DESIGN AND ANALYSIS OF SHIP PROPELLER USING FEA

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***ABSTRACT-* This project deals with the application to a propeller, which is the basic and the most important element for propelling the ships, submarines, etc. Propellers also used to develop significant thrust to propel the vehicle at its operational speed. The blade geometry and design are more complex involving many controlling parameters. The present work deals with modeling and analyzing the aluminium propeller blade of an underwater vehicle for its strength. A propeller is a complex geometry which requires high end modeling software. The solid model of propeller is developed in CATIA-V5 R20 and a tetrahedral mesh is generated for this model using HYPER MESH and static analysis is carried out using ANSYS.**

1. INTRODUCTION

The propeller, whose name comes from the Latin ‘‘propellare” (to drive forward) is a very old idea. An efficient screw propeller was produced at the beginning of the 19th century, as a suitable power source for the steam engine. The propeller converts the engine’s output by rotation into thrust which balances the resistance against driving forward at that particular throttle speed. Usually the engine’s revolutions are too high to directly drive the propeller and therefore the engine’s r.p.m. must be reduced by a reverse gear with a reduction. A propeller is the most common propulsor on ships, imparting momentum to a fluid which causes a force to act on the ship. A ship propels on the basis of Bernoulli’s principle and Newton’s third law. A pressure difference is created on the forward and aft side of the blade and water is accelerated behind the blades.

The thrust from the propeller is transmitted to move the ship through a transmission system which consists of a rotational motion generated by the main engine crank shaft, intermediate shaft and its bearings, stern tube shaft and its bearing and finally by the propeller itself. The propeller is an important part of the propulsion plant. The propeller must be carefully designed in conjunction with each specific vessel in order to obtain not only a high efficiency but also a high level of comfort.

The propeller design usually starts with determining the main particulars (diameter, mean pitch, blade area). The propeller is determined by the number of blades, its diameter and its pitch (definitions shown in the above drawings), and the direction of rotation (left or right). The 3-blade propeller is most often used, but the same definitions are valid for the 2-blade, 4-blade and multi-blade propellers. Typically the propeller size is shown as D x P, where P stands for pitch, D: Propeller diameter, Pitch: Distance the propeller travels in a single turn.

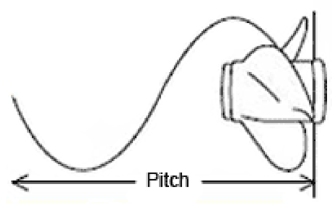

Fig 1. Pitch of the Propeller

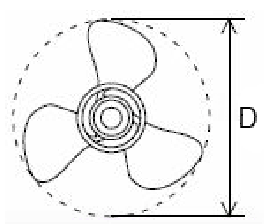

Fig 2. Diameter of the Propeller

The shape of the propeller blades greatly influences its performance.

2. LITERATURE REVIEW

D. W. Taylor [1] studied the speed and power of ships for the designing parameters of the propeller like Pitch, Diameter, No of blades etc.

Ab Volvo Penta [2] carried down the propellers from inboard propellers and theory for introduction like History and designing of propeller.

The details of propeller are covered from https://en.wikipedia.org/wiki/File:Ship-propeller[3], https://you Boat. net.[4]

The material and its properties used for propeller are covered from S.Solomon Raj, Dr.P.Ravinder Reddy, Design of hybrid composite marine propeller for improved cavitation performance,[5]Er.N. Balasubramanyam,Design and analysis of a composite propeller[6].

The design and analysis are carried out by the reference ofAnsys 11.0 User Guide[7], Mohammed Ahmed khan, KhajaShahnawazuddin, Design and Dynamic analysis on composite propeller of ship using FEA[8].

