STATIC AND DYNAMIC ANALYSIS OF COMPOSITE ROTOR BLADE

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ABSTRACT

A typical turbo machinery blade is essentially a rectangular plate of considerable pre-twist. Blades are being developed in composite materials in order to achieve low weight and high strength construction. The main idea of this work is to evaluate the properties of the blade during the twist and to sustain for the high wing forces using composite material. In the present work rotor blade model has been created in Pro-E, static analysis is used to find the maximum safe stress and deformations .modal analysis is used to find natural frequencies and mode shapes. A composite is a structural material, which consists of combining two or more constituents in order to obtain a combination of properties that cannot be achieved with any of the constituents acting alone. Composite blades are made with unidirectional fibres parallel to the blade's long axis, as well as adaptive configuration with fibre orientation in off-axis directions to affect bend-twist coupling developing concept designs and analyzing the structural response of composite blades for different operating conditions is taken up in this project. the result of static analysis is the safe design stress; the stress is calculated as 59.306N/mm2 for corresponding blade twist, thickness and number of layers are 45^0, 5 mm and 5 layers respectively. Modal analysis presents the mode shapes which changes with blade twist associated with a variation in natural frequency.

Keywords: Composite fibre , Rotor blade, Vonmisess stress, Twist angle.

I. INTRODUCTION

Rotor blade is long airfoil that rotates to provide the lift that supports a helicopter in the air .The blades of a helicopter are long, narrow airfoils with a high aspect ratio, a shape which minimises drag from tip vortices. They generally contain a degree of washout to reduce the lift generated at the tips, where the airflow is fastest and vortex generation would be a significant problem. Rotor blades are made out of various materials, including aluminium, composite structure and steel or titanium with erosion shields along the leading edge. Applications of the rotor blades includes, marine-propeller vanes, fans and blowers, gear cases, valves and strainers, condenser shells, helicopter rotors, typical wind tunnel fan blades.

The objective is usually to make a component which is strong and stiff, often with a low density; commercial material commonly has glass or carbon fibres in matrices based on the thermosetting polymers, such as epoxy or polyester resins. Furthermore, in these composites the reasons for adding the fibres (or, in some cases, particles) are often rather complex; for example, improvements may be sought in creep, wear, fracture toughness, thermal stability, etc

A composite is a structure material, which consists of combining two or more constituents in order to obtain a combination of properties that cannot be achieved with any of the constituents acting alone .The constituents are combined at a macroscopic level and or not soluble in each other. The constituents as well as the interface between them are recognizable and it is the behaviour and properties of the interface that generally control the properties of the composite. The main difference between a composite and an alloy is that in a composite retain their properties, where as in alloys, constituent materials are soluble in each other and form a new material which has different properties from their constituents. Wind turbine blades are most often fabricated by hand using multiple layers of fibreglass cloth. The traditional method is for the sheets to be cut to shape, laid down in a mold by hand, sprayed or rolled with resins, and finally cured.

1.1 Aim of The Project

- It is planned to develop blade design that use carbon fibre to its fullest advantages by maximizing energy capture while mitigating loads throughout the turbine system.
- It is also planned to develop blade designs using hybrid carbon/fibreglass designs.
- Developing the design requirements for composite combining the functional requirements and requirements that arise out of using the composite material system
- Developing the analytical design for composite blades
- Modelling and analysis using FEM for different configurations and obtaining the optimized structure based on static and dynamic analysis.

1.2 Problem Fromulation

The design of modern rotor includes choices of blade number, airfoils, chord and twist distributions, and materials. Thin airfoils are desirable foe their high lift to drag ratios and are roughness tolerant, whereas thick airfoils sacrifice some of these qualities to achieve the greater blade stiffness required for large machines. For large commercial machines, the upwind, three-bladed rotor is the industry-accepted configuration. The design parameters are taken from “NASA TECHNICAL PAPER 3641".the design parameters taken for the rotor blade are length, width and thickness. The values are as follows:

Length=304.8mm

Width=76.2mm

Thickness=5.08 mm

Load calculations:-

The values required for the load calculations are taken from "code book 875_3"

Wind Load Calculations:

Wind pressure P_w=0.6*V^2

Wind velocity=150KMPH

Wind pressure =1041.83*10^{-3} N/mm2

Boundary conditions:-The blade is fixed at end at four holes

II. MODELLING AND ANALYSIS OF ROTOR BLADE

Rotor blade is modelled by using the design package Pro/ENGINEER. In the Pro-e file is usually saved in PART(.prt) format by default. To export the part to ANSYS we saved the part in IGES(.igs) format. usually we save surfaces so that retrieval time and memory space required will be reduced .This saved part can be retrieved in ANSYS and can be converted to volume so that the model represents the real time structure. This geometric model should be converted to a finite element model in order to perform finite element analysis on it.

