Modal Analysis Of Composite Propeller For Ships Application

Dr.Y.SEETHARAMA RAO*, B.SRIDHAR REDDY*
*(Dept of Mechanical Engineering,G.V.P College Of Engineering,Visakhapatanam-48,Andhrapradesh,India)

ABSTRACT

Present work proposes a modal analysis to design a propeller with a metal and composite material to analyze its natural frequencies and mode shapes using ANSYS software. In order to evaluate the effectiveness of composite over metals, modal analysis is performed on both composite and metal propellers using ANSYS. Proposed method shows substantial improvements in composite propeller over the metal propeller.From the results of modal analysis composite propeller is safe against resonance phenomenon. In this paper effort is made to reduce frequency of the composite propeller so that advantage of weight reduction can be obtained. The comparison analysis of metallic and composite propeller has been made for the natural frequencies.

Keywords: Composite Propeller, Natural frequency, Modal analysis, FEA

1. INTRODUCTION:

Fibre reinforced plastic(FRP) is extensively applied in various structures because of its light weight, high strength and corrosion resistance. Bend-twist coupling effect is another unique characteristic of composite material. Structures can be stiffened or deformed in a certain direction by arranging the orientation of the fibres.

Most marine propellers are made of metal material such as bronze or steel. The advantage of replacing metal with an FRP composite is that the latter is lighter and corrosion resistant. Another important advantage is the deformation of the composite propeller can be controlled to improve its performance. Propellers always rotate at constant velocities that maximize the efficiency of the engine. When the ship sails at designed speed, the inflow angle is close to its pitch angle. When the ship sails at a lower speed, the inflow angle is smaller. Hence, the pressure on the propeller increases as the ship speed decreases.

The propeller is an important component for the safe operation of ship at sea. It is therefore important to ensure that ship propeller must have adequate strength to with stand the forces that act upon them. The forces that act on propeller blade arises from thrust, torque of the propeller and the centrifugal forces on each blade caused by its revolution around the axis. Owing to somewhat complex shape of propeller blades, the accurate calculations of the stresses resulting from these forces is extremely difficult.

The modal analysis of propeller blade with aluminum and composite propeller is carried out in the present work. The objective of this work is to compare the natural frequencies of the composite and metal propeller.

2. LITERATURE REVIEW:

The application of composite materials technology to marine architecture has increased with particular benefits of its light weight, less noise and pressure fluctuation and less fuel consumption[1].The finite element method is so popular and has been used by many researchers[2].The technology advances and the costs of composites are becoming cheaper[3].Moreover composites can offer the potential benefits of reduced corrosion and cavitation damage, improved fatigue performance, lower noise, improved material damping properties and reduced life time maintenance costs[4].Changes to the tensile and flexure properties of marine-grade glass – reinforced polyster, vinylster and resole phenolic composites after exposure to radiant heat are investigated[5].When using the Genetic Algorithm approach, some techniques for parameter setting to provide quick and correct results were discussed along with the influence of these parameters[6].The numerical results are in aggrement with experimental data and the general characteristics of the propeller flow seem to be quite well predicted[7].A strong correlation was identified between the divergence ship speed and the change in the tip pitch angle of the blades in brief communication static divergence of self twisting composite rotors. The methodology used is equally applicable to other structures such as tidal and wind turbines[8].Taylor[9] considered a propeller blade as a cantilever rigid at the boss. Chang Suplee[10] investigated the main sources of propeller blade failure and resolved the problems related to blades symmetrically. G.H.M.Beek[11] examined the interference between the stress conditions in the propeller blade and the hub. Gau Fenglin[12] carried out stress calculations for fibre reinforced composite thrust blade.

3. MODELING OF PROPELLER:

Modeling of the propeller has been done by using CATIA V5R17. In order to model the blade, it is necessary to have sections of the propeller at various radii. These sections are drawn and rotated through their respective pitch angles. Then all rotated sections are projected on to right circular cylinders of respective radii. Finally the propeller is modeled by using four noded quadrilateral shell element and is converted into a solid model.

3.1. MESH GENERATION USING HYPER MESH:

The solid model is imported to Hyper mesh 10.0 and hexahedral mesh is generated for the same. The composite propeller meshed model is shown in Fig.1.2D mesh is generated by splitting the areas and then converted into 3D mesh using the tool linear solid. The number of elements created is 27388 and number of nodes created is 52412. Now the pressures are applied on the propeller which is obtained from FLUENT 6.3. Then the meshed model is imported into the ANSYS. Solid 45 element is selected for aluminum metal and solid 46 element type is selected for composite propeller.

