Structural Analysis of NAB Propeller Replaced With Composite Material

M.L.Pavan Kishore, [1] R.K.Behera, [2] Sreenivasulu Bezawada[3]

[1]Research Scholar, Department of Mechanical Engineering, NIT Rourkela, Odisha, INDIA
[2]Professor, Department of Mechanical Engineering, NIT Rourkela, Odisha, INDIA,
[3] Assistant professor, Department of Mechanical Engineering, MITS, Madanapalle, Andhra pradesh, INDIA

Abstract : *The present work deals with modeling and analyzing the propeller blade of a underwater vehicle for their strength. A propeller is a complex geometry which requires high end modeling software. The solid model of propeller is developed in CATIA V5 R17. Hexa solid mesh is generated for the model using HYPER MESH. Static, Modal analysis of both NAB and composite propeller are carried out in ANSYS software. The stresses obtained are well within the limit of elastic property of the materials. The deflection for composite propeller blade as well as for NAB was determined. On comparison which shows that by changing the layup sequence further composite materials can be made much stiffer than NAB propeller.*

Keywords: *Boundary conditions, 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 ant 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.

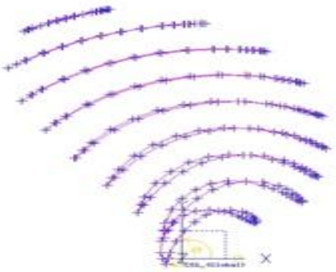
In the present project the propeller blade material is replaced from Nickel Aluminum Bronze (NAB) metal to a fiber reinforced composite material (FRP) for ship propeller. This complex analysis can be easily solved by finite element method techniques. The structural analysis is done for the four bladed solid NAB as well as Composite propeller. The structural analysis includes 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 strength problem was made by Taylor(1) who considered propeller as a cantilever rigidly fixed at the boss.thenstresses were evaluated following the theory of simple bending using section of the blade by a cylinder. The measurements of deflection and the stresses on model blades subjected to simulated loads was carried out by I.E.collony (2) combining both the 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 approached for the purpose of reduced weight and increased 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[l7] 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 with composite material for strength analysis.paper. (10)

II. MODELING OF A B-SERIES PROPELLER BLADE

In order 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 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. Then 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.



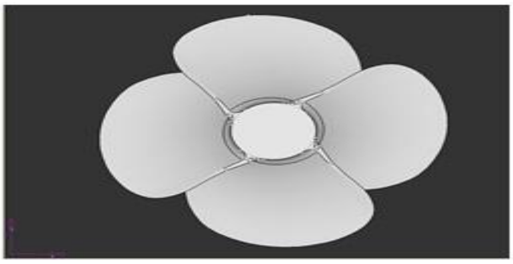


Figure1.construction of hydrofoils by joining of points on surface of the blade

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 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 [7] work. The loading condition is 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 solid46element is chosen for composite material.

