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Modelling And Analysis of Propeller Blade of A Underwater Vehicle

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ABSTRACT

Ships and underwater vehicles like submarine and torpedoes use propeller for propulsion. In general, propellers are used as propulsors and they are also used to develop significant thrust to propel the vehicle at its operational speed(RPM). The blade geometry and design are more complex involving many controlling parameters. Propeller with conventional isotropic materials creates more vibration and noise in its rotation. It is undesirable in strength point of view. The present work is to carry out the dynamic analysis of aluminum and composite propeller CFRP (Carbon Fiber Reinforced Plastics) materials. Compared to conventional materials, the main advantages of composites are their superior stiffness to mass ratio as well as high strength to weight ratio.The present project deals with modeling and analyzing the propeller blade of a underwater vehicle for their strength and rigidity. The solid model of propeller is developed in CATIA V5 R19. Tetrahedral mesh is generated for the model using HYPER MESH. Static and Modal analysis of both aluminum and composite propeller are carried out in ANSYS. Interlaminar shear stresses are calculated for composite propeller by varying the number of layers. The stresses obtained are well within the limit of elastic property of the materials.

Keywords: *composite ,interlaminar, propeller, propulsion ,submarine,*

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I. INTRODUCTION

Propeller being an important component for propulsion, more emphasis is done on design of the propeller. It has to withstand to the high pressure acting over on it. The metal propellers generally used cause vibration and noise during its operation. In order to avoid it, conventional isotropic materials are replaced with composite materials. CFRP materials are woven with fiber orientation angles 45,-45. Strength analysis is carried out for composite propeller by using different number of layers for composite materials and inter laminar shear stresses are found out.

II. LITERATURE SURVEY

The papers collected could be broadly classified into theoretical study on propeller strength and experiential studies on propeller strength and a few on composite material and their fem treatment.

J E Connolly[2] "**Strength Of Propellers**"(1960) addresses the problem of wide blades, tried to combine both theoretical and experimental investigations. The author carried out the measurements of deflection and stresses on model blades subjected to simulated loads with an aim to develop a theoretical model calibrated against the laboratory experiments. This model was validated by measurements of pressure and stress distribution on the blades of a full scale ship propeller at sea based on the experimental results it was concluded that wide blades are subjected to tensile stress on the face and compressive stress of similar magnitude on back side. It was pointed out the accuracy of the predication from the model depends on the accuracy of working load determined.

Chang suplee[4] et.al "**Case Study On The Structural Failure Of Marine Propeller Blades**" investigated the main sources of propeller blade failures and resolved the problem systematically. An FEM analysis is carried out to determine the blade strength in model and full scale condition and the range of safety factor for the propeller under study is determined.

III. FIBER REINFORCED PLASTIC MATERIALS FOR PROPELLERS

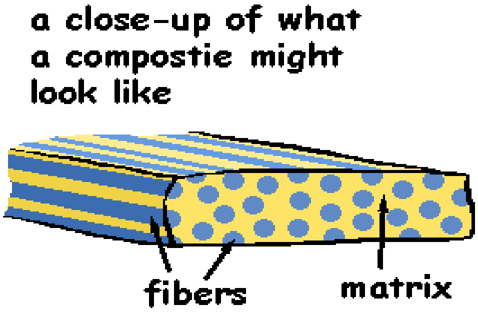
Fiber reinforced composite material consists of fibers of high strength and modulus embedded in or bonded with matrix. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. In general, fibers are the principal load carrying members; while the surrounding matrix keeps them in desired location and orientation, acts as a load transfer medium between them and protects them from environmental damages due to elevated temperatures and humidity. Thus, even though the fibers provide reinforcement for the matrix, the latter also serves a number of useful functions in a fiber reinforced composite material.

The most common form in which fiber reinforced composites are used in structural applications is called a laminate. Stacking a number of thin layers of fibers and matrix and consolidating them into desired thickness. Fiber orientation in each layer has a swell as the stacking sequence of various layers can be controlled to generate a wide range of physical and mechanical properties for the composite laminate.

Each layer may differ from the other in

1) Relative volumes of the constituent materials.
2) Form of the reinforcement used as continuous or discontinuous fibers, woven or non woven reinforcement.
3) Orientation of fibers with respect to common reference axis.

One of the most important factors for determining the properties of composites is relative proportion of the matrix and reinforced materials. The relative proportionate can be given as the weight fractions or the volume fractions. The weight fractions are easier to obtain during fabrication or by one of the experimental methods after fabrication. The volume fractions are exclusively used in the theoretical analysis of composite materials.



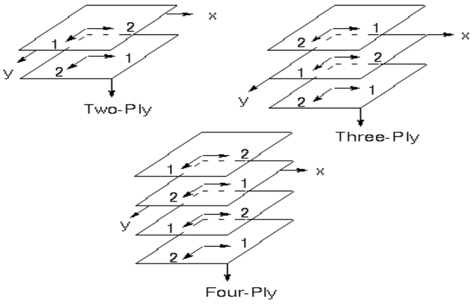


Fig3.1 Composite Material With Fiber And Matrix **Fig.3.2** Exploded View Of 3 Cross- Ply Laminated Plates

3.1 Modeling Of Propeller

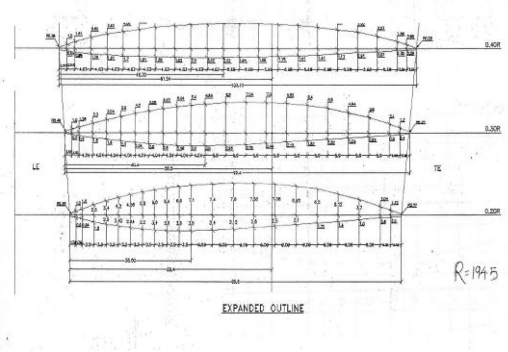


Fig. 3.1.1a Dimensions Of Propeller

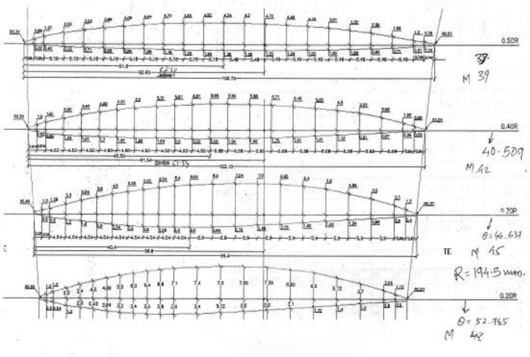


Fig. 3.1.1b Dimensions Of Propeller
(Same dimensions of figure 3.3a, only 0.50R is extra)