Table 1. Material Properties:

S_2Glass fabric/Epoxy	**Aluminium**
E_x=22.925Gpa	Young's modulus E= 70000 MPa
E_y=22.925Gpa	Poisson's ratio NUXY=0.34
E_z=12.4Gpa	Mass density =2700 kg/m^3
NUXY =0.12	Damping co-efficient =0.03
NUYZ=0.2	
NUZX=0.2	
G_{xy}=4.7Gpa	
G_{yz}=G_{zx} =4.2Gpa	
ρ =1.8gm/cc	

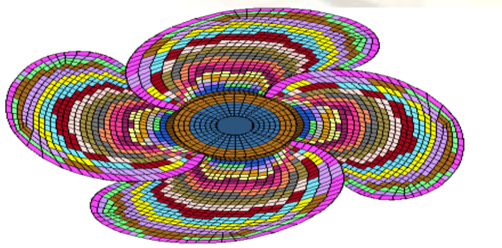

Fig.1 Composite propeller meshed model

3.2 BOUNDARY CONDITIONS AND LOADS:

The propeller is fixed in all directions at hub and shaft intersection. The pressure is applied to the propeller which is obtained from the FLUENT 6.3. The boundary conditions are shown in Fig.2

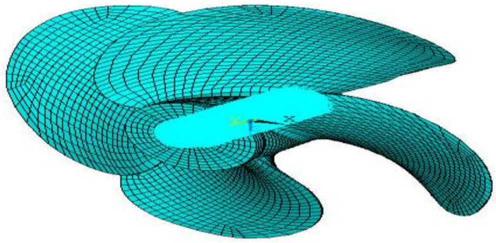

Fig.2 Propeller FE model in ANSYS boundary conditions

4. MODAL ANALYSIS:

It computes the natural frequencies and the mode shapes of a propeller. The natural frequencies are the frequencies at which a propeller will tend to vibrate when it is subjected to a disturbance.

In normal mode analysis there is no applied load and the structure has no damping properties. The equation of motion is of the form:

$$m\ddot{u}(t) + ku(t) = 0 \quad \text{----(1)}$$

where [K] and [M] are the stiffness and mass matrices representing the elastic and inertial properties of the structure respectively

Assuming a harmonic solution, the above reduces to an eigenvalue problem.

$[K-\lambda_i M]\{\phi_I\}=0$ ----(2)

Where {ϕ}is the eigenvector (or mode shape) corresponding to the eigenvalue (the natural or characteristic frequency).

5. RESULTS AND DISCUSSIONS:

Modal analysis is carried out for Aluminum propeller, and composite propeller using Block Lanczos method. This analysis does not represents the response due to any loading but yields by natural frequencies and corresponding mode shapes in the form of Eigen vectors of the propeller when there is no dissipation of energy due to damping. In short cut it is the analysis of undamped free vibration of propeller in the absence of damping and applied loads. First ten natural frequencies are obtained for Aluminum and composite propeller as shown in Table 2. The Natural frequency of Aluminum and composite propeller were shown in Fig.3.

Modal analysis results show that the first critical speed of Aluminum propeller is 1312 Hz and next critical speed is 1322 Hz and are tabled in table 2. The tenth mode shapes obtained in Modal analysis are shown in Fig.4.

Modal analysis results show that the first critical speed of composite propeller is 763.64 Hz and next critical speed is 765.03 Hz and are tabled in Table 2. The tenth mode shapes obtained in Modal analysis are shown in Fig5. The natural frequencies of Aluminum and composite propeller are compared. The natural frequencies of Aluminum materials were found 41% more. Even though the natural frequencies are reduced in composite still they are more than the operating frequency(31Hz).The weight of the composite propeller is 42% less than Aluminium propeller.