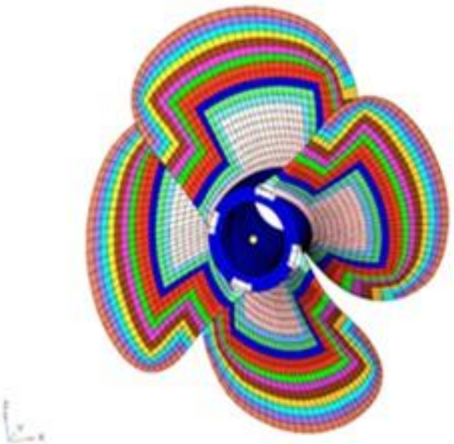


Fig3.Composite Propeller

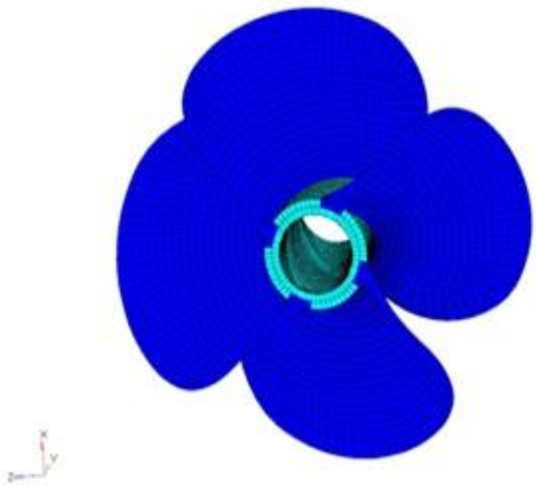


Fig4.Meshed model

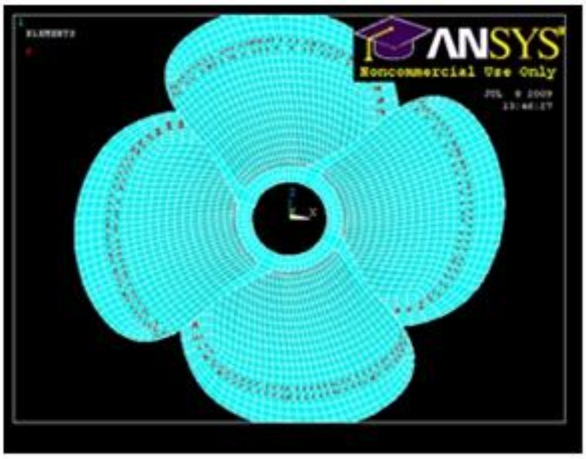


Fig5.Load Distribution at 0.75R

Table1.Material properties for NAB

Yield strength	178.3 mpa
Young's modulus	1.21x1e5 mpa
Poisson's ratio	0.34
Density	0.07556g/cc
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 DISSCUSSIONS

3.1. Static Analysis of NAB Propeller

The thrust of 332.17N 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 6.1. The maximum deflection was found as 0.597 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 also calculated in the present analysis. The maximum von mises stress induced for aluminum blade is 125.484 N/mm2 as shown in figure 7.0 which exceeds the allowable strength of aluminum i.e 178N/mm2 that may cause failure. The stresses are greatest near to the mid chord of the blade-hub intersection with smaller stress magnitude toward the tip and edges of the blade. Figure 5,6 shows induced deformations and stresses in NAB and composite propeller.

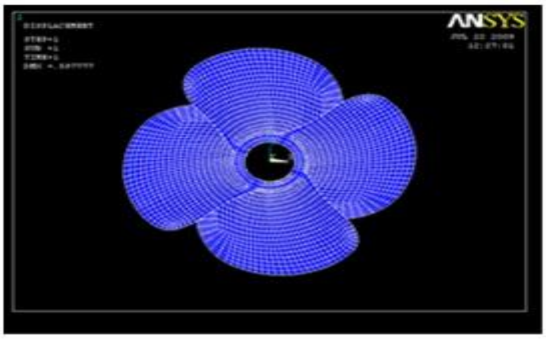


Fig5.Deformed model for NAB

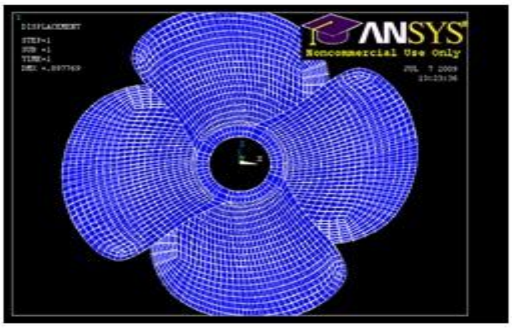


Fig6.Deformed model for Composite

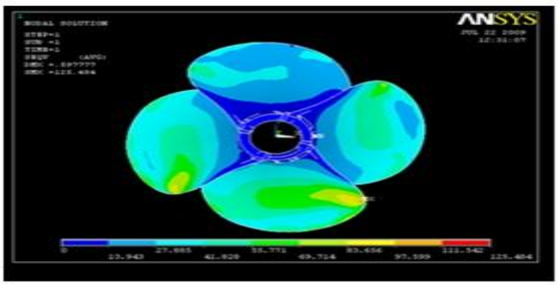


Fig7.Von Mises Stress for NAB

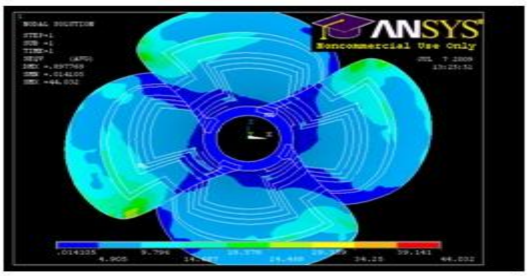


Fig8. Von Mises Stress for Composite

Table4. Comparison of NAB vs. Composite Propeller:

Deformation(mm)	0.597	0.897
Von misses Stress(MPa)	125.484	44.032
X component stress(MPa)	60.932	21.52
Y component stress(MPa)	23.641	11.947
Z component stress(MPa)	75538	17.543

3.2Eigen value analysis of propeller blade

The required boundary conditions and density are given for extracting the first ten mode shapes of both aluminum and composite propeller blade. Type of analysis is changed to model and First ten mode shapes are obtained. By using Block Lancozs 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.

