ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Dynamic Analysis on Composite Propeller of Ship Using FEA

Ahmed Abdul Baseer
Assistant Professor,
Nizam Institute of Engineering and Technology.

ABSTRACT:

Ships and underwater vehicles like submarine and torpedoes use propeller for propulsion. In general, propellers are used as propulsions and they are also used to develop significant thrust to propel the vehicle at its operational speed and 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 stealth point of view. In current years the increased need for light weight structural element with acoustic insulation has led to use of fiber reinforced multi layered composite propeller. The present work is to carry out the dynamic analysis of aluminum, composite propeller which is a combination of GFRP (Glass Fiber Plastics) materials. The present thesis deals with modeling and analyzing the propeller blade of a under water 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. Tetrahedral mesh is generated for the model using HYPER MESH. Static, Eigen and frequency responses analysis of both aluminum and composite propeller are carried out in ANSYS. Interlaminar shear stresses are calculated for composite obtained are well within the limit of elastic property of the materials. The results were compeered with Tsai-Wu failure theory and found they were within the safe limits.

KEYWORDS:

Composite Propeller,Fea, Stress Analysis.

1. INTRODUCTION:

Ships and under water vehicles like submarines, torpedoes and submersibles etc., uses propeller as propulsion. The blade geometry ant its design is more bcomplex involving many controlling parameters. The strength analysis of such complex 3D blades with conventional formulas will give less accurate values. In cases numerical analysis (Finite Element Analysis) gives comparable results with experimental values. In the present project the propeller blade material is converted from aluminum metal to fiber reinforced composite material for underwater vehicle propeller. Such complex analysis can be easily solved by finite element method techniques. The present thesis 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. Tetrahedral mesh is generated for the model using HYPER MESH. Static and composite propellers 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. The results were compeered with Tsai-Wu failure theory and found they were within the safe limits. The propeller is a vital component for the safe operation of ship at sea. It is therefore important to ensure that ship propeller have adequate strength to with stand the forces that act upon them. Fiber reinforced plastic composite have high strength to weight and these materials have better corrosion resistance, lower maintenance, non-magnetic property and it also have stealth property for naval vessels.

The forces that act on a propeller blade arise from thrust and torque of the propeller and the centrifugal force on each blade caused by its revolution around the axis. Owing to somewhat complex shape of propeller blades, the accurate calculation of the stresses resulting from these forces is extremely difficult. The stress analysis of propeller blade The calculation of the stresses in a propeller is extremely complicated owing to a number of reasons: the loading fluctuates, its distribution over the propeller blade surface is difficult to calculate, and the geometry of the propeller is rather complex. It is therefore usual to use simplified methods to calculate the stresses in the propeller blades and to adopt a large factor of safety based on experience. The simple method described here is based on the Following principal assumptions:

• The propeller blade is assumed to be a cantilever fixed to the boss at the root. The critical radius is just outside the root fillets.

• the propeller thrust and torque, which arise from the hydrodynamic pressure distribution Over the propeller blade surface, are replaced by single forces each acting at a point on the propeller blade.

• The centrifugal force on the propeller blade is assumed to act through the centroid of theblade, and the moment of the centrifugal force on the critical section can be obtained by multiplying the centrifugal force by the distance of the centroid of the critical section from theline of action of the centrifugal force.

• The geometrical properties of the radial section (expanded) at the critical radius may be used instead of a plane section of the propeller blade at that radius, and the neutral axes may be taken parallel and perpendicular to the base line of the expended section. Let the propeller have Z blades, and be turning at a revolution rate n when developing a thrust T with a torque Q. J.P.Ghouse [11] suggested the following formulas.

2 ANALYTICAL METHODS TO FIND OUT STRESSES IN A BLADE SECTION:

The calculation of the stresses in a propeller is extremely ncomplicated owing to a number of reasons: the loading fluctuates, its distribution over the propeller blade surface is difficult to calculate, and the geometry of the propelleris rather complex. It is therefore usual to use simplified methods to calculate the stresses in the propeller blades and to adopt a large factor of safety based on experience. The simple method described here is based on the following principal assumptions:

• the propeller blade is assumed to be a cantilever fixed to the boss at the root. The critical radius is just outside the root fillets.

• The propeller thrust and torque, which arise from the hydrodynamic pressure distributionover the propeller blade surface, are replaced by single forces each acting at a point on the Propeller blade.

• The centrifugal force on the propeller blade is assumed to act through the centroid of the blade, and the moment of the centrifugal force on the critical section can be obtained by multiplying the centrifugal force by the distance of the centroid of the critical section from the line of action of the centrifugal force.

• The geometrical properties of the radial section (expanded) at the critical radius may be used instead of a plane section of the propeller blade at that radius, and the neutral axes may be taken parallel and perpendicular to the base line of the expended section.Let the propeller have Z blades, and be turning at a revolution rate n when developing a thrust T with a torque Q. J.P.Ghouse

3. FINITE ELEMENT ANALYSIS OF METALLIC AND COMPOSITE PROPELLER:

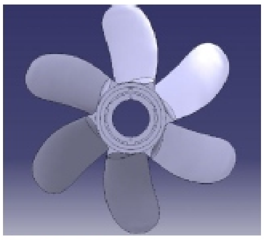
With the rapid advancement of technology, the complexity of the problem to be dealt by a design engineer is also increasing. This scenario demand speedy, efficient and optimal design from an engineer. To keep pace with the development and ensure better output, the engineer to day resorting to numerical methods. For problems involving complex shapes, material properties and Complicated boundary conditions, it is difficult and in many cases intractable to obtain analytical solutions.