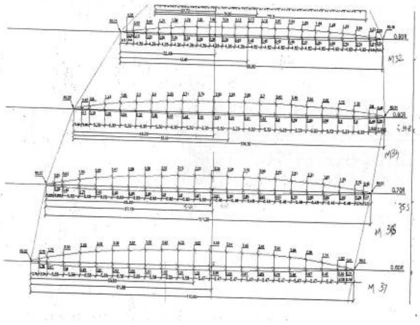


Fig. 3.1.1c Dimensions of propeller

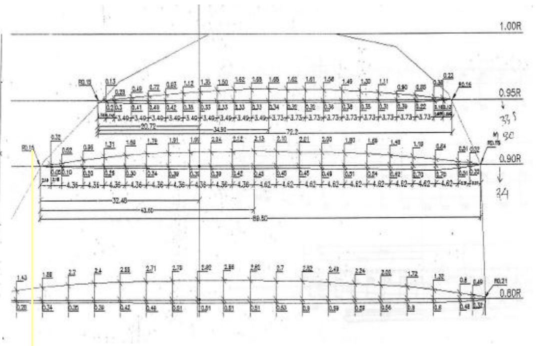


Fig. 3.1.1d Dimensions Of Propeller
(Same dimensions of figure 3.3c, only 0.95R and 1.0R is extra)

3.2 Modeling Of Propeller In Catia

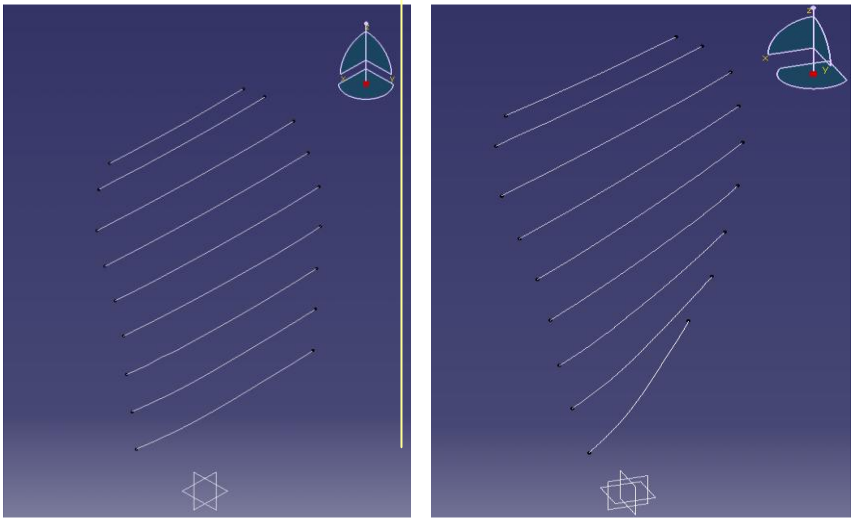


Fig.3.2.1 Construction of Hydrofoils Midline (profile) by Joining of Points of Macros& Rotating Profiles According to Their Pitch Angles(Right side)

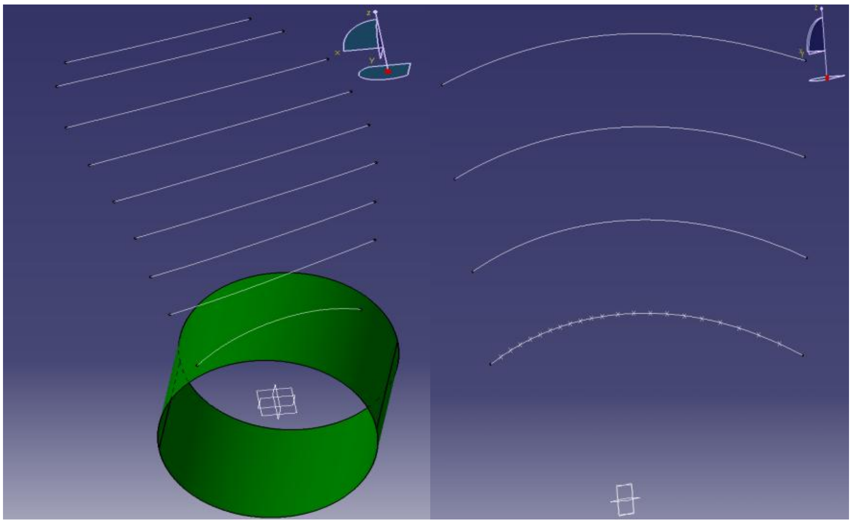


Fig.3.2.2 Developing Of Profiles Onto Right Circular Cylinder And Then Dividing Each Profile Into Equal No Of Divisions

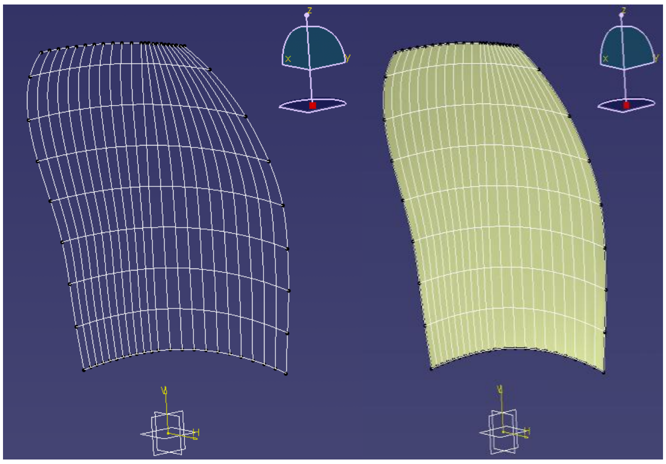


Fig.3.2.3 Creating Guides With Divided Profiles Points And Creating Net Surface By Using Both Guides And Profiles