Carbon fibre -resign matrix is taken as composite material and modelling is done. Dimensions of the composite rotor blade are length, width and thickness are 304.8, 76.2 and 5.08 mm respectively.

A3-D model rotor blade is modelled at different angles 0^0, 15^0 & 45^0.

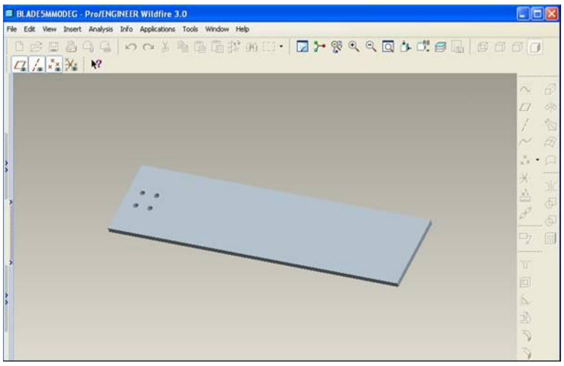

Fig:2.1 Modeled blade at 0^0

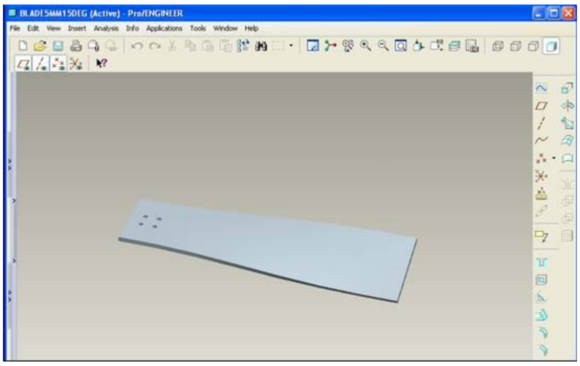

Fig: 2.2 Modeled blade at 15^0

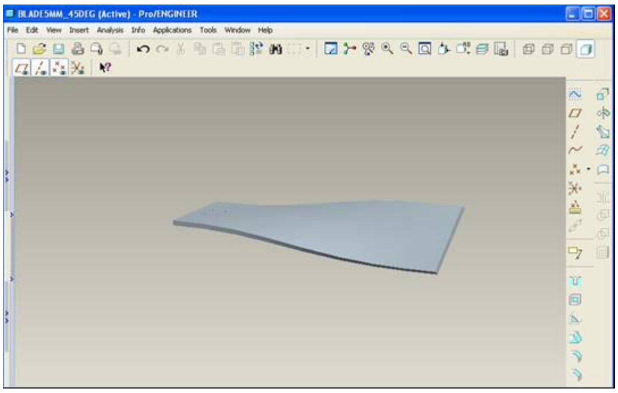

Fig: 2.3 Modeled blade at 45^0

The model and material properties are given below:-

Element Type : SHELL 99

Material : Material ID=2

Carbon Fibre-Epoxy Resin Matrix

E_{xx}=138 GPa, E_{yy}=E_{zz}=8.96 GPa

G_{XY}=G_{YZ}=G_{ZX}=1GPa; v = 0.3

Model : shell model

Blade size : Length -304.8 mm

Width-76.2 mm

Thickness -5 mm

Above values are taken from the "NASA TECHNICAL PAPER 3641"

Modelling : composite blade assembly.

Analysis : Static, dynamic and Natural modes of vibration

Fibre Orientation: 0^0, 15^0 & 45^0

The Blade is modelled in Pro-e. A 2-D model is taken and meshed with 4 elements across the width of the blade .Shell 99 type elements were used for modelling which are 8 node elements in ANSYS. The rotor blade is fixed at end at four holes.

