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Research Article

Harmonic Analysis of Nab Propeller Replaced with Composite Material

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Abstract

Current work intends on harmonic analysis to design a propeller of underwater vehicle with a composite material and to analyze its displacements and natural frequencies using Ansys software. Harmonic analysis is performed to evaluate the suitability of composite material for underwater vehicle propeller over NAB propeller. A propeller is a complex geometry which requires high end modelling software. The solid model of propeller is developed in CATIA V5 R17. Hexa solid mesh is generated for the model using HYPER MESH. Static analysis and Modal analysis are carried on both NAB and composite propeller in ANSYS software. The comparison analysis of metallic and composite propeller has been made and the response graphs for the displacements and frequency were plotted.

Keywords: *Under Water Vehicles (UWV), Composite propeller, Harmonic Analysis, FE Analysis.*

1. Introduction

Ships and UWV's as submarines, torpedoes and submersibles etc., uses propeller as propulsion. The Propeller blade geometry and its design is more complex involving many controlling parameters. The strength analysis of such complex 3D blades with conventional formulas will give less accurate values. In such cases numerical analysis (Finite Element Analysis) gives comparable results with experimental values. The conventional UWV Propellers are made up of Nickel Aluminium Bronze (NAB) and Manganese-Nickel Aluminium Bronze (MAB) the present work aims to replace the propeller blade material from Nickel Aluminium Bronze (NAB) metal to a fiber reinforced composite material (FRP). This complex analysis can be solved easily by finite element method techniques. The Harmonic analysis is done for the three bladed solid NAB as well as Composite propeller. The Harmonic analysis includes the evaluation of Displacement and frequency analysis for the propeller blades Eigen value analysis are performed. The goal of this work is to design, and evaluate the performance of the composite Propeller with that of the NAB propeller.

The earliest approach to strength problem was made by Taylor who considered propeller as a cantilever rigidly fixed at the boss. Then stresses were evaluated by considering the theory of simple bending and using section of the blade by a cylinder. The Deflection and Stresses are measured on model blades subjected to simulated loads was carried out by J.E.collony combining both the theoretical and experimental investigations. The main propeller blade failure sources are resolved systematically by changsuplee carried out Fem analysis to evaluate the blade strength.

George compared the actual and theoretical distribution of thrust and torque along the radius. W.J Colclough the benefits of using a fiber reinforced material (FRP) as a composite over the propeller blade from other materials. Christopher Leyens [6] discussed two distinct materials and design approached for the purpose of reduced weight and improved strength and stiffness. Gau-Feng Lin et.al, carried out stress calculations for a fiber reinforced composite thruster blade. Jinsoo cho developed a numerical optimization technique to evaluate the optimum propeller blade shape for efficiency improvement. Charles Dai discusses preliminary propeller design strategy, numerical Optimization, knowledge based systems and geometric algorithms in general and in specific as applied to the design of a exacting propeller. Based on above discussions replacement of NAB propeller blade was done to replace with composite material for strength analysis.

2. Modelling of B-Series Propeller Blade

To model a propeller blade of particular series type airfoil points of specific type are required. In present work a B-series standard airfoil points are chosen for the modelling. The outline airfoil points and propeller blade are modelled in Solid works 2010 and the hub and filleting portion of blade are done in CATIA V5R17. Since the propeller blade consisting of various radii are located through corresponding pitch angles. Then all rotated sections are

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Material properties for composite Propeller used for present work

Mat no 1: S2Glass fabric/Epoxy	Mat no 2: Carbon UD/Epoxy
Ex = 22.925Gpa	Ex = 120Gpa
Ey = 22.925Gpa	Ey = 10Gpa
Ez = 12.4Gpa	Ez = 10Gpa
NUXY = 0.12	NUXY = 0.16
NUYZ = 0.2	NUYZ = 0.2
NUZX = 0.2	NUZX = 0.16
Gxy = 4.7Gpa	Gxy = 5.2Gpa
Gyz=Gzx = 4.2Gpa	Gyz = 3.8Gpa
ρ = 1.8gm/cc	Gzx = 6Gpa
	ρ = 1.6gm/cc

projected onto a right circular cylinder of respective radii as shown in fig below. Then by using multi section surface option, the blade is modelled.

