Characterization of Gas Turbine Blade with Different Materials through Frequency Response by Modal and Dynamic Analysis

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ABSTRACT

In manufacturing industry turbine blades are made of composite materials which form the essential element of many structural components like gas turbine, steam turbine, marine engines and airplane propellers. These plates are subjected to in-plane load on account of fluid (hot gases) or aerodynamic pressures, so the blades are subjected to high dynamic loadings. It requires doing vibration analysis by verification of frequency response to know the dynamic character accurately as they are working at high speeds. The existing gas turbine blade made up of N155 material is replaced with Al/SiC-MMC; thereby decrease the weight of the blade for improving the efficiency. Al/SiC-MMC has a more strength when compared to the existing material. The frequency range and mode of vibrations are determined by using ANSYS software. Frequency ranges are also coded using MATLAB. In the results von-mises stresses and deformation of Al/SiC-MMC blade is less when compared to the existing N155 blade.

Keywords: *Turbine Blade, N155 Material, Al/Si C-MMC, Deformation.*

1. INTRODUCTION

Now a days the industries and companies thinking that the development and improvements as parallel to new technology, so that the purpose of turbine technology extracts the maximum output of energy to convert it into useful work with better efficiency by means of a plant having maximum reliability, minimum cost, minimum supervision and minimum starting time. The gas turbine obtains its power by utilizing the energy of burnt gases and the air which is at high temperature and pressure by expanding through the number of rings of fixed and moving blades. The rotor blades heart of the turbo machinery, so that the whole system depends on it for reliable operation. If the rotor blade fails the whole system remains shutdown. So the very important component in the turbine is rotor blade and its proper functioning gives better results. For a good design of the turbo machine rotor blade considerations are as follows:

i. Optimization of geometric characteristics for which analyzed proto type model by dynamic analysis.
ii. Observation of steady loads acting causes stresses and deformations on the blade.
iii. By the analysis know the natural frequencies and mode shapes which observed from the vibration.
iv. Identify unsteady forces acting on blade and their effects.
v. Cumulative damage fatigue theories helpful in estimation of dynamic forces and life of the blade

1.1 Motivation

In present days composite materials play key role in manufacturing industry. If the material has good properties then we expect the developments in particular areas like power plants, aerospace, automobile industry and marine engine applications etc. Here the work is to increase the plant efficiency by decreasing the mass of the blade. The Existing blade material is replaced with a Al/Si C-MMC, which is the glass-ceramic matrix systems reinforced with silicon carbide which have the strength, stiffness and low density. Here the output increased high by increasing the inlet temperature of hot gases and speed. The material is identified for both extreme heat (close to 620ºC in some areas) and high vibrations.

II.LITERATURE REVIEW

Previously some work had been carried out on failure of turbine blade through metallurgical examination which includes the activities such as determination of material composition, visual inspection and micro-scopic examination. This metallurgical examination was carried out assuming that there might be some micro-structural changes in the blade material due to blade operation at elevated temperature which led to the ultimate failure a gas turbine blade [1]. The improvement of modern turbo machines efficiency, especially gas turbines, is achieved mainly by increasing their temperature level in the combustion chamber. The maximum temperature at the inlet of the turbine is currently limited by the resistance of the materials used for the impeller blades. The deterioration of the thermal barrier systems occurs by peeling the ceramic layer. The bared metal is then exposed to dangerously hot gases from the combustion chamber. So far, numerous studies have been conducted on the materials of gas turbine blades [2].Uses ANSYS16 for static, thermal and modal analysis of the distribution of thermal stress and temperature in the gas turbine blade of different titanium alloy, stainless steel and aluminum 2024 materials [3]. A study was carried out by other authors [4] on thermo-mechanical fatigue behavior for material Inconel 738. The work is mainly focused on the resistance of solid turbine blades to investigate the balanced thermal and structural performance of the blade for Inconel 738 materials and Inconel U500. A coupled thermo-mechanical simulation of a coated vane is used to model the flaking of the thermal barrier that occurs under the service conditions of the blade [5]. Another work [6] An attempt to analyze the gas turbine blade by comparing the Hastelloy X material to Nimonic alloy 80A and Inconel 625.