Table 2. Comparison of natural frequency of Aluminum and composite propeller

S.No	Natural frequencies of Aluminum propeller in Hz	Natural frequencies of Composite propeller in Hz
1	1312	763.64
2	1322	765.03
3	1322	765.03
4	1322.5	765.45
5	2120.3	1294.6
6	2127.3	1295.7
7	2127.3	1295.7
8	2129.1	1296.2
9	2982.8	1787.2
10	3114.6	1801.5

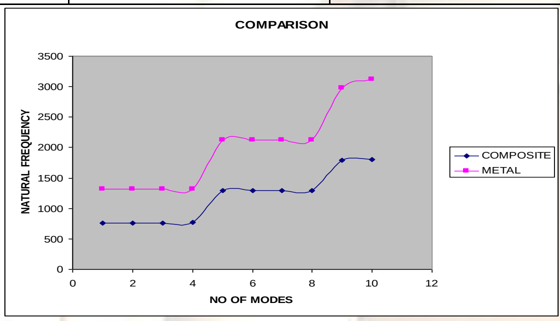

Fig.3 Natural frequency of Aluminum and composite propeller

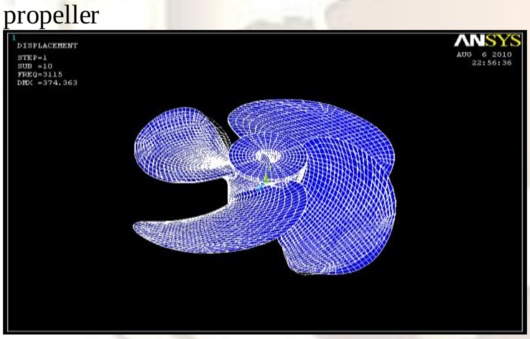

Fig.4 Tenth mode shape of Aluminium Propeller

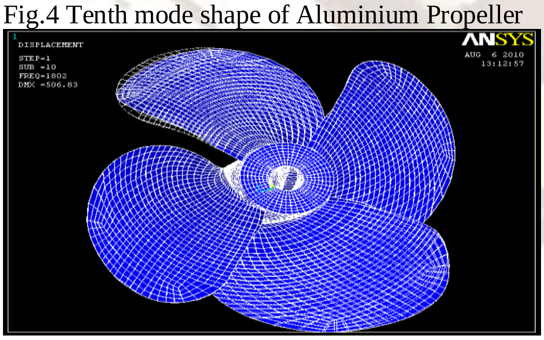

Fig.5 Tenth mode shape of Composite Propeller

6. CONCLUSIONS:

1. Modal analysis shows that the first critical speed of Aluminium propeller is 1312 Hz and next critical speed is 1322 Hz.
2. The natural frequencies of aluminium and composite propeller were compared. The natural frequencies of Aluminium propeller were found 41 % more than the composite propeller.
3. The weight of the composite propeller is 42 % less than the Aluminium propeller.
4. This study helps in predicting the operating frequency of the propeller.

REFERENCES:

[1] J.F.Tsai, H.J.L.a., Analysis of Underwater Free Vibrations of a Composite Propeller Blade. *Journal of Reinforced Plastics And Composites, 2008. Vol. 27, No. 5:* p. 447-458.

[2] H.J.Lin , W.M.L.a.Y.M.K., effect of stacking sequence om nonlinear hydroelastic behavior composite propeller *Journal of Mechanics, 2010. Vol. 26, No. 3:* p. 293-298.

[3] Toshio Yamatogi, H.M., Kiyoshi Uzawa,Kazuro Kageya, Study on Cavitation Erosion of Composite Materials for Marine Propeller. 2010.

[4] Young, Y.L., Fluid–structure interaction analysis of flexible composite marine propellers. *Journal of Fluids and Structures, 2008. 24(6):* p.799-818.

[5] A.P. Mouritz, Z.M, Post fibre mechanical properties of marine polymer composites, *Elseveir science Ltd,2000,47*:p.643-653.

[6] Chang j.h, Y.S. Shih, Basic design of series propeller with vibration consideration by genetic algorithm, *Journal of Marine Science and Technology,2007.12(3),*119-129.

[7] Amoraripei M, Prediction of marine propeller performance using RANS, Numerical analysis and Applied Mathematics, *International Conference,2008,*771-774.

[8] Liu Z,Y L Young, Static divergence of self twisting composite rotors, *journal of fluids and structures, 2010,26(5),*841-847.

[9] Taylor,D.W, "The speed and power of ships", Washington,1933.

[10] 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

[11] G.H.M.Beek, visitor, Lips B.V., Drunen. "Hub-Blade Interaction In Propeller Strength*", the society of naval architects and marine engineers, May 24-25, 1978,* pp 19-1-19-14.

[12] Gau-Feng Lin "Three Dimensional Stress Analysis of a Fiber Reinforced Composite Thruster Blade", *the society of naval architects and marine engineers ,1991*.