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Replacement of Nab Propeller Blade with Composite for Strength Criteria

M.L.Pavan Kishore[1]*, R.K.Behera[1],

[1]*Department of Mechanical Engineering, NIT Rourkela, INDIA*

ABSTRACT: *The objective of the present work is to model and analyze a propeller blade for strength. A propeller is a twisted airfoil which converts rotating power of the engine into thrust which propels the vehicle to move ahead. In order to predict the strength of propeller blade a comparison has been made between Aluminum alloy based and composite material. Propeller being a complex geometry requires a high end modeling software. Modeling of such complex geometry is done using CatiaV5R20,meshing and application of boundary conditions to propeller blade are done by using Hyper mesh 11.0 software. The deformation,stresses,mode shapes for composite propeller blade as well as for NAB are determined using Ansys13.0. On comparison which shows that by changing the layup sequence further composite materials can be made much stiffer than NAB propeller*

Keywords: *Composite material, Deformation, Elements, Nodes, Meshed model*

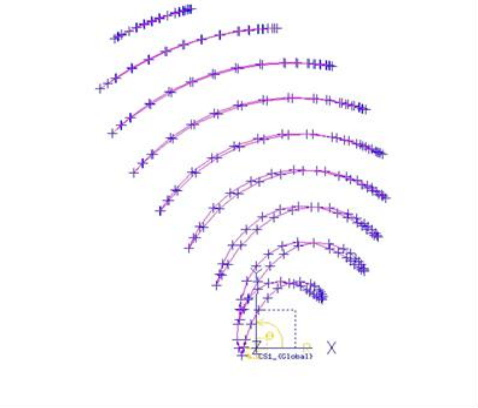
I. INTRODUCTION

Ships and under water vehicles like submarines, torpedoes and submersibles etc., uses propeller as propulsion. The blade geometry and its design are 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. In the present project the propeller blade material is replaced from Nickel Aluminum Bronze (NAB) metal to a fiber reinforced composite material (FRP) for ship propeller. This complex analysis can be easily solved by finite element method techniques. The structural analysis is done for the four bladed solid NAB as well as Composite propeller. The structural analysis include the evaluation of static and dynamic analysis for the propeller blades Eigen value analysis are performed to compare the results. The goal of this work is to design, and evaluate the performance of the composite Propeller with that of the NAB propeller. The first approach to strengthen the problem was made by Taylor, (1) who considered propeller as a cantilever rigidly fixed at the boss, then stresses were evaluated following the theory of simple bending using section of the blade by a cylinder. The measurement of deflection and the stresses on model blades subjected to simulated loads was carried out by I.E.collony. (2) Combining both theoretical and experimental investigations. The main sources of propeller blade failure are resolved systematically by changsuplee (3) carried out Fem analysis to determine the blade strength.

The distribution of thrust and torque along the radius to compare actual performance of a propeller with the calculated performance was given by George (4).W.J Colclough (5) the advantage of using a fiber reinforced material as a composite overt the propeller blade from other materials. Christopher Leyens (6) discussed two different materials and design approach for the purpose of reducing weight and increasing strength and stiffness. Gau-Feng Lin (7) et.al, carried out stress calculations for a fiber reinforced composite thruster blade. Jinsoo cho (8) developed a numerical optimization technique to determine the optimum propeller blade shape for efficiency improvement. Charles Dai (9) et.al, 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 particular propeller. Based on above discussions replacement of NAB propeller blade was done to replace composite material for strength analysis.

II. MODELING OF A B-SERIES PROPELLER BLADE

To model a propeller blade of particular series airfoil points of specific type are required .In present work a B-series standard airfoil points are chosen for the modeling. The outline airfoil points and propeller blade are modeled 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,next all rotated sections are projected onto a right circular cylinder of respective radii as shown in fig below. Then by using multi section surface option, the blade is modeled.