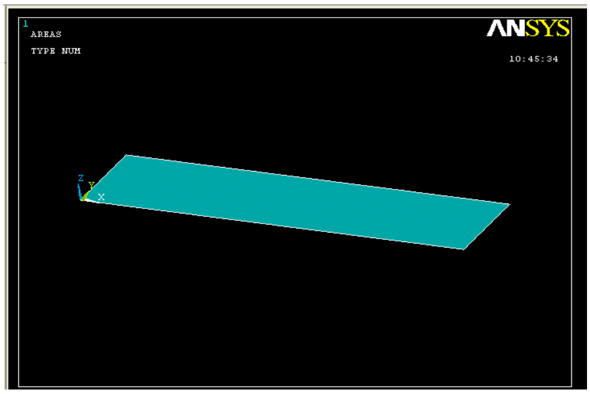

Fig: 2.4 Modelled Blade from Pro-e

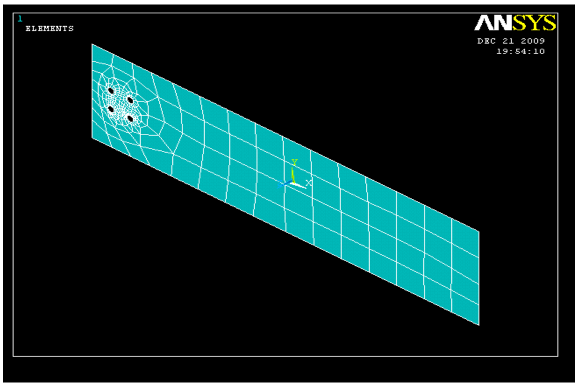

Fig:2.5 Finite element Model of 0^0 Blade with coarse meshing

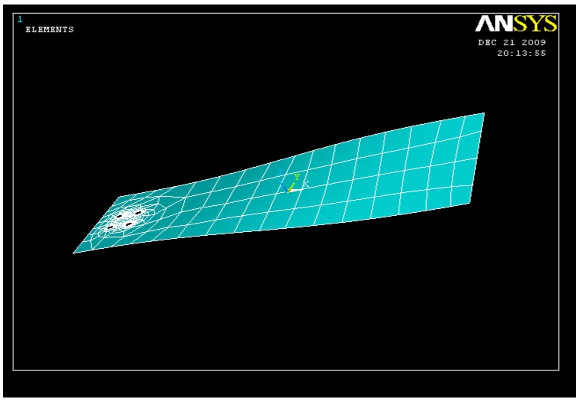

Fig: 2.6 Finite element Model of 15^0 Blade With coarse meshing

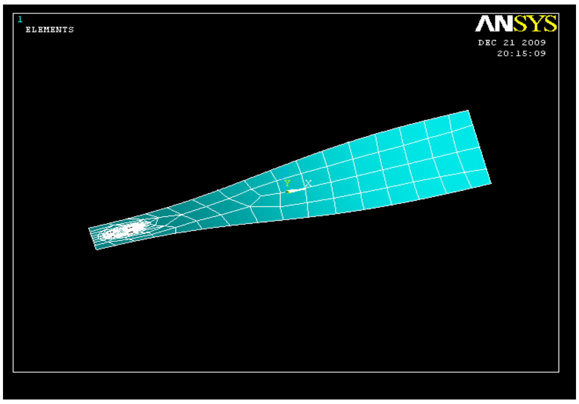

Fig: 2.7 Finite element Model of 45^0 Blade with coarse meshing

III. RESULTS AND DISCUSSIONS

Composite Blade was modelled using Pro-engineer. These models were imported to Ansys by using IGES format different cases were taken up to estimate the values of deformations and stress values by altering the angle of twist the blade and number of layers. Initially the work is carried out for 0 degree, 15 degree and then for 45 degree twist in blade construction by taking thickness value 5 mm .Model analysis was done to extract the natural frequencies of vibration for all the above cases and extracting their model shapes.

3.1 Static Analysis

Used to determine displacements, stresses, and etc. Under static loading condition. Both linear and nonlinear static analysis, Nonlinearities can include Plasticity , stress stiffening , large deflection , large strain , hyper elasticity, contact surface and creep.

In this work static analysis is used to determine Von-Misses stresses and deformations according to design parameters, load conditions and material properties on a composite rotor blade at angles of 0^0, 15^0 & 45^0.

Table: 3.1 Results of Static analysis for coarse meshed blade

Angle of Blade (degrees)	No of Layers	Deformation (mm)	Vonmisess stress value
0	1	.019467	77.922
0	3	.030019	69.982
0	5	.019459	64.728
15	1	.019665	68.82
15	3	.031439	64.987
15	5	.019433	64.798
45	1	.016021	68.687
45	3	.029799	64.687
45	5	.013686	59.717