Numerical methods provide approximate but acceptable solutions to such problems. Finite element analysis is one of such numerical procedure for analyzing and solving wide range of complex engineering problems (may be structural, heat conduction, flow field...) which are complicated to be solved satisfactorily by any of the available classical analytical
Methods. In the present problem, element type solid 46 is used for composite propeller and solid 45 is used for aluminum propeller.

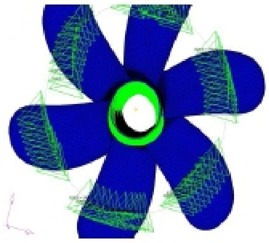
3.1 finite element modeling of the propeller:

Modeling of the propeller is done using CATIA V5 R19. 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 as shown in figure below. Now by using multi section surface option, the blade is modeled.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal



3.1.1 Solid model



3.2 MESH GENARATION USING HYPERMESH:

The solid model is imported to HYPERMESH 7.0 and tetrahedron mesh is generated for the same. Boundary conditions are applied to meshed model. The contact surface between hub and shaft is fixed in all degrees of freedom. Thrust of 4000 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 region on each blade. The loading condition is as shown in fig 4.7.Nummber of nodes created
Power=50 Kw velocity=12.5 m/s
Thrust = power/velocity
=50000/12.5
=4000 N

3.2.1 Loading on meshed model

Exporting Mesh to the Ansys 11.0 First delete all the surfaces and 2d elements before Exporting to the ANSYS so that only 3D elements are\ exported. Now select the user profile in the preferences then go to utility menu and mention the ET type as solid45 if it is aluminum or solid 46 for composite material, specify material properties and real constants if necessary. Then go to 3D option and mention the ET type and element types. Update all the components in the component option and at lat renumber all the components. Now go to export the FE model to the ANSYS. Boundary conditions are applied to meshed model. The contact surface between hub and shaft is fixed in all degrees of freedom. Thrust of 4000 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 region on each blade. The loading condition is as shown in fig 4.7.Nummber of nodes created were 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

3.2.1 loading on meshed model

Exporting Mesh to the Ansys 11.0 First delete all the surfaces and 2d elements before exporting to the ANSYS so that only 3D elements are exported. Now select the user profile in the preferences then go to utility menu and mention the ET type as solid45 if it is aluminums or solid 46 for composite material, specify material properties and real constants if necessary. Then go to 3D option and mention the ET type and element types. Update all the components in the component option and at lat renumber all the components. Now go to export the FE model to the ANSYS.

Material properties of propeller

Aluminum properties Young's modulus E=70000 MPa
Poisson ration NUXY=0.34
Mass density = 2700 kg/m3
Damping co-efficient = 0.03

Mat no 1: S.Glass fabric/ Epoxy		Mat no 2: carbon UD/Epoxy	
E_x	= 22.925	E_x	= 120 Gpa
Gpa		E_y	= 10 Gpa
E_y	= 22.925	E_z	= 10 Gpa
Gpa		NUXY	= 0.16
E_z	= 12.4 Gpa	NUYZ	= 0.2
NUXY	= 0.12	NUZX	= 0.16
NUYZ	= 0.2	G_{xy}	= 5.2 Gpa
NUZX	= 0.2	G_{yz}	= 3.8 Gpa
G_{xy}	= 4.7 Gpa	G_{zx}	= 6Gpa
$G_{yz} = G_{zx}$	= 4.2 Gpa	P	= 1.6gm/cc
P	= 1.8gm/cc		

4 RESULS AND DISSCUSSIONS

4.1 Linear static analysis:

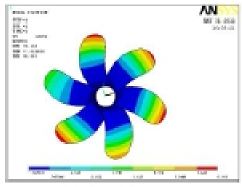
Linear static analysis is concerned with the behavior of elastic continua under prescribed boundary conditions and statically applied loads. The applied load in this case is thrust acting on blades. Under water vehicle with contra rotating (aft) propeller is chosen for FE analysis.

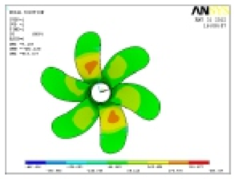
The FE analysis is carried out using ANSYS. The deformations and stresses are calculated for aluminum (isotropic) and composite propeller (orthotropic material). In composite propeller 4 cases are considered, those are number of layers is varied as 4, 8, 12, 16. For propeller blade analysis
3D solid element type 92 is considered for aluminum and solid 46 for composite propeller.