After verifying the detailed report of authors and researchers, the present work carried on analysis of the gas turbine blade and its importance in improving efficiency and to get better results by replacement of existing blade material with composite materials.

III.MATERIALS and METHODS

3.1 Composite Materials Used in Turbine Blade

Composite material extensively used in different fields of engineering branches, markets, industry due to their different engineering structures and good properties such as high specific strength, excellent fatigue resistance, high hygroscopic sensitivity and high resistance, can be put to use in a better way while minimizing the extents of the effect of their deficiencies. Here the following blade materials are used to check their suitable optimum results. Materials are N155 and Aluminum Silicon Carbide Composite

Table 3.1: Properties of N155 and Al/Si C

Properties	**E(Pa)**	**P(kg/cu m)**	**K** (W/m-K)	**μ**	**α (e-06/^{0}C)**	**Melting Point(**0 C)	**Yield stress (Mpa)**
N155	143e9	8249	20	0.3	16.5	900	275
Aluminum Silicon Carbide	100e9	2600	17	0.25	14	700	430

3.2Modeling of Gas Turbine Blade

The blade under examination belonging to 1st stage turbine blades of 30 MW gas turbine engine intended for operation onboard ship. Reverse Engineering (RE) is being applied to generate 3D surface data of turbine blade of a gas turbines engine meant for marine applications. The gas turbine blade model profile is generated by using CATIA V5R21software. 3D model of a gas turbine blade with root was done in two stages. These two were then combined to make a single volume using union Boolean operation. Geometric model of gas turbine blade created using CATIA V5 R21. The Design Data as follows: Blade tip diameter D_0=1416 mm, Blade rotor root diameter D_i=1191 mm, Turbine speed N=3426, Number of blades=120

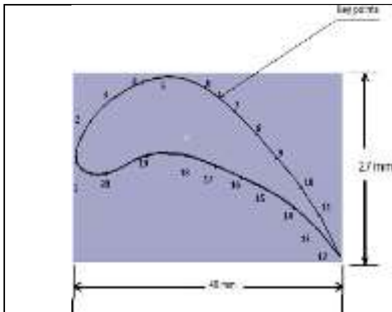
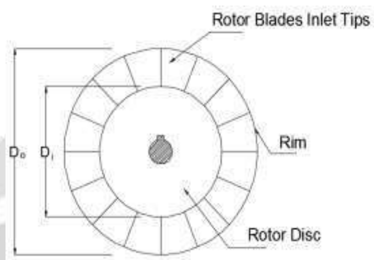
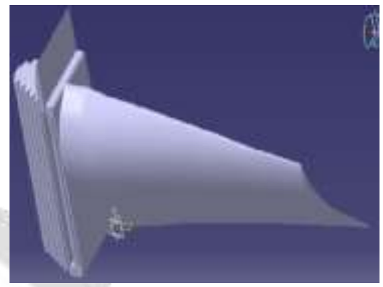
		

Fig 3.1: Geometry of the aerofoil section	**Fig 3.1:** Blade details	**Fig 3.3:** Geometrical model using CATIA V5 R21

A Turbine rotor blade consists of 120 blades each blade height is 117 mm. The blade model profile is generated by using CATIA software. The aerofoil profile of the rotor blade was generated on the XY plane with the help of key points defined by the coordinates as given below. Key points are created along the profile in the working plane.A rectangle of dimensions 49*27 mm was generated as shown in the figure.

(a)The element taken for meshing is Solid 185 in ANSYS

Solid185 is used for 3-D modeling of solid structures. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x,y, and z directions. The element has plasticity, hyper elasticity, stress stiffening, creep, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elasto-plastic materials, and fully incompressible hyper elastic materials. SOLID185 is available in two forms: (i) Homogeneous Structural Solid (ii) Layered Structural Solid