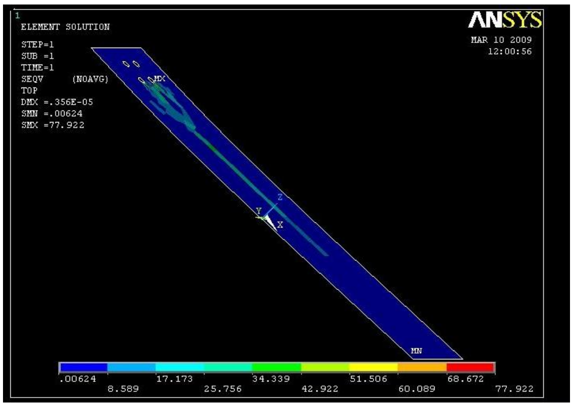

Fig: 3.1 Stress distribution of coarse meshed, 1 layered 0^0 Blade

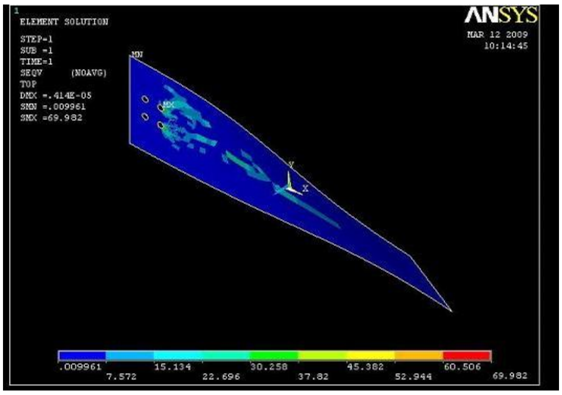

Fig:3.2 Stress distribution of coarse meshed, 3 layered 0^0 Blade

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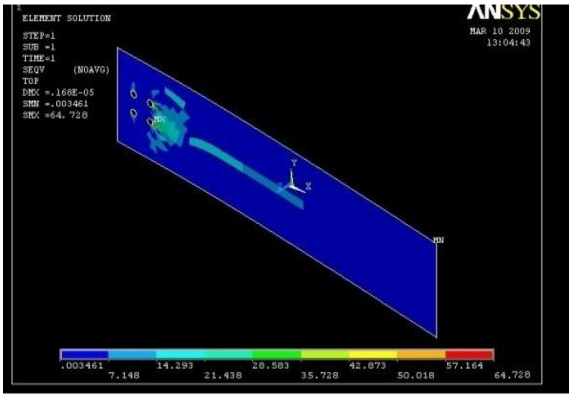