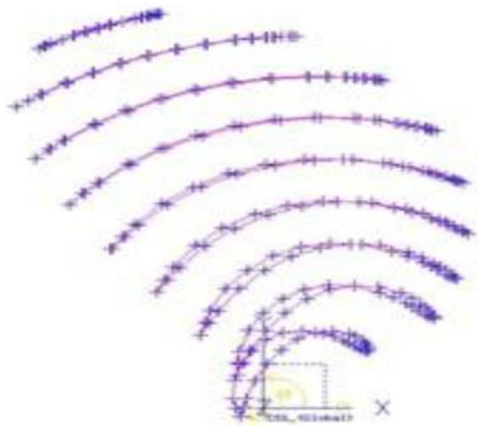

Fig.1 Construction of Aerofoil points

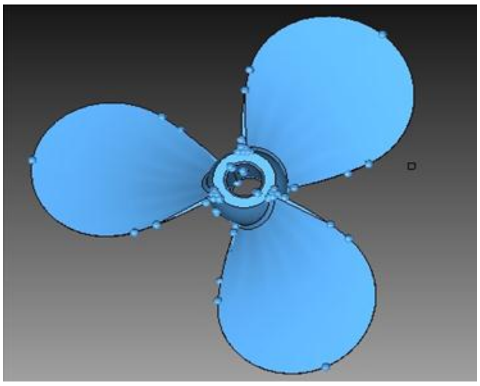

Fig.2 Solid model of NAB propeller joining of points on surface of the blade

2.1. Mesh Generation Using Hyper Mesh:

The solid model of the propeller blade along with hub is imported to HYPERMESH 11.0 and solid mesh is generated for the model as shown in figure 3. The model with and without mesh are shown in figure below. Boundary conditions are applied to meshed model. The contact surface between hub and shaft is fixed in all degrees of freedom. Thrust of 332.14 N is uniformly distributed in the region between the sections at 0.7R and 0.75R on face side of blade, since it is the maximum loading condition zone on each blade as per the George work. The loading condition is as shown in figure 4. Quality checks are verified for the meshed model. Jacobian, war page and aspect ratio are within permissible limits. Solid45 element type is chosen for NAB and solid46element is chosen for composite material.

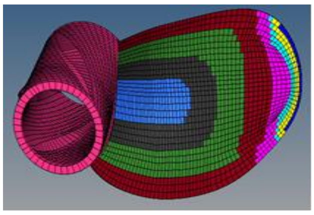

Fig.3. Meshed Model

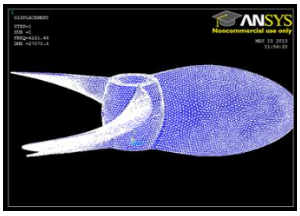

Fig.4. Loading conditions of NAB Propeller

Material properties of propeller

Nickel Aluminium Bronze properties
Young's modulus E= 1.21e5 MPa
Poisson's ratio NUXY=0.34
Mass density =2700 kg/m^3
Damping co-efficient =0.03

3. Harmonic Analysis

This analysis gives the ability to estimate the sustained dynamic behaviour of structures, thus it enabling to validate the designs will successfully overcome resonance, fatigue and other harmful effects of forced vibrations. Harmonic response analysis is a mode used to find out the steady state response of a linear structure to loads that vary sinusoidal with time. It calculates the propellers response at several frequencies and obtains the graphs of displacement versus frequencies.

4. Results and Discussions

From the harmonic analysis, the displacements of various nodes and stresses for different elements for the entire frequency range 0 to 3000 Hz with amplitude were obtained. The natural frequencies of the propeller lie in the same above frequency range. The observed peaks in the frequency response graphs were plotted. Fig 5(a), Fig 5(b) and Fig 5(c) shows the variation of displacement in X, Y and Z directions with frequency at node 1428.

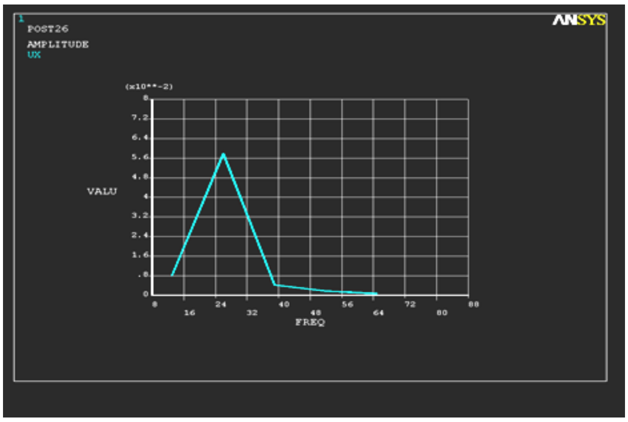

Fig:5(a) Frequency response of propeller made of Nickel-Aluminium-Bronze(NAB)(in Ux direction)

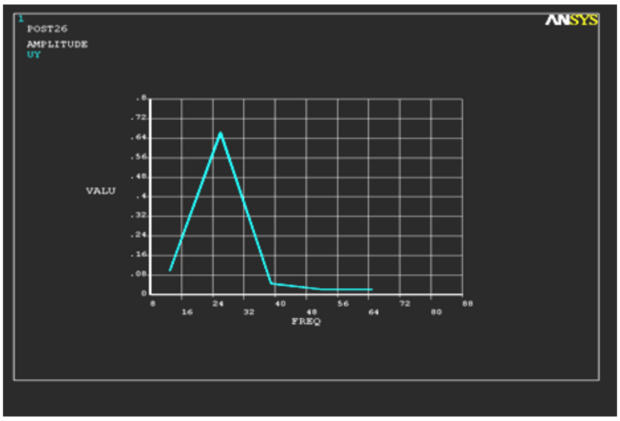

Fig:5(a) Frequency response of propeller made of Nickel-Aluminium-Bronze(NAB)(in Uy direction)