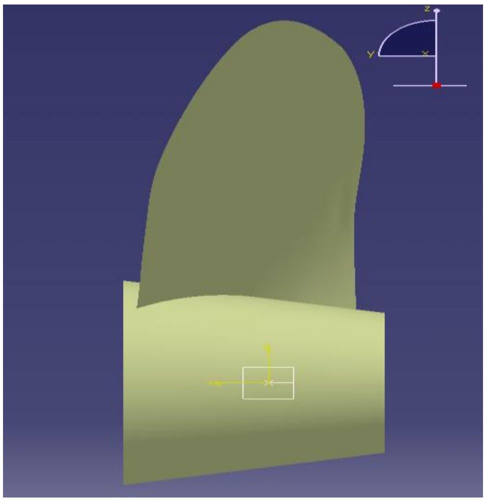


Fig.3.2.4 Single Blade And Hub

The model thus obtained is full model of single blade, and then by copying the full blade at an angle of 60 deg will give full model of Torpedo Aft Propeller with 6 Blades.

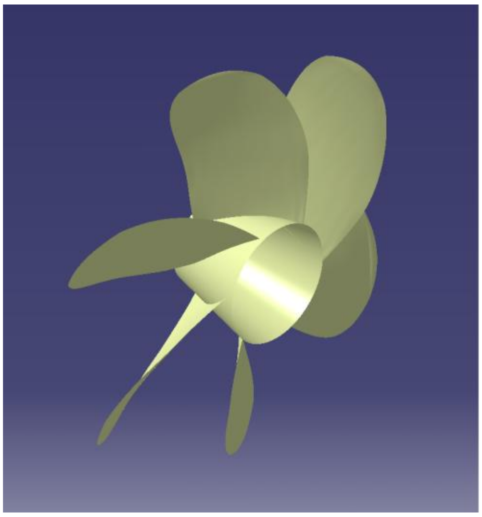


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Fig.3.2.5 Final Model Of Torpedo Aft Propeller

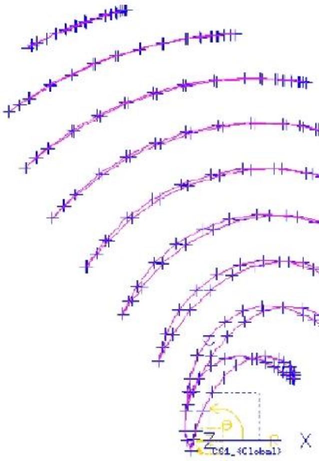


Fig.3.2.6 Construction Of Hydrofoils By Joining Of Points On Surface Of The Blade using CATIA V5 R19

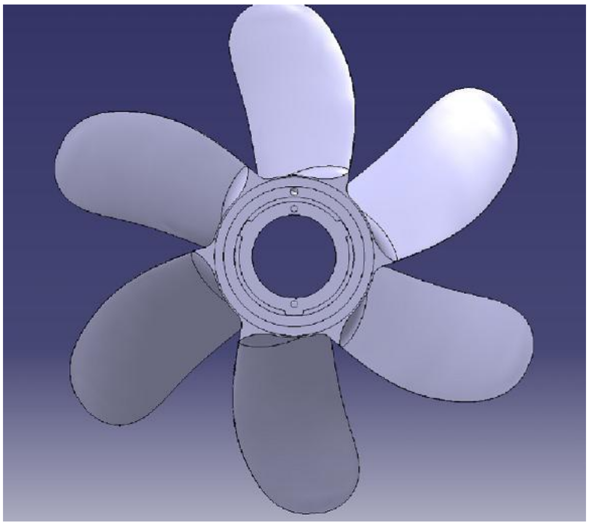


Fig 3.2.7 Final Solid Model Of Propeller

3.3. Mesh Genaration Using Hypermesh

Number of nodes created were 3,05,283 and number of elements created are 1,65,238.

Power=50 Kw velocity=12.5 m/s

Thrust = power/velocity
=50000/12.5
=4000 N

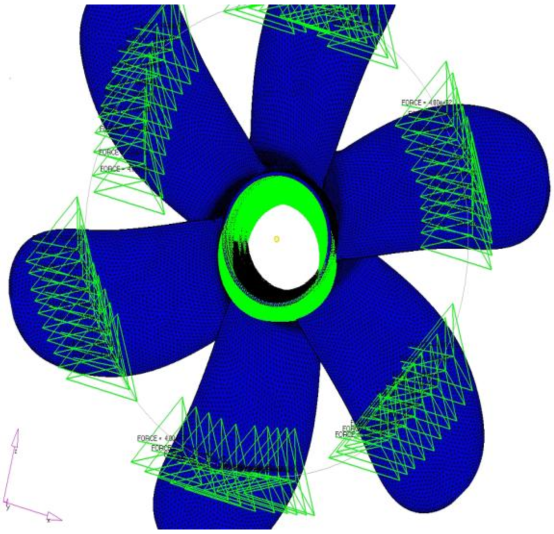


Fig.3.3.1 Loading On Meshed Model.

IV. ELEMENT TYPES USED IN FEM FOR THIS THESIS

In present thesis, element type solid 46 is used for composite propeller blades.