Fig:3.3 Stress distribution of coarse meshed, 5 layered 0^0 Blade

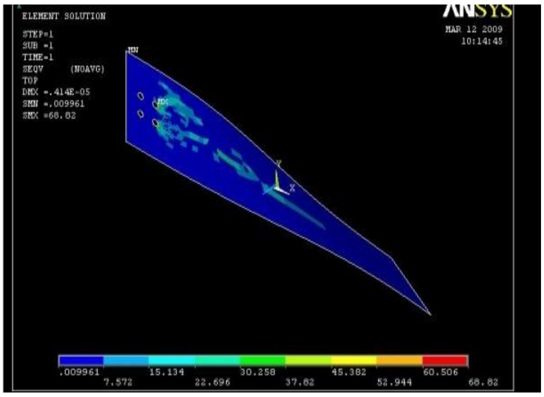

Fig: 3.4Stress Distribution of coarse meshed, 1 layered 15^0 Blade

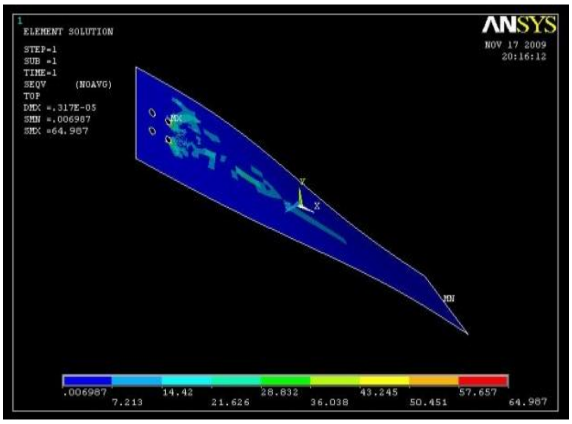

Fig:3.5 Stress Distribution of coarse meshed, 3 layered 15^0 Blade

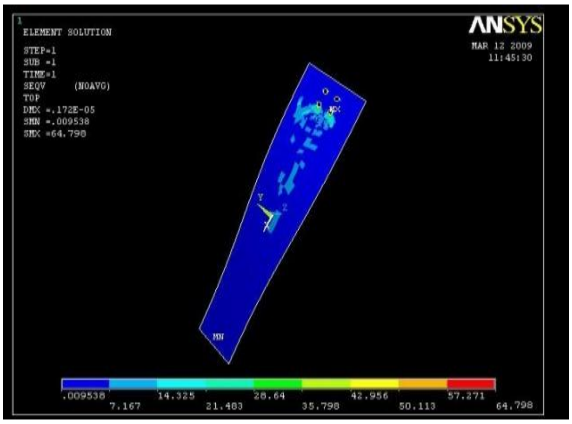

Fig:3.6 Stress Distribution of coarse meshed, 5 layered 15^0 Blade

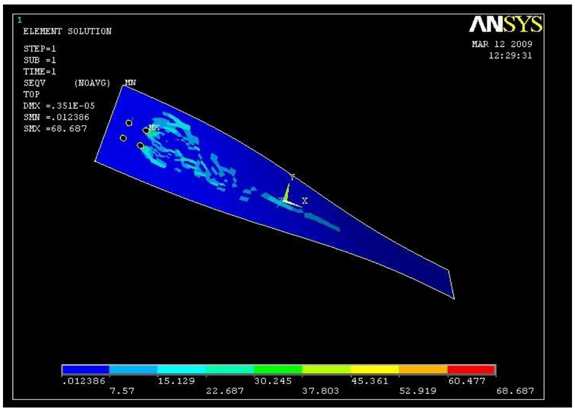

Fig: 3.7 Stress Distribution of coarse meshed, 1 layered 45^0 Blade

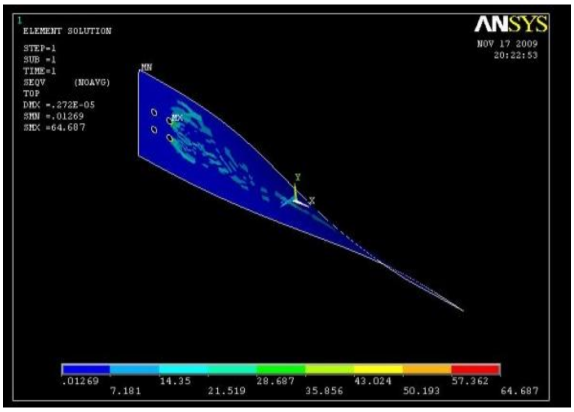

Fig: 3.8 Stress Distribution of coarse meshed, 3 layered 45^0 Blade

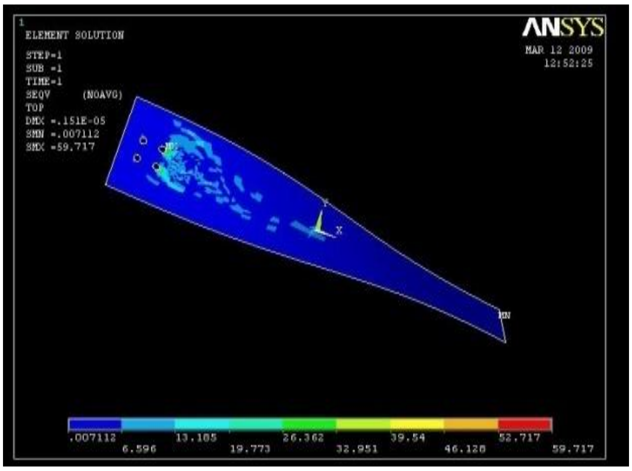

Fig: 3.9 Stress Distribution of coarse meshed, 5 layered 45^0 Blade

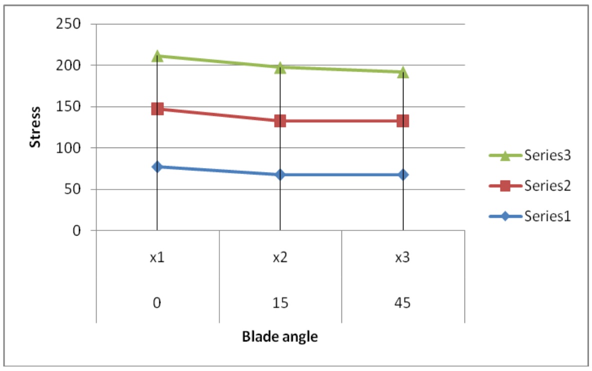

Fig: 3.10 Graph between Blade angle and Von-Misses stress for fine meshed blade

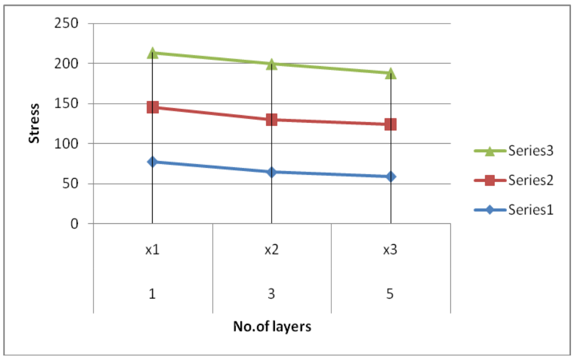

Fig:3.11 Graph between No. of layers angle and Von-Misses stress for fine meshed blade