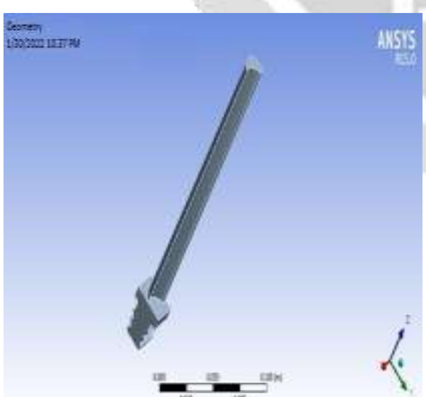
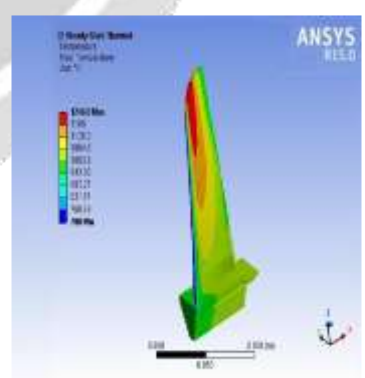
		

Fig 3.4: Turbine blade	**Fig 3.5:** Blade meshing	**Fig 3.6:** Thermal distribution

3.3 Structural Analysis

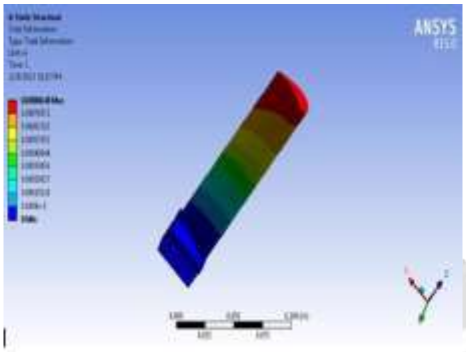


Fig 3.7: N155 Von mises stresses

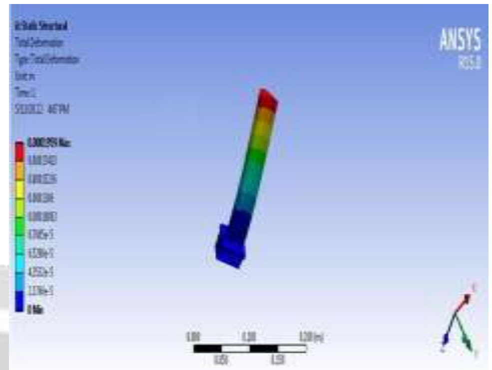


Fig 3.8: Al/Si C Von mises stresses

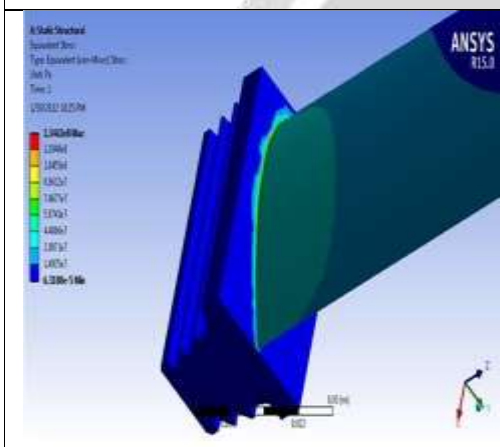


Fig 3.9: N155 Von mises stresses

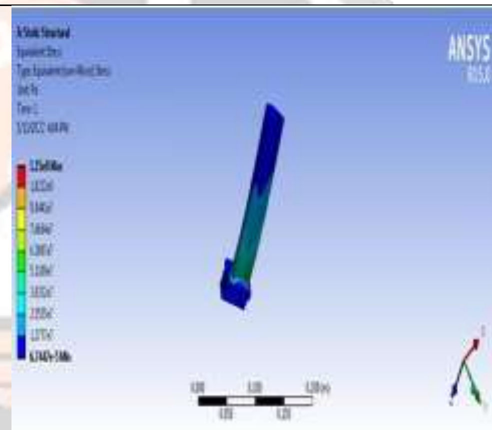


Fig 3.10: Al/Si C Von mises stresses

Details of the element as follows: Elements 30247 and nodes 17047
Structural Analysis reveals that (i) deformations of N155 is 0.80 and Al/Si C 0.19 (ii) Von-mises stresses N155-134e6 and Al/Si C-115e6