A. SOLID46 Element Description

3-D 8-Node Layered Structural Solid

SOLID46 is a layered version of the 8-node structural solid (SOLID45) designed to model layered thick shells or solids. The element allows up to 250 different material layers. If more than 250 layers are required, a user-input constitutive matrix option is available. The element may also be stacked as an alternative approach. The element has three degrees of freedom at each node: translations in the nodal x, y, and z directions. See SOLID46 in the *ANSYS, Inc. Theory Reference* for more details about this element. A similar element for shells is SHELL99.

In present thesis, Element type solid 92 is used for aluminum propeller.

SOLID92

3-D 10-Node Tetrahedral Structural Solid

B. SOLID92 Element Description

SOLID92 has a quadratic displacement behavior and is well suited to model irregular meshes (such as

4.1 Interpolation model using FEM:

If a polynomial type of variation is assumed for the field (x)’ in one dimensional element, (x) can be expressed as

$\Phi(x) = \alpha_1+\alpha_2 x+\alpha_3 x^2+\ldots\ldots\ldots\ldots..+\alpha_m x^n$…………………….. 5.1

Similarly in two and three dimensions the polynomial form of the interpolation functions can be expressed as

$\Phi(x,y) = \alpha_1+\alpha_2 x+ \alpha_3 y+ \alpha_4 x^2+ \alpha_5 y^2 +\alpha_6 xy+ \ldots\ldots+ \alpha_m y^n$………………………………5.2

$\Phi(x,y,z) = \alpha_1+\alpha_2 x+ \alpha_3 y+ \alpha_4 z+ \alpha_5 x^2+ \alpha_6 y^2+ \alpha_7 z^2+ \alpha_8 xy+ \alpha_9 yz+ \alpha_{10} xz+\ldots\ldots+ \alpha_m z^n$…5.3

produced from various CAD/CAM systems). See SOLID95 for a 20-node brick shaped element

4.2 Linear Static Analysis of Composite Propeller:

For linear static analysis of composite propeller CFRP materials are used. For the composite propeller, the static analysis is done by varying the number of layers viz. 4, 8, The maximum thickness of the blade is 10.36mm.intially the number of layers is given as 4, and fiber orientation angle of +45 and -45 are given for CFRP matermaterials respectively .

Material Properties

1) Aluminum properties
A) Young’s modulus Ex = 70Gpa
B) Poisson’s ratio nuxy = 0.29
C) Mass density = 2800 kg/m3
D) Damping co-efficient = 0.006

Mechanical properties of Composite material properties (CFRP) (tested properties):

Young’s modulus Ex = 180Gpa
Ey = l0Gpa
Ez = l0Gpa
Poisson’s ratio nuxy = 0.28
Shear modulus Gxy = 7. 1 Gpa
Mass density =1600 kg/m3
Damping co-efficient = 0.018

V. RESULTS AND DISSCUSSIONS

5.1 Static Analysis Of Aluminum Propeller:

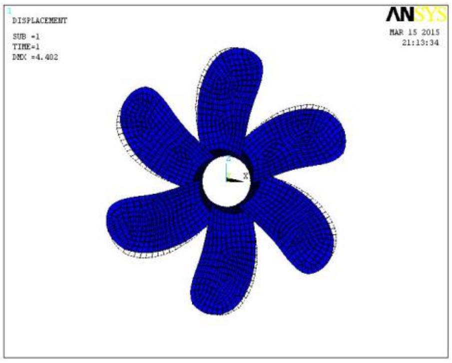


Fig. 5.1.1 Deformation Of Aluminum Propeller

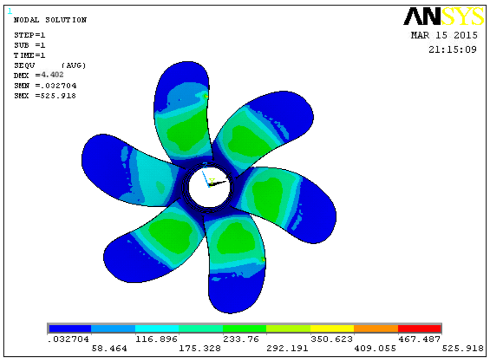


Fig.5.1.2 Max Von Mises Stress Of Aluminum Propeller

5.2 Static Analysis Of Composite Propeller

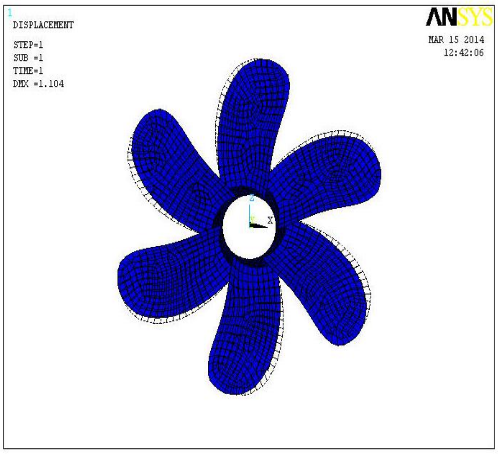


Fig.5.2.1 Deflection Of Composite Propeller With 4 Layers.

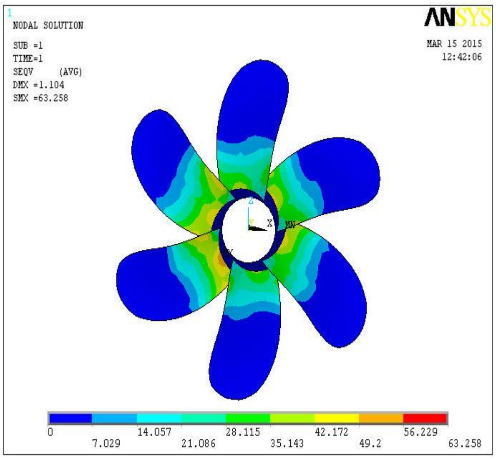
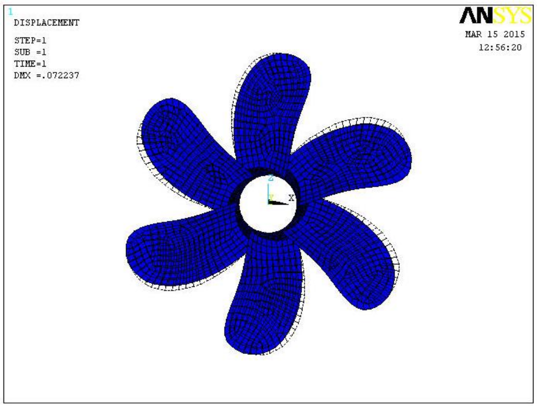


