisted angle is around 14.5^0 by comprehensive study.
- The Present research work is on different angles (15^0, 18^0, 21^0 and 25^0) of pre-twisted Aero-foil blade of structural gas turbine assembly was analyzed for good accurate results to optimize for better performance of the assembly.
- The varying nature of results of natural frequency at 15^0 and 25^0 is very close, so it can be used as structural criteria which is good for design purpose. But the best is found at 15^0 is found to be close to the experimental value.
- Thus, INCONEL 718 with an angle of 15^0 is found to perform well and good results are found in natural frequencies when analyzed.

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