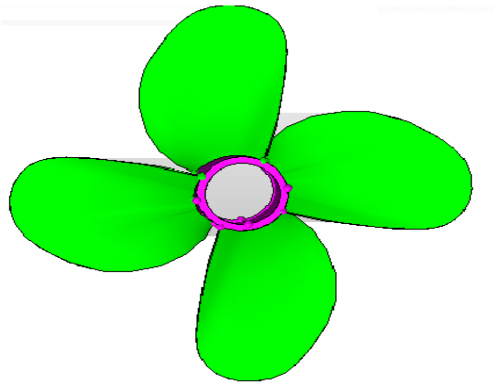


Figure1 construction of hydrofoils by joining of points on surface of the blade

Fig2. Solid model of NAB propeller

2.1. Hyper mesh as a tool for Meshing

The solid model of the propeller blade along with hub is imported to HYPERMESH 11.0 and solid mesh is generated for the model. The model with and without mesh are shown in figure 2,3. Boundary conditions are applied to meshed model fig5,6. The contact surface between hub and shaft is fixed on all degrees of freedom. Thrust of 260.14 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 [7] work. The loading condition as shown in figure 4.8., 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 solid46 element is chosen for composite material.

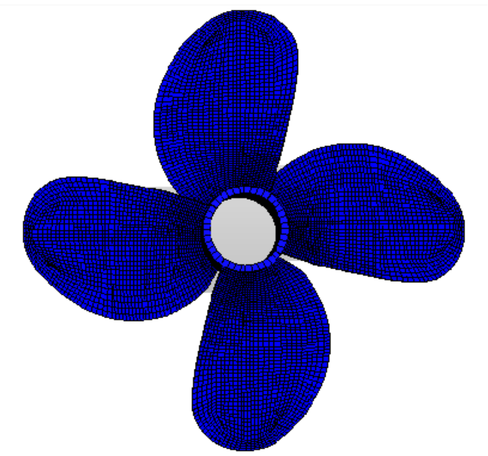


Fig3. Meshed NAB Propeller

Fig4.MeshedCompositemodel

Table1.Material properties for NAB

Yield strength	**178.3 mpa**
Young's modulus	**1.21x1e5 mpa**
Poisson's ratio	**0.34**
Density	**7556.51kg/m^3**
Hardness	**152-190 BHN**
Melting point	**650°c**

Table2.Material properties for composite

RGlass roving UD/Epoxy	S2Glass fabric/Epoxy	Carbon UD/Epoxy
E_x= 53.1Gpa	E_x=22.925Gpa	E_x=142Gpa
E_y=12.4Gpa	E_y=22.925Gpa	E_y=10Gpa
E_z= 12.4Gpa	Ez=12.4Gpa	E_z=10Gpa
N_{UXY}=0.16	N_{UXY}=0.12	NUXY =0.16
N_{UYZ}=0.16	N_{UYZ}=0.2	NUYZ =0.2
N_{UZX}=0.28	N_{UZX}=0.2	NUZX =0.16
G_{xy}=6.6Gpa	G_{xy}=4.7Gpa	G_{xy}=5.2Gpa
G_{yz}=4.14Gpa	G_{yz}=4.2Gpa	G_{yz}=3.8Gpa
G_{zx}= 4.14Gpa	G_{zx}=4.2Gpa	G_{zx}=6Gpa
density = 2gm/cc	density=1.8gm/cc	density=1.6gm/cc

III. RESULTS AND DISCUSSIONS

3.1. Static Analysis of NAB Propeller

The thrust of 260.14N is applied on face side of the blade in the region between 0.7R and 0.75R. The intersection of hub and shaft point's deformations in all directions are fixed. The thrust is produced because of the pressure difference between the face and back sides of propeller blades. This pressure difference also causes rolling movement of the underwater vehicle. This rolling movement is nullified by the forward propeller which rotates in other direction (reverse direction of aft propeller). The propeller blade is considered as cantilever beam i.e. fixed at one end and free at other end. The deformation pattern for aluminum propeller is shown in figure 5.0.The maximum deflection was found as 1.225 mm. Similar to the cantilever beam the deflection is maximum at free end.