Fig.5.2.2 Max Von Mises Stress Of composite propeller with 4 layers



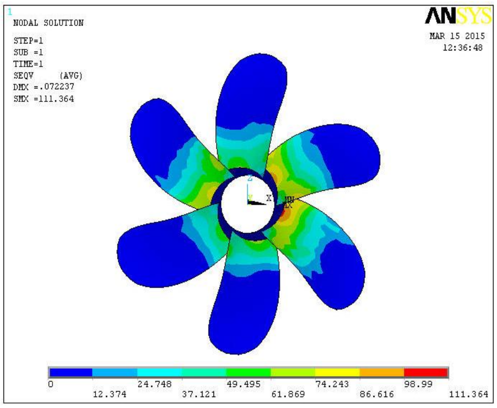


Fig. 5.2.3 Deflection Of Composite Propeller With 8 Layers

Fig.5.2.4 Max. Von Mises Stress Of Composite Propeller With 8 Layers

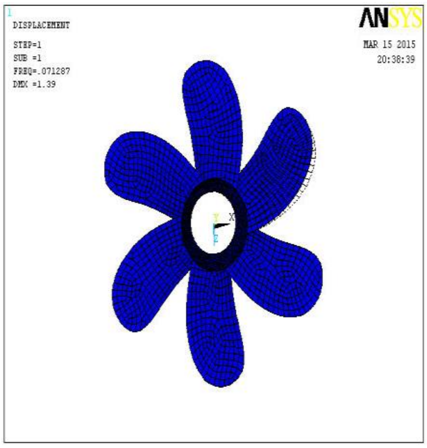
Table 5.1 Static Analysis Results Of Composite Propeller

No.of layers	Max deflection in mm	Von mises stress, N/mm^2
4	1.104	63.258
8	0.072237	111.364

The variation of deflection, stress for different layers was not found to be of much difference.

5.3 MODAL ANALYSIS OF PROPELLER

Modal Results Of Aluminium and Composite Propeller: ALUMINIUM Propeller



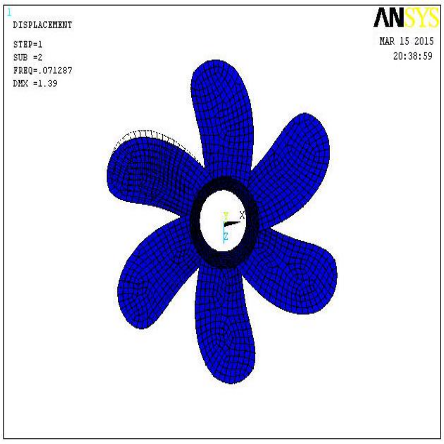


Fig. 5.3.1 First Mode Of Aluminum Propeller Fig.5.3.2 Second Mode Of Aluminum Propeller