3. OVERALL VIEW OF PROPELLER

3.1 PROPELLER TYPES

Depending on the type of application different propellers are to be used

(1) Nozzle propeller
(2) Voith Schneider Propeller
(3) Contra rotating Propeller
(4) Super cavitating Propeller
(5) Jet propeller

3.2 PROPELLER AND ITS MATERIAL For underwater vehicles the main criteria in selection of the material depends on its strength, stiffness, weight, thermal expansion and corrosion resistant to seawater. The material used for the manufacturing of propeller depends upon the strength, ease of manufacturing, production methods, environment, weight etc,. The material used for propellers must be light, strong and ductile, easy to cast and machine, and resistant to erosion and corrosion.

Table 1.Chemical composition of Aluminium.

Metal	Chemical composition: (in %)
Copper	0.1
Magnesium	0.2 to 0.65
Silicon	6.5 to 7.5
Iron	0.5 max
Manganese	0.3 max
Nickel	0.1 max
Zinc	0.1 max
Lead	0.1 max
Tin	0.05 max
Titanium	0.2 max
Aluminum	90.4 (approx.)

Table 2.Mechanical Properties of Aluminium.

Casting Condition	Chill Cast
Proof stress	230 N/mm^2
Tensile strength	280 N/mm^2
Young’s modulus	7.00 x $10^4 N/mm^2$
Rigidity modulus	2.71 x $104 N/mm^2$
Poisson’s ratio	0.29
Density	2.7 g / cc
%Elongation	2
Hardness	105 BHN
Melting point	650° C

The Ship propellers also manufactured by using commercially available materials like gray cast iron, carbon and low-alloy steels, chromium stainless steels, chromium-nickel stainless steel, manganese bronze, nickel- manganese bronze, nickel-aluminum bronze, Naval brass etc. Nickel-Aluminium Bronze (NAB) is widely used in marine applications because of its high toughness and erosion-corrosion resistance.

4. MODELING OF PROPELLER

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 withstand the forces that act upon them. 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 with aluminium is carried out in the present work.

The calculation of the stresses in a propeller is complicated due to:

1. The loading fluctuationos,
2. Its distribution over the propeller blade surface
3. The complex geometry of the propeller.

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 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.

4.1 MODELING IN CATIA

Modeling of the propeller is done using CATIA V5 R 20. 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 onto right circular cylinders of respective radii as shown in figure below. Now by using multi section surface option, the blade is modeled.

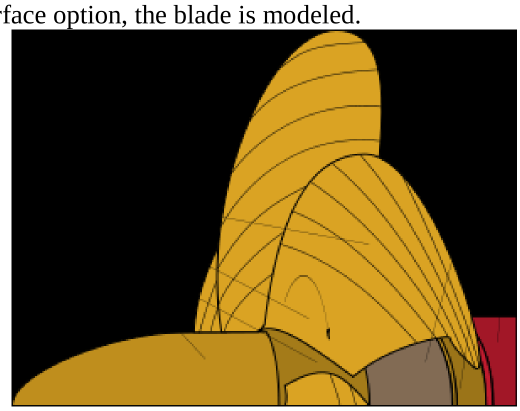

Fig 3: Modeling of propeller

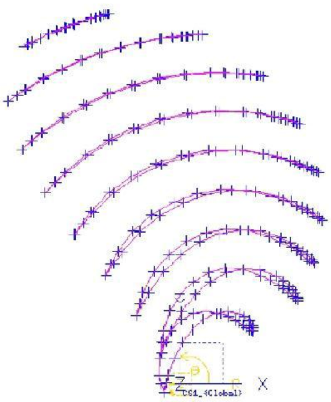

Fig 4: Construction of hydrofoils by joining of points on surface of the blade.

Now by using multi section surface option, the blade is modeled.

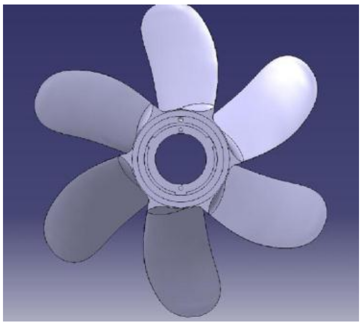

Fig 5. Final view

4.2 MESH GENARATION USING HYPERMESH

The solid model is imported to HYPERMESH 7.0and tetrahedron mesh is generated for the same.