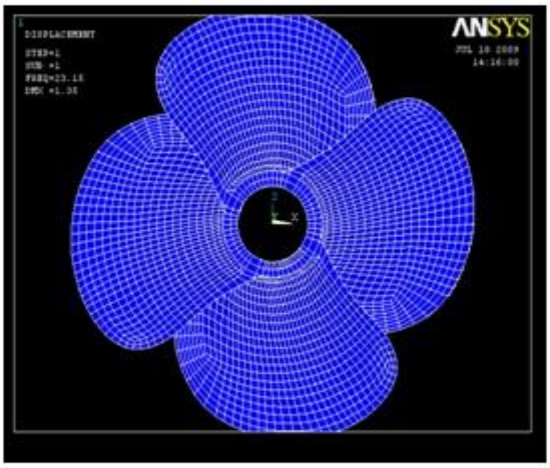


Fig9. First Mode shape for NAB

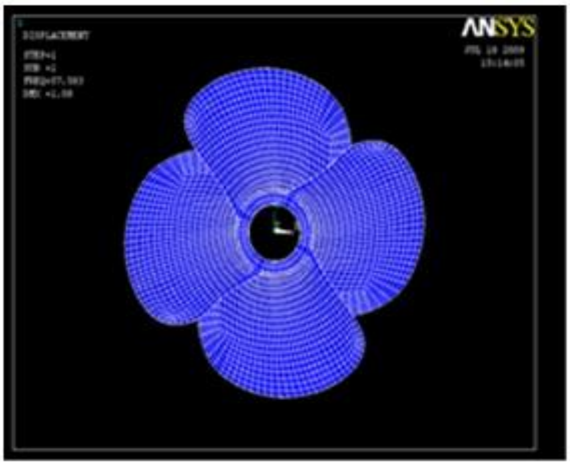


Fig10. First Mode shape for Composite

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	23.159	57.583
2.	30.119	59.270
3.	30.973	59.706
4.	31.327	59.706
5.	50.735	65.222
6.	58.530	65.788
7.	61.356	65.788
8.	63.777	67.984
9.	66.102	84.627
10.	68.805	85.755

IV. CONCLUSIONS

1. The deflection for composite propeller blade was found to be around 0.897mm for all layers which is same as than that of NAB propeller i.e. 0.597mm, 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 125.484 N/mm^2 which is greater than composite propeller i.e. 47.4618 N/mm^2.
3. Eigen value analysis results showed that the natural frequencies of composite propeller were 22 % more than Nickel Aluminum Bronze (NAB) propeller.
4. Eigen value analysis results show that the first critical speed of composite propeller is 57 Hz and next critical speed is 59 Hz.
5. Eigen value analysis results show that the first critical speed of NAB propeller is 23 Hz and next critical speed is 30 Hz

REFRENCES

[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] Chang-sup lee, yong-jik kim,gun-do kim and in-sik nho. “Case Study On The Structural Failure Of Marine Propeller Blades” Aeronautical Journal, Jan 1972, pp87-98
[4] George W.Stickle and John L Crigler., “Propeller analysis from experimental data” report No.712, pp 147-164.
[5] W.J.Colclough and J.G.Russel. “The Development Of A Composite Propeller Blade With A CFRP Spar” Aeronautical Journal, Jan 1972, pp53-57
[6] Christoph Layens, Frank Kocian , Joachim hausmann., “Materials And Design Concepts For High Performance Compressor Components”, plastics and polymers, Dec 1973, pp312-327
[7] Gau-Feng Lin “Three Dimensional Stress Analysis of a Fiber Reinforced Composite Thruster Blade”, the society of naval architects and marine engineers ,1991
[8] Jinsoo Cho and Seung-Chul Lee, “Propeller Blade Shape Optimization For Efficiency Improvement ”,Computer and Fluids, Vol.27, pp 407-419
[9] 9. Charles Dai, Stephen Hanbric, lawerence mulvihill. “A Prototype Marine Propulusur Design Tool Using Artificial Intelligence And Numerical Optimization Techniques ” ,Sname transations, Vol 102, 1994, pp 57-69.