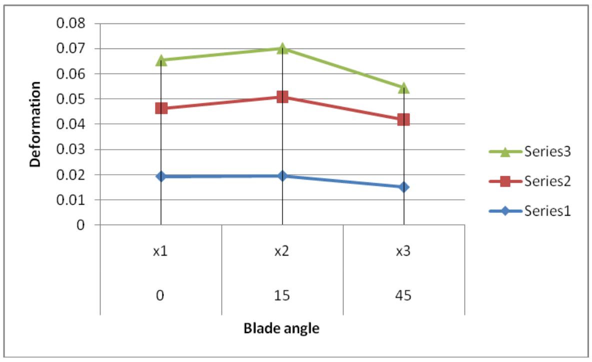

Fig: 3.12 Graph between Blade angle and Deformation for fine meshed blade

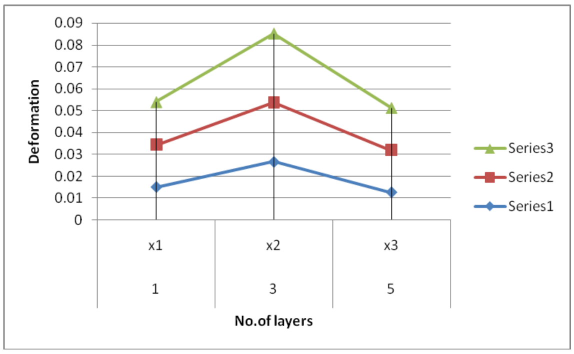

Fig: 3.13Graph between No. of layers and Deformation for fine meshed blade

Table: 3.2 Results of Static analysis for non composite blade

Angle of Blade	Deformation (mm)	Vonmisses stress value
0	.025276	79.055
15	.029477	70.098
45	.019087	69.068

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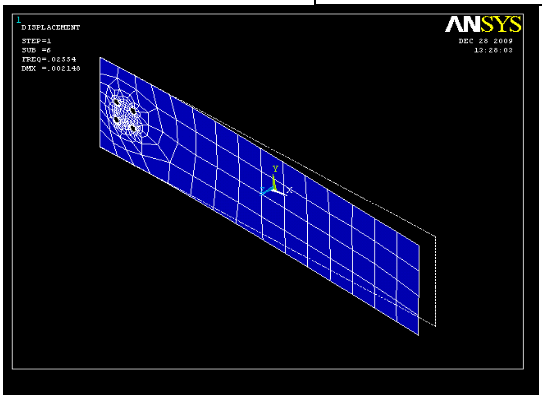
Table: 3.3 Modal analysis of coarse meshed blade

Angle of Blade (degrees)	No of Layers	Frequency (Hz)
0	1	0.2554E-01
0	3	0.3484E-01
0	5	0.4854E-01
15	1	0.29248E-01
15	3	0.31748E-01
15	5	0.43792E-01
45	1	0.28223E-01
45	3	0.321223E-01
45	5	0.51223E-01