4.1.1 Static analysis of aluminum propeller:

The thrust of 4000N 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 6.883mm in y-direction. Similar to the cantilever beam the deflection is maximum at free end. Maximum principal stress value for the aluminum propeller are shown in figure 6.2
The Von misesstress on the basis of shear distortion energy theory also calculated in the present analysis. The maximum vonmises stress induced for aluminum blade is 525.918N/mm2 asshown in figure 6.3.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. 4.1.2 Static analysis of aluminum propeller

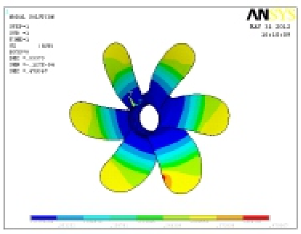
Result	Aluminum propeller
Deflection in mm	6.883
Max. normal stress N/mm^2	485.337
Von mises N/mm^2	525.918
1st principal stress N/mm^2	518.775
2nd principal stress N/mm^2	206.945

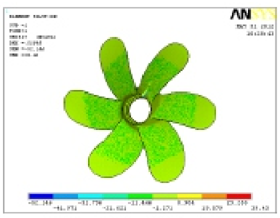

max deflection of aluminum propeller


Max normal stress of aluminum propeller

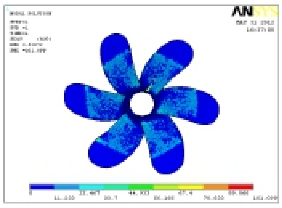
Static analysis of composite propeller:

Four cases are considered for static analysis of composite propeller by varying the number of layers to check the bonding strength. Interlaminar shear stresses are calculated for all cases.
Case 1: 4 Layers
Case2: 8 layers
Case 3: 12 layers
Case 4: 16 layers.
Case1: Analysis results of 4 layers
Maximum deflection for composite propeller with 4 layers was found to be 0.47939mm Z-direction i.e perpendicular to fibers of the blade as shown in figure 6.4. The maximum normal stress was found to be 77.555 N/mm2 as shown in figure 6.5.The maximum von mises stress was found to be 97.038 N/mm2 as shown in figure 6.6. The maximum interlaminar shear stress was found to be 51.327 N/mm2 as shown in figure 6.7 at top of 4th layer.


Max. deflection of composite propeller with 4 layers.


max. Interlaminar shear stress of composite propeller with 8 layers

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal



max.von mises stress of composite propeller with 12 layers

Static analysis results of composite propeller

No. of layers	Max deflection in mm	Max. normal stress, N/mm^2	von mises stress, N/mm^2	Interlaminar shear stress, N/mm^2
4	0.479367	77.555	97.038	51.327
8	0.47721	77.611	99.276	52.146
12	0.4846	78.784	101.099	52.744
16	0.488923	79.511	101.876	53.01

The variation of deflection, stress for different layers was not found to be of much difference. The maximum variation of interlaminar shear stresses was found to 3.1748%.

CONCLUSIONS AND FUTURE SCOPE OF WORK:

The following conclusions are drawn from the present work:

1. The deflection for composite propeller blade was found to be around 0.5mm for all layers which is much less than that of aluminum propeller i.e 6.883mm, which shows composite materials is much stiffer than aluminum propeller..

2. Interlaminar shear stresses were calculated for composite propeller by incorporating different number of layers viz. 4,8,12,16 and was found that the percentage variation was about 3.147%,which shows that there is strong bonding between the layers and there's no peel-off.

3. Eigen value analysis results showed that the natural frequencies of composite propeller were 80.5% more than aluminum propeller, which indicates that the operation range of frequency is higher for composite propeller.

4. Harmonic analysis results for aluminum propeller shows that the resonance occurs in the frequency range of 400 Hz in Ux, Uy, Uz directions, so the propeller may be operated in frequency range other than 400Hz.

5. Harmonic analysis results for composite propeller shows that the resonance occurs in the frequency range of 2000- 2500Hz in Ux, 2500-3000 Uy, around 2000Hz in Uz directions, so the propeller may be operated in frequency range other than 2000-3000Hz.

Future scope of work:

1. The present work only consists of static,Eigen value 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. For present purpose only modeling and analysis of a propeller blade is carried only for GFRP and CFRP materials.

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 insik 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.

7. George W.Stickle and John L Crigler. "Propeller analysis from experimental data" report No.712, pp 147-164.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

8. P.Castellini, C.Santolini. “Vibration Measurements On Blades Of A Naval Propeller Rotating In Water With Tracking Laser Vibromneter ”Dept. of mechanics, university of Ancona, pp43-54.

9. W.J.Colclough and J.G.Russel. “The Development Of A Composite Propeller Blade With A CFRP Spar” aeronautical journal, Jan 1972, pp53-57.

10. J.G.Russel “use of reinforced plastics in a composite propeller blade” plastics and polymers, Dec 1973 pp292-296.

11. Ching-Chieh Lin, Ya-jung Lee. “Stacking Sequence Optimization Of Laminated Composite Structures Using Genetic Algorithm.

Author Profile :

Ahmed Abdul Baseer completed his post graduation and currently working as Asst. Professor in Civil Dept at Nizam Institute of Engineering and Technology Deshmukhi pochampally (mandal). near Ramoji film city. Nalgonda – 508284.