5. FINITE ELEMENT ANALYSIS (FEA) OF METALLIC PROPELLER

5.1 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. Update all the components in the component option and at last renumber all the components. Now go to export the FEA 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.Nummber of nodes created were and number of elements created are 165 and 238.

Power=50 KW
Velocity=12.5 m/s
Thrust = power/velocity
=50000/12.5=4000 N

Material properties of propeller (Aluminium)

Young's modulus E=70000 MPa
Poisson ratio = 0.34
Mass density = 2700 kg/m^3
Damping co-efficient = 0.03

5.2 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 fig 6. The maximum deflection is 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 fig 7 .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 525.918N/mm^2 as shown in fig 8.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.

Table 3.Results from Ansys.

Result	Aluminum propeller
Deflection in mm	6.88
Max. normal stress N/mm^2	485.33
Von misses N/mm^2	525.91
1st principal stress N/mm^2	518.77
2nd principal stress N/mm^2	206.94

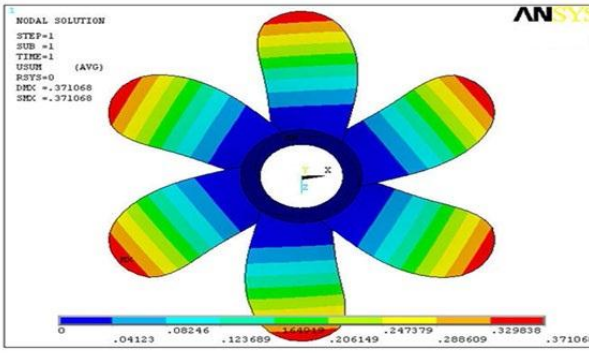

Fig 6.Max deflection of Al propeller

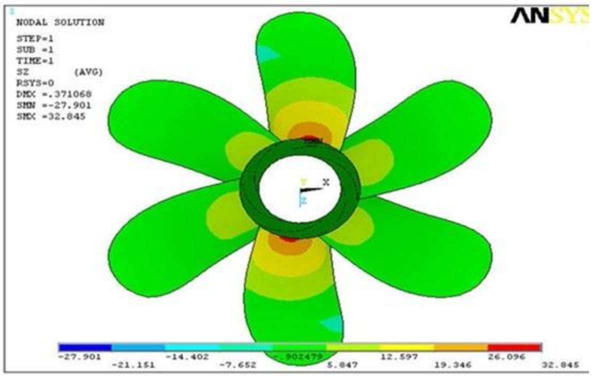

Fig 7.Max. Normal stress of Al propeller

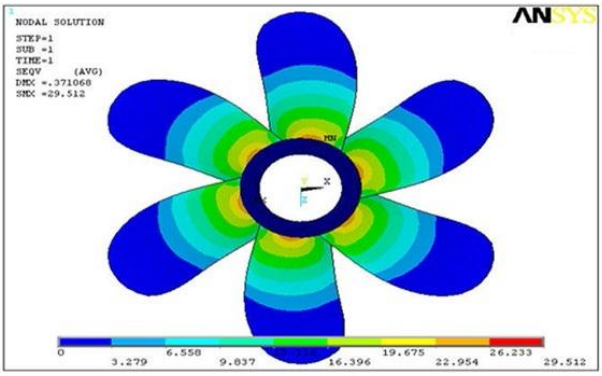

Fig 8.Max. Von misses stress of Al propeller

CONCLUSION

The propeller is an important part of the propulsion plant. The propeller must be carefully designed in conjunction with each specific vessel in order to obtain not only a high efficiency but also a high level of comfort. Metallic propellers can be replaced by composite propellers for enhanced performance with regard to the operating range. Composites will give flexibility with regard to design of structures because of the various couplings exhibited by them. The operating range of composite propeller is increased from cavitation inception point of view without compromising the performance. Further, experiments can be done to validate the numerical results obtained for better reliability.

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