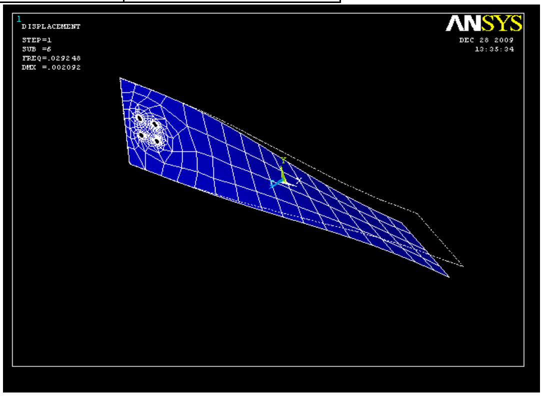


Fig: 3.13 Mode shape of coarse meshed Fig: 3.14 Mode shape of coarse meshed 0deg

1layered blade 15deg 1 layered blade

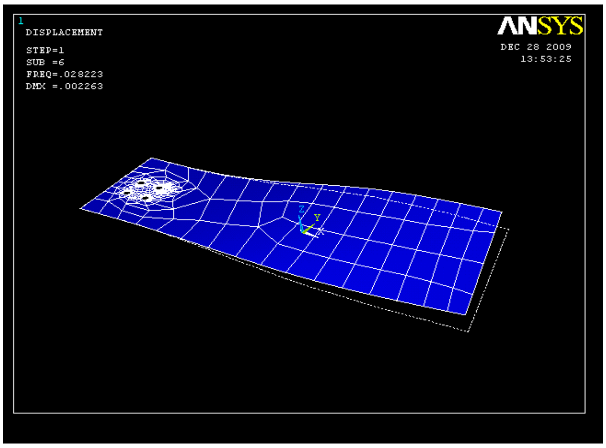


Fig: 3.15 Mode shape of coarse meshed 45deg 5 layered blade

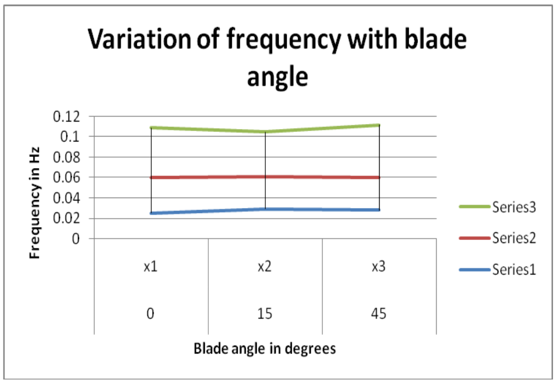


Fig: 3.16 Graph between Frequency and Blade angle for coarse meshed blade

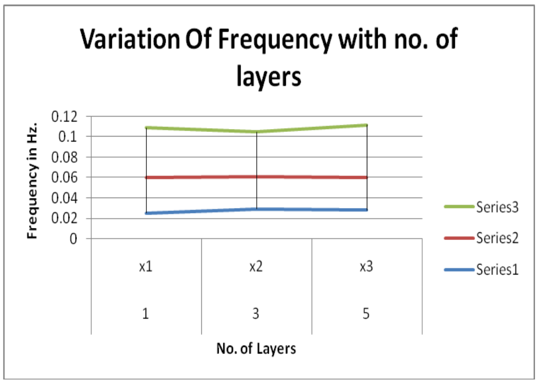


Fig: 3.17 Graph between Frequency and No. of layers for coarse meshed blade

Table: 3.4 Modal analysis of fine meshed blade:

Angle of Blade (in degrees)	No of Layers	Frequency (Hz)
0	1	0.24309E-01
0	3	0.34548E-01
0	5	0.43824E-01
15	1	0.26929E-01
15	3	0.30836E-01
15	5	0.41990E-01
45	1	0.28135E-01
45	3	0.31955E-01
45	5	0.42765E-01

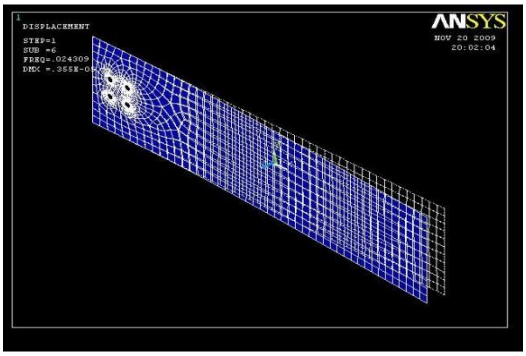


Fig: 3.18 Mode shape of fine meshed 0deg 1 layered blade

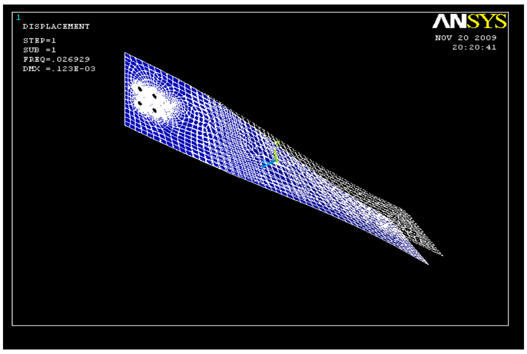


Fig: 3.19 Mode shape of fine meshed 15deg 1 layered blade

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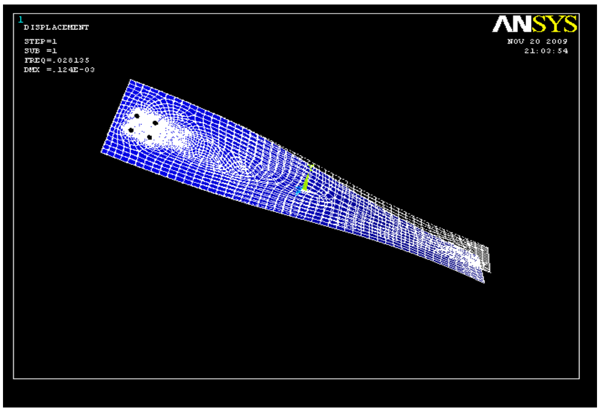