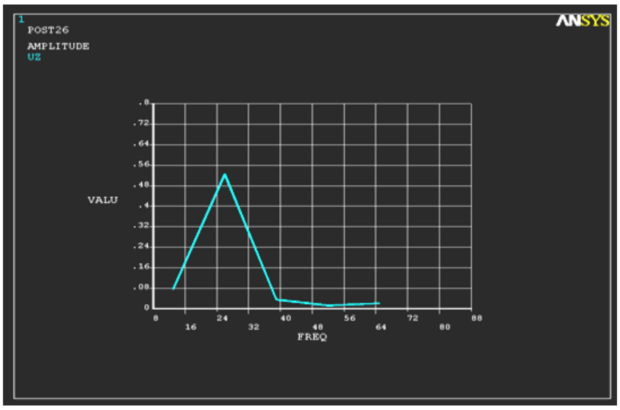

Fig:5(a) Frequency response of propeller made of Nickel-Aluminium-Bronze(NAB)(in Uz direction)

4.1.Harmonic analysis of composite propeller with 25 layers

The natural frequencies of the propeller lie in the frequency range of 0 to 2000Hz. The observed peak in the frequency response graphs was plotted. Fig 6(a), Fig 6(b) and Fig 6(c) shows the variation displacement in X, Y and Z directions with frequency at node 1428.

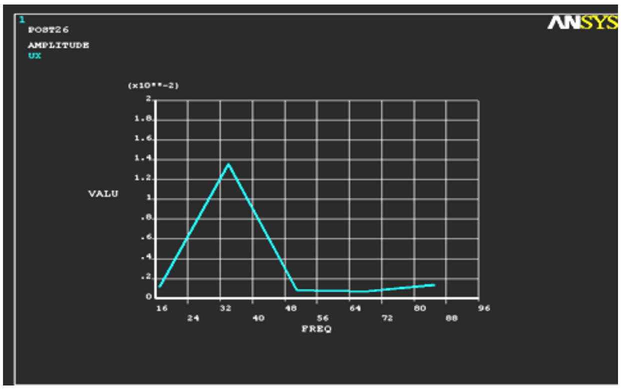

Fig. 6(a) Frequency response of propeller made of composite material (in Ux direction**)**

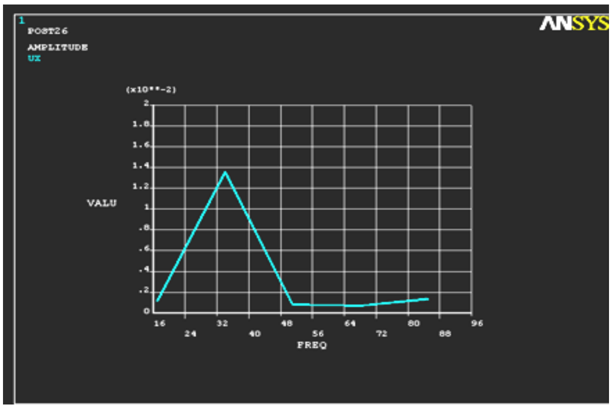

Figure 6 (b) Frequency response of propeller made of composite material (in Uy direction)

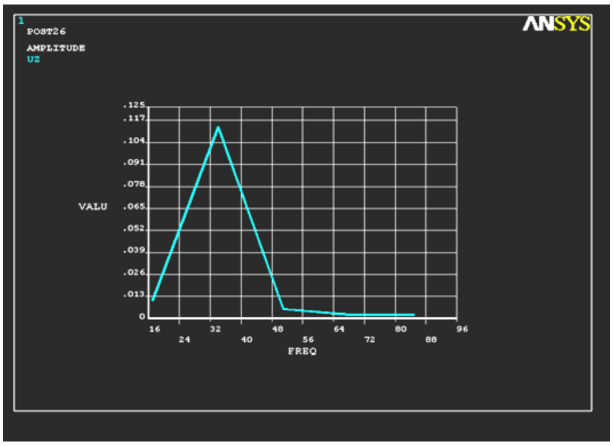

Fig. 6 (c) Frequency response of propeller made of composite material (in Uz direction)

Conclusions

1. From the results of harmonic analysis, composite propeller is safe against resonance phenomena.
2. Harmonic analysis is carried out on both aluminium and composite propellers, it was observed maximum

displacement for composite propeller is less than the aluminium propeller.

3. From the results of harmonic analysis, damping effect is more in composite propeller which controls the vibration levels.
4. The weight of the composite propeller is 42% less than the aluminium propeller.

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