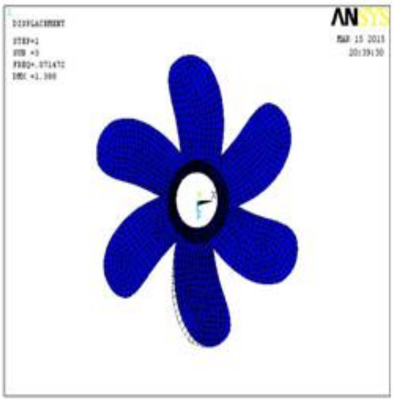


Fig. 5.3.3 Third Mode Of Aluminum Propeller

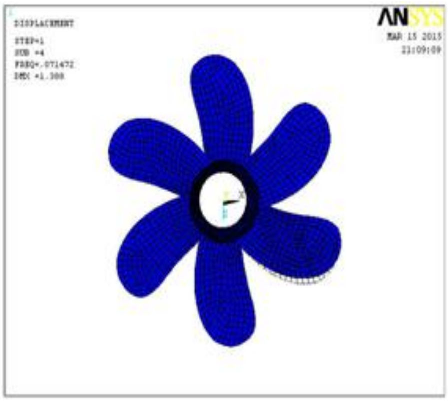


Fig. 5.3.4 Fourth Mode Of Aluminum Propeller

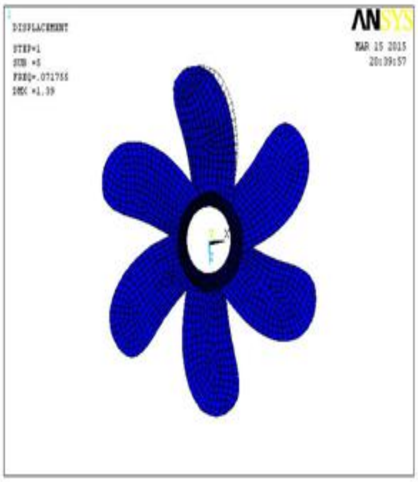


Fig. 5.3.5 Fifth Mode Of Aluminum Propeller

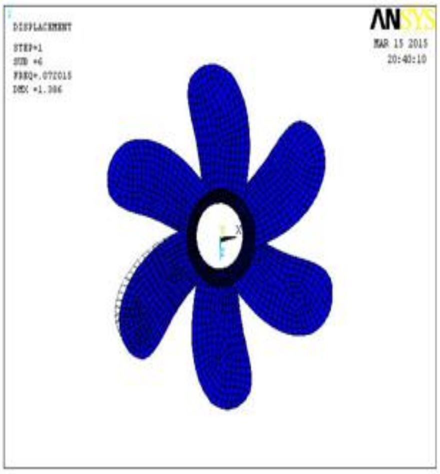


Fig 5.3.6 Sixth Mode Of Aluminum Propeller

5.4 Composite Results:

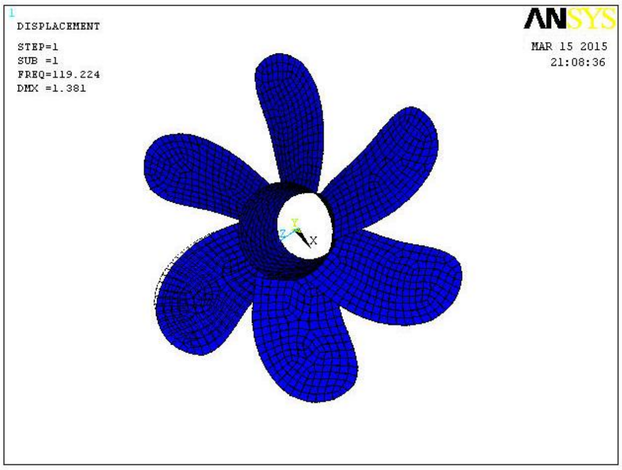
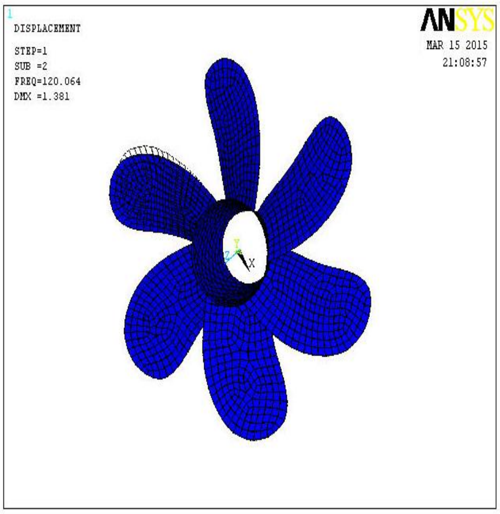


Fig 5.4.1 First Mode Of Composite Propeller With 8 Layers



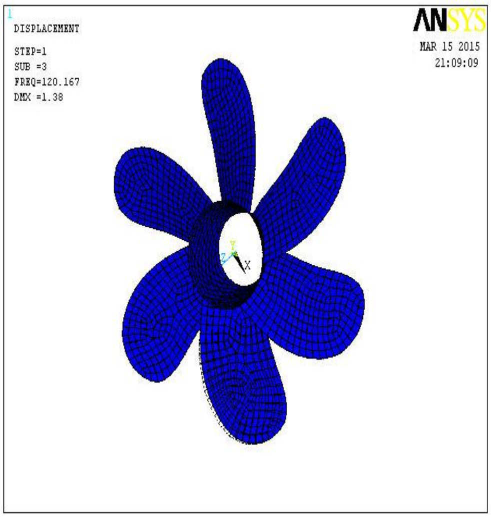
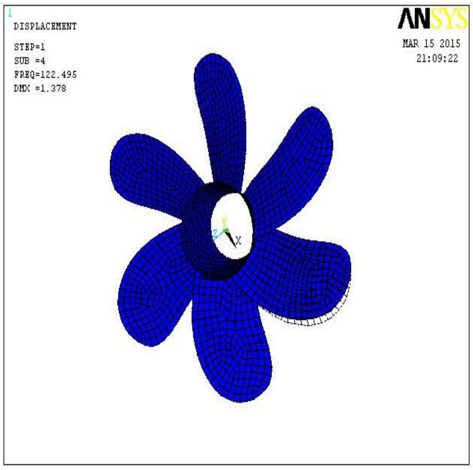


Fig 5.4.2 Second Mode Of Composite Propeller With 8 Layers   Fig 5.4.3 Third Mode Of Composite Propeller With 8

layers



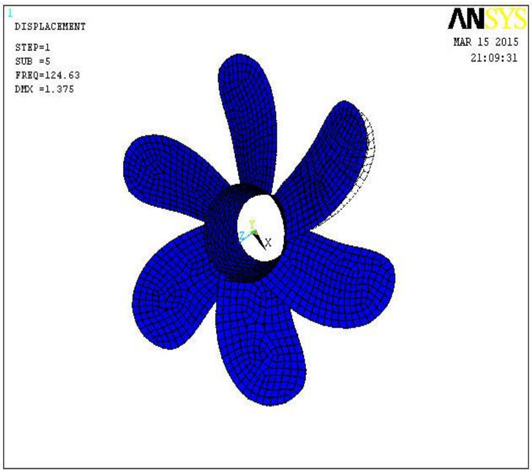


Fig 5.4.4: Fourth Mode Of Composite Propeller With 8 Layers
Fig 5.4.5 Fifth Mode Of Composite Propeller With 8 Layers

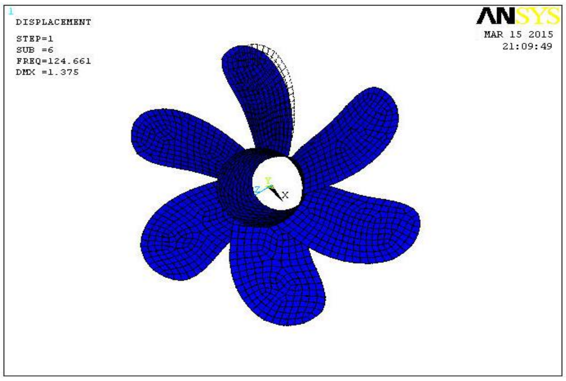


Fig 5.4.6 Sixth Mode Of Composite Propeller With 8 Layers

The natural frequencies of aluminum and composite propeller are compared. The natural frequencies of composite materials were found more as the mass of the composite materials were less than that of aluminum.