The Von mises stress on the basis of shear distortion energy theory was also calculated in the present analysis. The maximum von mises stress induced for aluminum blade is 22.072 N/mm^2 as shown in figure 7.0 The stresses are greatest near to the mid chord of the blade-hub intersection with smaller stress magnitude towards the tip and edges of the blade. Figure 7,8,9,10 shows induced deformations and stresses in NAB and composite propeller.

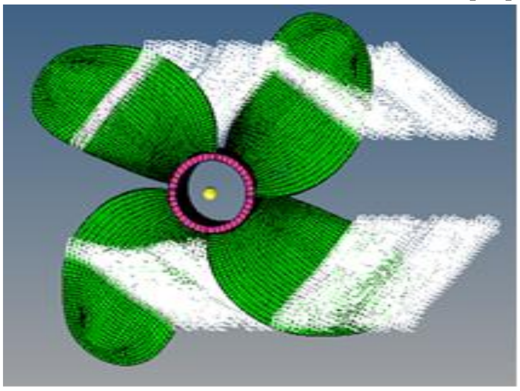


Fig5.LoadDistributionat0.75R

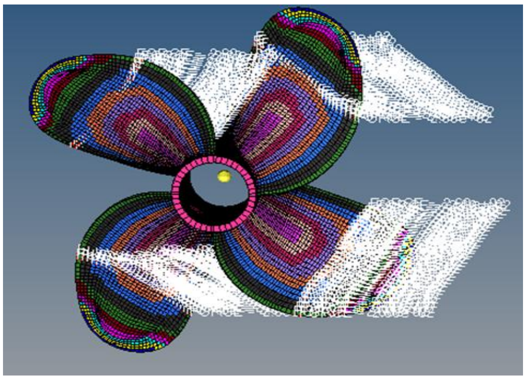


Fig6.Load distribution at 0.75R

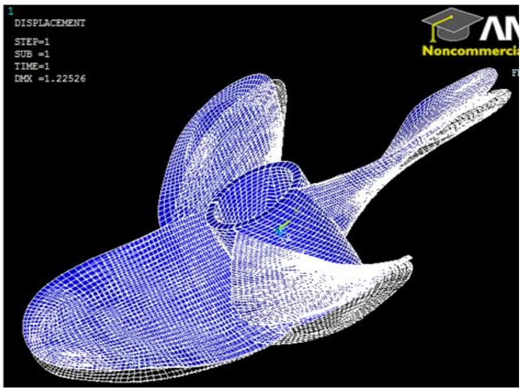


Fig7.Deformed model for NAB

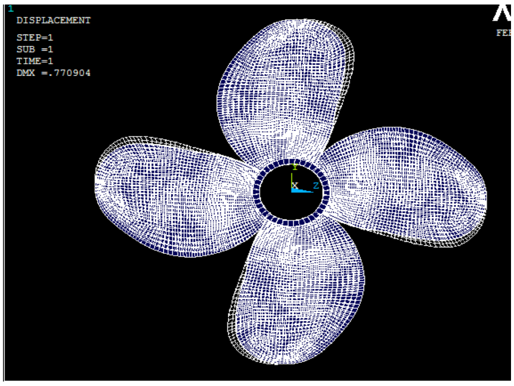


Fig8. Deformed model for Composite

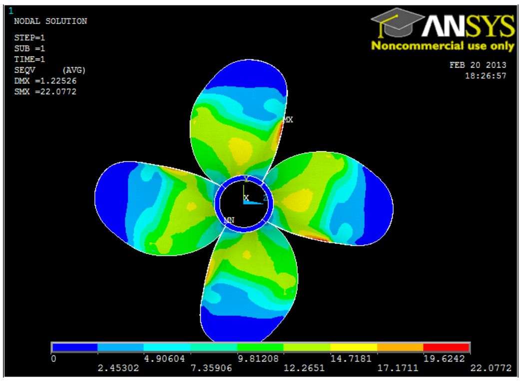


Fig9.Vonmises Stress for NAB

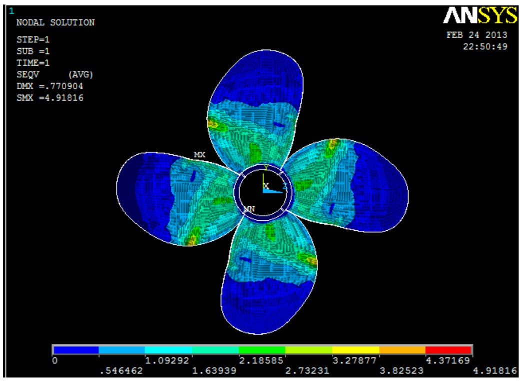


Fig10.Vonmises Stress for Composite

Table4. Comparison of NAB vs. Composite Propeller

	Solid Propeller	Composite Propeller
Deformation(mm)	1.225	0.770
Von misses stress(MPa)	22.072	4.918
X component stress(MPa)	12.1063	3.735
Y component stress(MPa)	23.6746	4.009
Z component stress(MPa)	25.4475	2.680

3.2Eigen value analysis of propeller blade

The required boundary conditions and density are given for extracting the first ten mode shapes of both NAB and composite propeller blade. Type of analysis is changed to model and first ten mode shapes are obtained. By using Block Lanczos method the Eigen value analysis is carried out for NAB and composite propeller. This analysis helps in finding out the response due to loading the natural frequency and the corresponding mode shapes