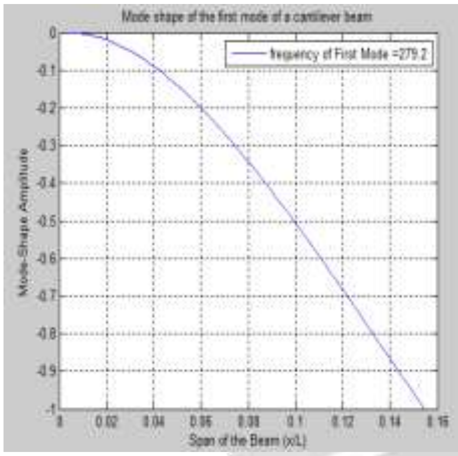
IV. Mathematical Approach through MATLAB and Dynamic Analysis through ANSYS

Here the cantilever beam subjected to free vibration, and the system is considered as continuous system in which the beam mass is considered as distributed along with the stiffness of the shaft, so the equation of motion can be written as:

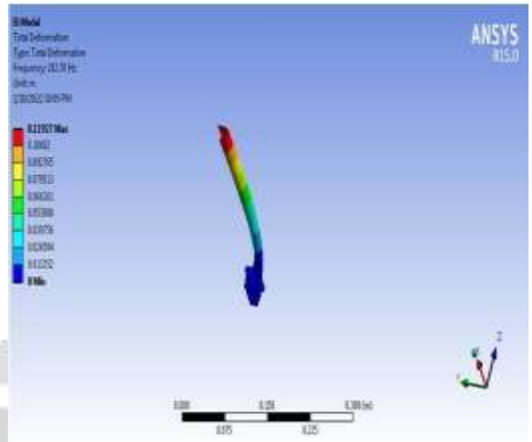
$$\frac{d^2}{dx^2}\left\{EI(x)\frac{d^2 y(x)}{dx^2}\right\} = \omega^2 \, m(x)y(x) \qquad (1)$$

Here is the program is coded in MATLAB and results are compared with ANSYS.

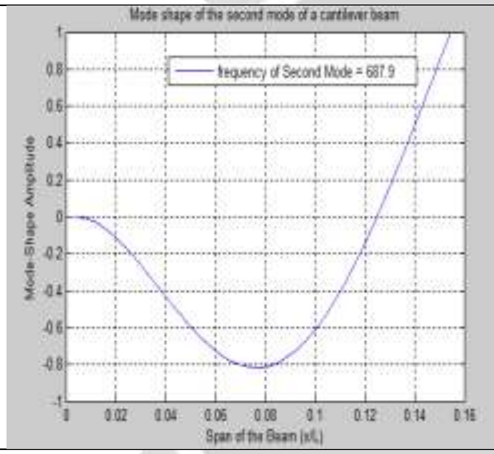
The boundary condition assumed in the code is Cantilever Where as one end is fixed and the other is free.



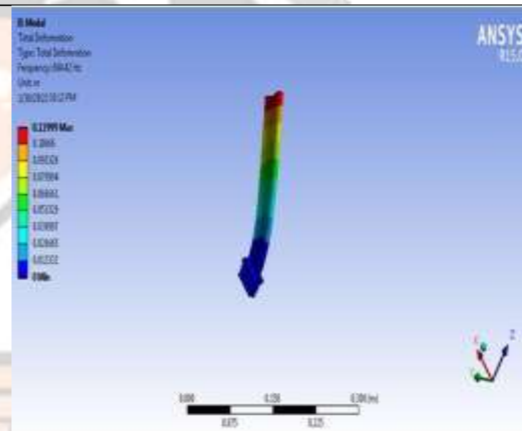
1st Mode of frequency for N155 blade (MATLAB)