Table 5.4 Natural Frequencies Of Propeller Blade

Mode shapes	**Modal analysis for aluminum in HZ**	**Modal analysis for composite propeller in HZ**
Mode 1	0.071287	119.224
Mode 2	0.071287	120.064
Mode 3	0.071472	120.167
Mode 4	0.071472	122.495
Mode 5	0.071755	124.63
Mode 6	0.072015	124.661

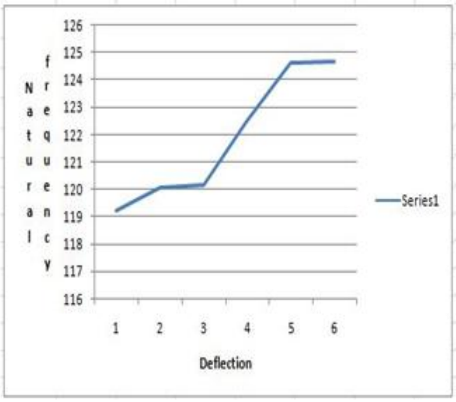


Fig.5.4.7 Composite Material Frequency Vs. Deflection

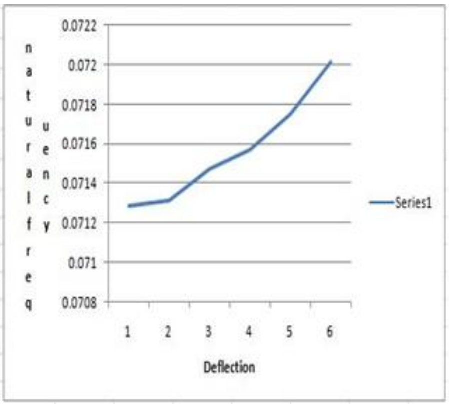


Fig.5.4.8 Aluminium Material Frequency Vs. Deflection

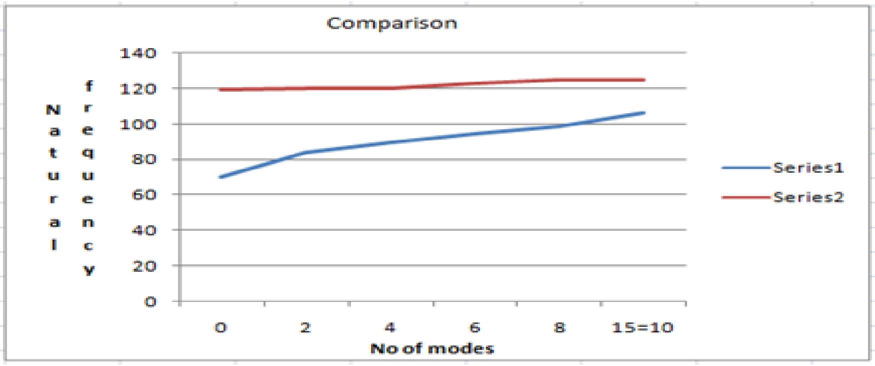


Fig.54.9 Natural Frequency Of Aluminum And Composite Blower

5.5 HARMONIC ANALYSIS OF PROPELLER:

5.**5.1** Harmonic Analysis Of Aluminum Propeller

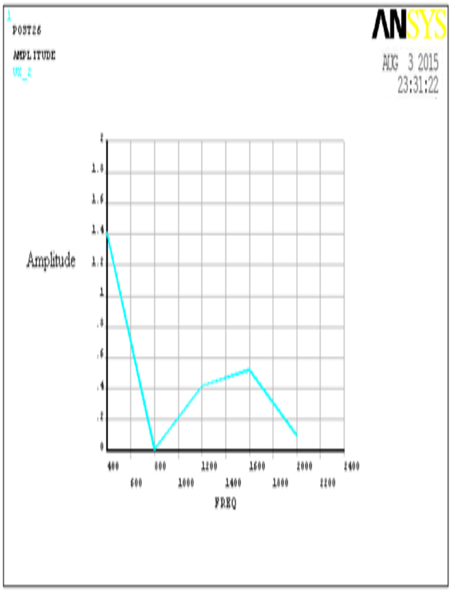


Fig.5.5.1 Amp-Freq Graph Of Aluminum Propeller In Ux Direction

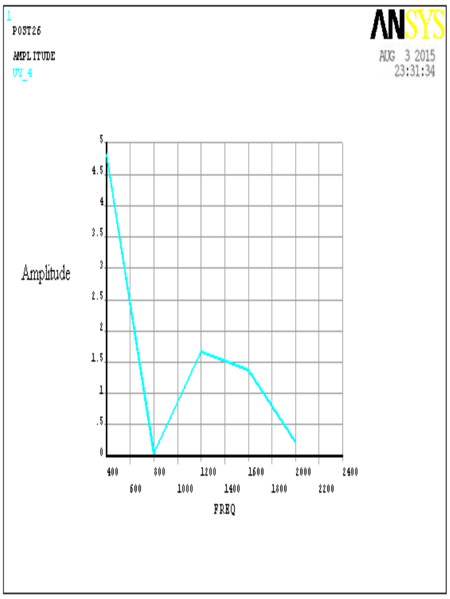


Fig.5.5.2 Amp-Freq Graph Of Aluminum propeller In Uy Direction

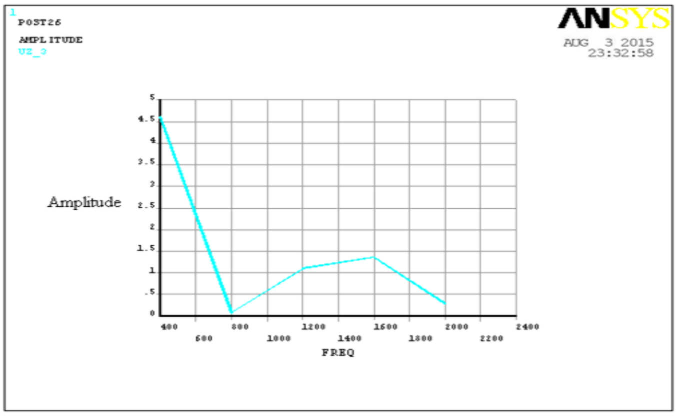


Fig.5.5.3 Amp-Freq Graph Of Aluminum Propeller In Uz Direction

5.6 HARMONIC ANALYSIS OF 8 LAYERS COMPOSITE PROPELLER

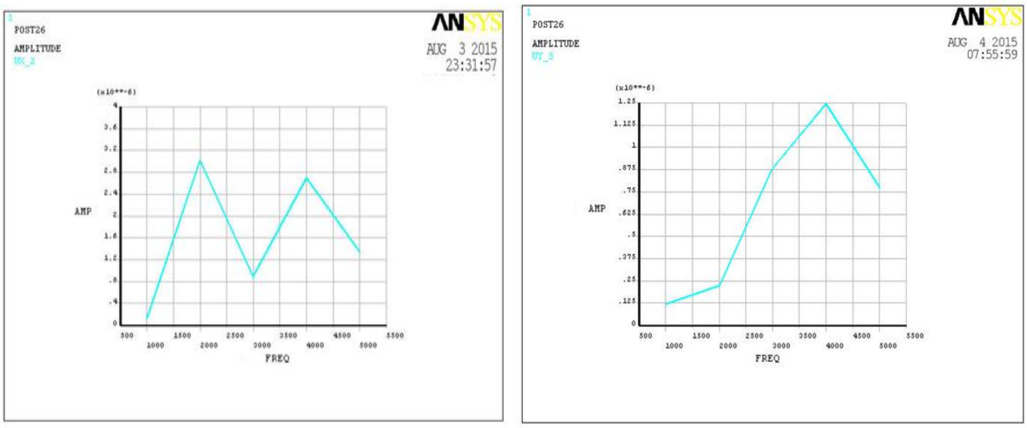


Fig.5.6.1 Amp-Freq Graph Of Composite Propeller In Ux and Uy Direction respectively

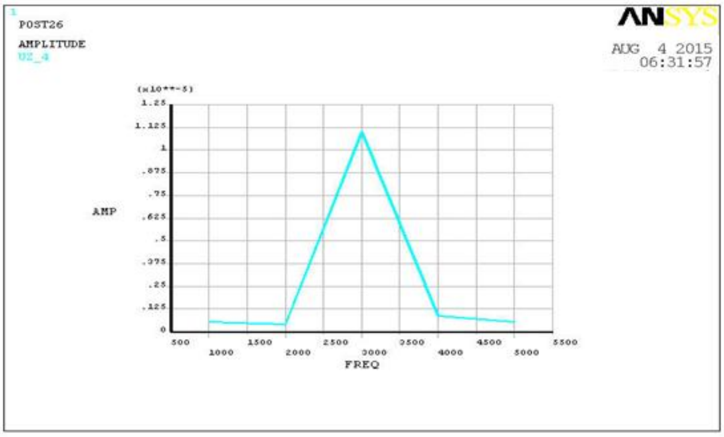


Fig.5.6.2 Amp-Freq Graph Of Composite Propeller In Uz Direction

From the above graphs we observe that:

1. Harmonic analysis results for aluminum propeller shows that the resonance occurs in the frequency range of 1500 Hz in Ux, Uy, Uz directions, so the propeller may be operated in frequency range other than 1500 Hz.
2. Harmonic analysis results for composite propeller shows that the resonance occurs in the frequency range of 2000-3000Hz in Ux, 3000-4000 Uy, around 3000Hz in Uz directions, so the propeller may be operated in frequency range other than 2000-3500 Hz.

VI. ONCLUSION

CONCLUSIONS

After performing simulation for different material and layers the following conclusions are drawn.

1. The deflection for composite propeller blade was found to be for 4 layers as 1.104mm and 8 layers as 0.072237mm which is much less than that of aluminum propeller i.e. 4.402mm, which shows composite materials is much stiffer than aluminum propeller..