in the form of Eigen vectors of the propeller blade. This analysis also represents the undamped free vibration of the propeller blade in absence of damping and applied loads. First ten natural frequencies are obtained for Nickel-Aluminum-Bronze (NAB) and composite propeller.

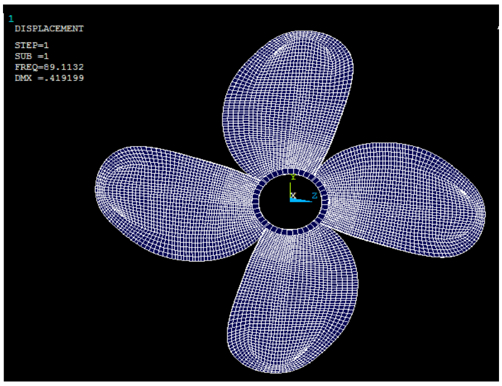


Fig9. First Mode shape for NAB

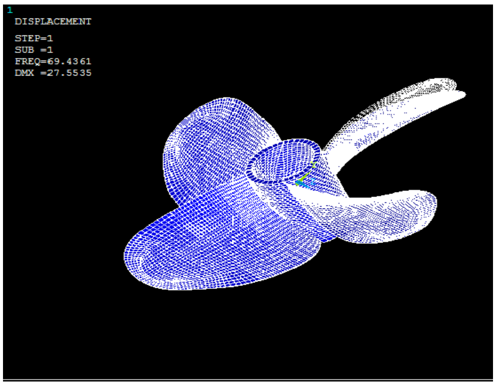


Fig10. First Mode shape for Composite

Table5.Natural frequencies of Both NAB&Composite Material

S.No	Eigen value analysis for Nickel-Aluminum-Bronze(NAB)in Hz	Eigen value analysis for composite propeller in Hz
1	89.113	69.436
2.	89.574	70.963
3.	89.581	72.189
4.	89.702	72.254
5.	201.85	152.56
6.	203.25	156
7.	203.28	160.07
8.	203.80	160.26
9.	241.03	196.91
10.	241.22	199.75

IV. CONCLUSIONS

1. The deflection for composite propeller blade was found to be around 0.770mm for all layers which is same as NAB propeller i.e 1.225mm, which shows that by changing the layup sequence further composite materials can be made much stiffer than aluminum propeller.
2. Maximum induced von mises stress for aluminum was found to be 22.072 N/mm^2 which is greater than composite propeller i.e. 4.918 N/mm^2.
3. Eigen value analysis results showed that the natural frequencies of NAB propeller were 22 % more than composite propeller.
4. Eigen value analysis results show that the first critical speed of NAB propeller is 89.113 Hz and next critical speed is 89.574 Hz.
5. Eigen value analysis results show that the first critical speed of composite propeller is 69.43 Hz and next critical speed is 70.96 Hz.

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