Fig:3.20 Mode shape of fine meshed 45deg 1 layered blade

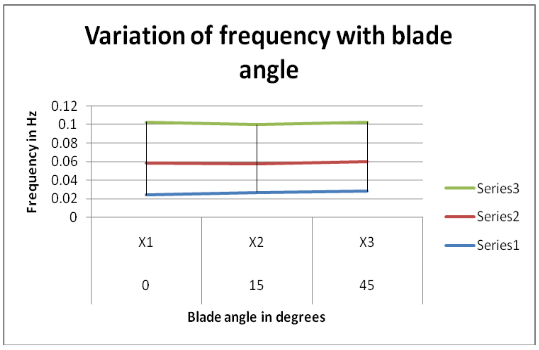

Fig: 3.21 Graph between Frequency and Blade angle for fine meshed blade

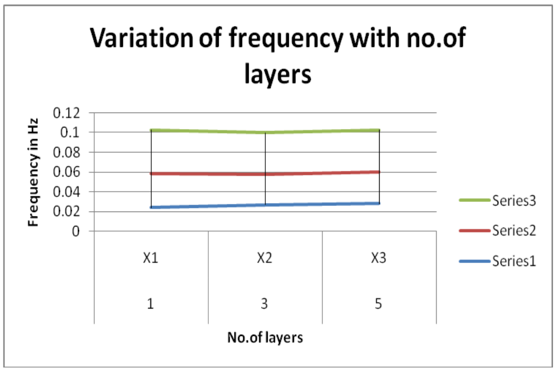

Fig: 3.22 Graph between Frequency and No. of layers for fine meshed blade

Table: 3.5Modal analysis of non composite blades:

Angle of Blade	Frequency in Hz
0	0.03589
15	0.03956
45	0.04467

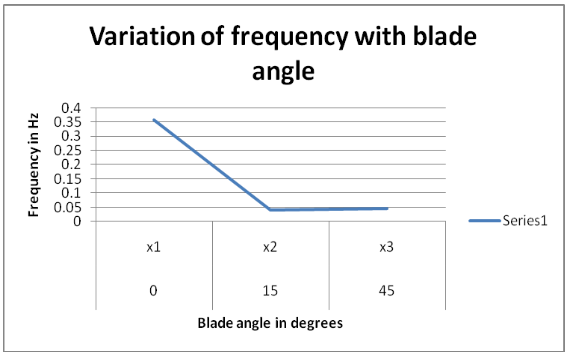

Fig: 3.23 Graph between frequency and blade angle of non composite blade

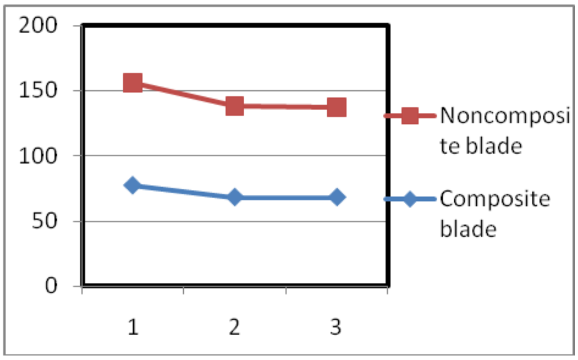

Fig:3.24 Graph between Vonmisess stresses of composite and non composite blades

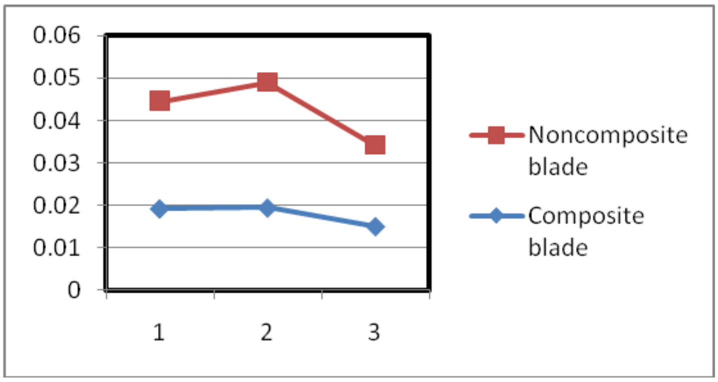

Fig: 3.25 Graph between frequencies of composite and non composite blades

IV. CONCLUSIONS

The rotor blade has been modeled using shell 99 node element. From the present work the following conclusions have been given

- From static analysis it is found that the maximum safe stress is 59.306 N/mm^2 for 5 mm thickness at 45^0 blade twist.
- From the comparison between composite and non composites it is observed that composite blades offer potential benefits.
- From the comparison between the fine meshed composite blade and coarse meshed composite blades, we find that fine meshed blades are effective.
- From modal analysis we find the natural frequencies and mode shapes of the blade at different angles.
- From dynamic analysis it is observed that the natural frequency increases with increase of blade twist angles.

V. FUTURE SCOPE

- The future work can be carried out to find the stresses during the dynamic response by performing harmonic transient & spectrum analysis.
- We can also identify practical hazards like contact with sudden obstructions by performing fracture analysis. Optimization of mass distribution and fiber directions

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