2. Modal analysis results showed that the natural frequencies of composite propeller were more than aluminum propeller, which indicates that the operation range of frequency is higher for composite propeller.
3. From the results of harmonic analysis, the propeller may be operated in the frequency range other than 2000-3500Hz.

FUTURE SCOPE

1. The present work consists of static, Modal analysis and harmonic analysis which can be extended for transient and spectrum analysis in case of both aluminum and composite materials.
2. There is also a scope of future work to be carried out for different types of materials, which can be extended for CFD analysis.
3. Analysis will do to obtain relations between fiber angle orientation and parameters like stresses induced in each layer, deflection in each layer and natural frequencies of the composite shaft.

A conclusion section must be included and should indicate clearly the advantages, limitations, and possible applications of the paper. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

REFERENCES

[1]. Taylor, D.w, “The Speed and Power and Ships”, Washington, 1933

[2]. J.E.Conolly, “Strength Of Propellers”, reads in London at a meeting of the royal intuition of naval architects on dec 1.1960,pp 139-160

[3]. Terje sonntvedt, “Propeller Blade Stresses, Application Of Finite Element Methods” computers and structures, vol.4,pp193-204

[4]. Chang-sup lee, yong-jik kim,gun-do kim and in-sik nho. “Case Study On The Structural Failure Of Marine Propeller Blades”

[5]. M.jourdian, visitor and J.L.Armand. “Strength Of Propeller Blades-A Numerical Approach”, the socity of naval architects and marine engineers, may 24-25,1978,pp 20-1-21-3.

[6]. G.H.M.Beek, visitor, lips B.V.,Drunen. “Hub-Blade Interaction In Propeller Strength”, the socity of naval architects and marine enginers, may 24-25,1978,pp19-1-19-14

Cherupally Amareshwari "Modelling And Analysis of Propeller Blade of A Underwater Vehicle.” The International Journal of Engineering and Science (IJES), vol. 6, no. 12, 2017, pp. 68-81.