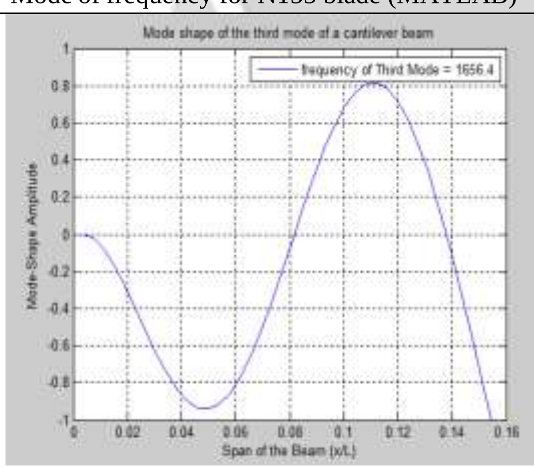
1st Mode of frequency for N155 blade (ANSYS)



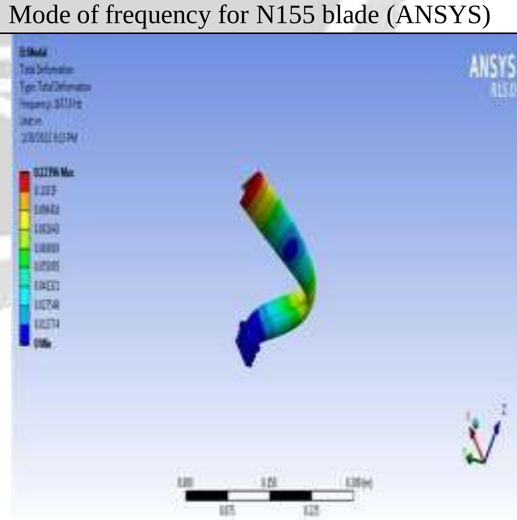
2nd Mode of frequency for N155 blade (MATLAB)



2nd Mode of frequency for N155 blade (ANSYS)

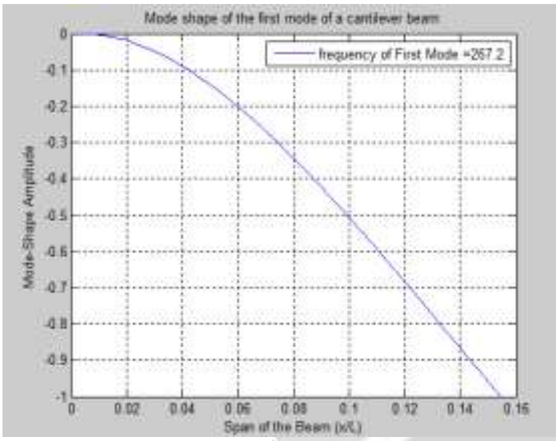


3rd Mode of frequency for N155 blade (MATLAB)

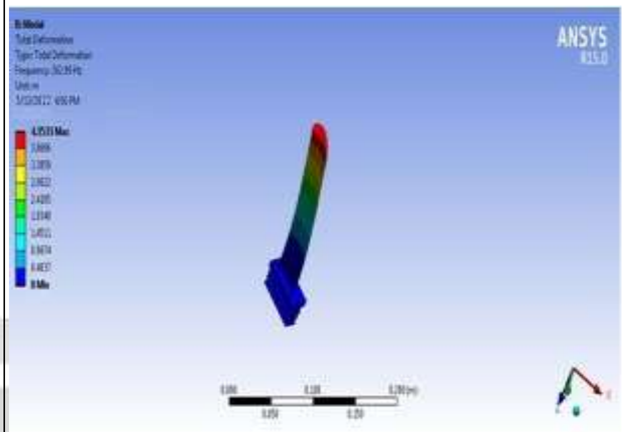


3rd Mode of frequency for N155 blade (ANSYS)

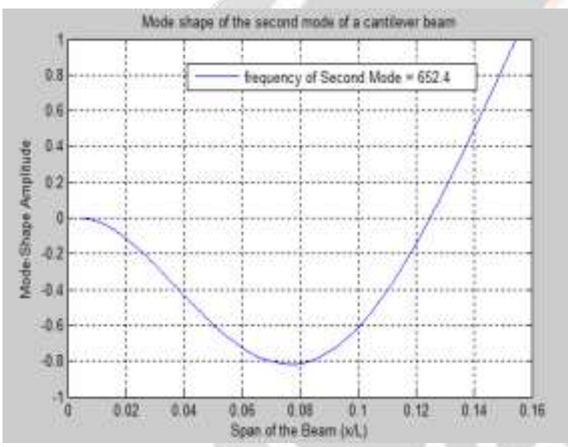
Fig 4.1 : 1st ,2nd and 3rd modes of frequency for N155 by MATLAB and ANSYS



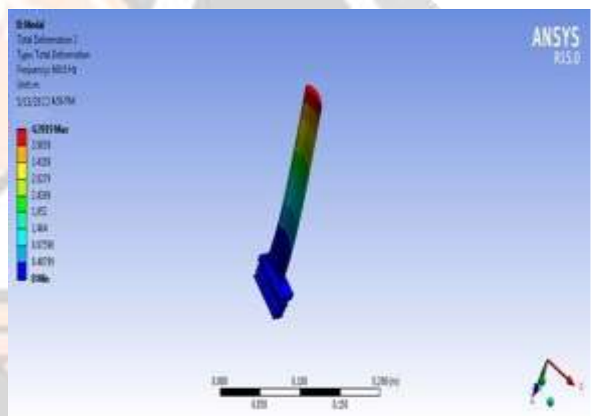
1st Mode of frequency for Al/Si C blade(MATLAB)



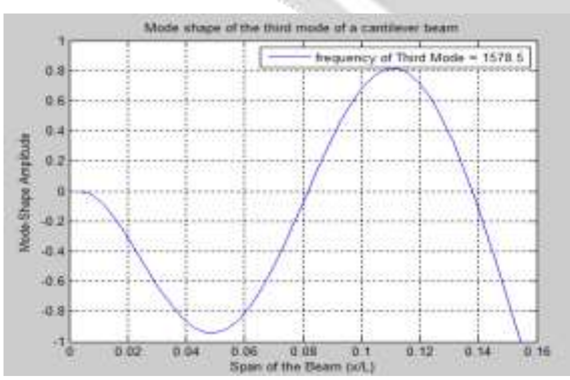
1st Mode of frequency for Al/Si C blade(ANSYS)



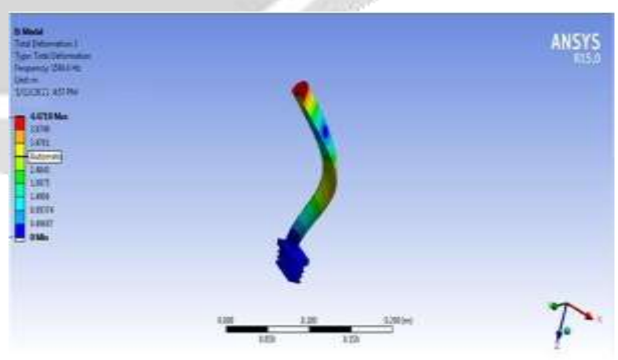
2nd Mode of frequency for Al/Si C blade(MATLAB)



2nd Mode of frequency for Al/Si C blade(ANSYS)



3rd Mode of frequency for Al/Si C blade(MATLAB)



3rd Mode of frequency for Al/Si C blade(ANSYS)

Fig 4.2: 1st, 2nd and 3rd modes of frequency for Al/Si C by MATLAB and ANSYS

Table 4.1: Frequencies and Modes of N155 & Al/Si C-MMC

	N155 (Hz)	Al/Si C-MMC (Hz)
1st Mode frequency	282.7	262.9
2nd Mode frequency	694.4	660.8
3rd Mode frequency	1677.8	1586.6

V. CONCLUSION

Based on the analysis and parametric vibration characteristics of a blade frequency response (free vibration) which accounted for N155 and Al/ Si C-CMM blade materials and the results obtained are gives the following conclusions by using the MATLAB and ANSYS software's.

(i). Von-mises stresses of Aluminum Silicon Carbide are low when compared to existing material N155

(ii) Deformations of Aluminum Silicon Carbide are low when compared to existing material N155

(iii) Blade frequencies are computed from ANSYS and MATLAB which are very close to each other.

The results and conclusions evident that, it is possible to replace the existing blade material with composites which give optimum results to supports and strengthen the design and tune the blade to rotate without desired range of natural frequency so that no resonance will occur.

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