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MODELING AND SIMULATION OF MARINE PROPELLER

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ABSTRACT

Composites materials are finding wide spread use in naval applications in recent times. Ships and under water vehicles like torpedoes Submarines etc. Torpedoes which are designed for moderate and deeper depths require minimization of structural weight for increasing payload, performance/speed and operating range for that purpose Aluminium alloy casting is used for the fabrication of propeller blades. In current years the increased need for the light weight structural element with acoustic insulation, has led to use of fiber reinforced multi-layer composite propeller. The present work carries out the structural analysis of a CFRP (carbon fiber reinforced plastic) , (Graphite fiber reinforced plastic), Nibral propeller blade which proposed to replace the Aluminium 6061 propeller blade. Propeller is subjected to an external hydrostatic pressure on either side of the blades depending on the operating depth and flow around the propeller also result in differential hydrodynamic pressure between face and back surfaces of blades. The propeller blade is modelled and designed such that it can with stand the static load distribution and finding the stresses and deformation, strain, for different materials aluminium, Nibral and Graphite fiber reinforced plastic ,carbon fiber reinforced plastic materials. This work basically deals with the modeling and design analysis of the propeller blade of a torpedo for its strength. A propeller is complex 3D model geometry. This requires high end modeling CATIA software is used for generating the blade model. This report consists of brief details about Fiber Reinforced Plastic materials and the advantages of using composite propeller over the conventional metallic propeller. By using ANSYS software static ,modal analysis were carried out for four different materials.

1. INTRODUCTION

1.1introduction

A propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. Propeller dynamics, like those of aircraft wings, can be modelled by either or both Bernoulli's principle and Newton's third law. A marine propeller of this type is sometimes colloquially known as a screw propeller or screw, however there is a different class of propellers known as cycloidal propellers – they are characterized by the higher propulsive efficiency averaging 0.72 compared to the screw propeller's average of 0.6 and the ability to throw thrust in any direction at any time. Their disadvantages are higher mechanical complexity and higher cost

Marine propeller is a component which forms the principal part of ships since it gives the required propulsion. Metal matrix composite material is extensively used in the manufacturing of various structures including the marine propeller. The hydrodynamic aspects of the design of composite marine propellers have attracted attention because they are important in predicting the deflection and performance of the propeller blade. For designing an optimized marine propeller one has to understand the parameters that influence the hydro-dynamic behaviour. Since propeller is a complex geometry, the analysis could be done only with the help of numerical tools. Most marine propellers are made of metal material such as bronze or steel. The advantages of replacing metal with an composite are that the latter is lighter and corrosion resistant. Another important advantage is that the deformation of the composite propeller can be controlled to improve its performance. Propellers always rotate at a constant velocity that maximizes the efficiency of the engine. When the ship sails at the 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 propulsion efficiency is also low when the inflow angle is far from the pitch angle. If the pitch angle can be reduced when the inflow angle is low, then the efficiency of the propeller can be improved.

Figure 1 Submarine propeller

Traditionally marine propellers are made of manganese-nickel-aluminum-bronze (MAB) or nickel-aluminium-bronze (NAB) for superior corrosion resistance, high-yield strength, reliability, and affordability. More over metallic propellers are subjected to corrosion, cavitations damage; fatigue induced cracking and has relatively poor acoustic damping properties that can lead to noise due to structural vibration. Moreover, composites can offer the potential benefits of reduced corrosion and cavitation's damage, improved fatigue performance, lower noise, improved material damping properties, and reduced lifetime maintenance cost. In addition the load-bearing fibers can be aligned and stacked to reduce fluttering and to improve the hydrodynamic efficiency.

2. TYPES OF MARINE PROPELLERS

- Controllable pitch propeller
- Skewback propeller
- Modular propeller

Controllable pitch propeller: A controllable pitch propeller one type of marine propeller is the controllable pitch propeller. This propeller has several

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advantages with ships. These advantages include: the least drag depending on the speed used, the ability to move the sea vessel backwards, and the ability to use the "vane"-stance, which gives the least water resistance when not using the propeller (e.g. when the sails are used instead).

Skewback propeller :

An advanced type of propeller used on German Type 212 submarines is called a skewback propeller. As in the scimitar blades used on some aircraft, the blade tips of a skewback propeller are swept back against the direction of rotation. In addition, the blades are tilted rearward along the longitudinal axis, giving the propeller an overall cup-shaped appearance. This design preserves thrust efficiency while reducing cavitation's, and thus makes for a quiet, stealthy design.

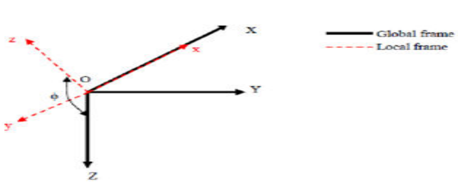
Modular propeller

A modular propeller provides more control over the boats performance. There is no need to change an entire prop, when there is an opportunity to only change the pitch or the damaged blades. Being able to adjust pitch will allow for boaters to have better performance while in different altitudes, water sports, and/or cruising.

3. PROPELLER GEOMETRY

Frames of Reference:

For propeller geometry it is convenient to define a local reference frame having a Common axis such that OX and Ox are coincident but Oy and Oz rotate relative to the OY and OZ fixed global frame.



The line normal to the shaft axis is called either propeller reference line or directory. In the case of controllable pitch propeller the spindle axis is used as synonymous with the reference line.

Generator line: The line formed by intersection of the pitch helices and the plane containing the shaft axis and propeller reference line.

The airfoil sections which together comprise the blade of a propeller are defined on the surfaces of cylinders whose axes are concentric with the shaft axis.

Face: The side of a propeller blade which faces downstream during a head motion is called face or pressure side (when viewed from aft of a ship to the

bow the seen side of a propeller blade is called face or pressure side).

Back: The side of a propeller blade which faces generally direction of a head motion is called back or suction side (when viewed from aft of a ship to the bow the unseen side of a propeller blade is called back or suction side).

Leading Edge: When the propeller rotating the edge piercing water is called leading edge.

Trailing Edge: When the propeller rotating the edge trailing the leading edge is called trailing edge.

Pitch

Consider a point P lying on the surface of a cylinder of radius r which is at some initial point P0 and moves as to from a helix over the surface of a cylinder.

The propeller moves forward as to rotate and this movement create a helix.

When the point P has completed one revolution of helix that means the angle of rotation: φ = 360o *or* 2π the cylinder intersects the X-Z plane and moves forward at a distance of P.

In the projection one revolution of the helix around the cylinder measured normal to the OX axis is equal to 2πr.

The distance moved forward by the helical line during this revolution is p and the helix angle is given by: θ

The angle θ is termed the pitch angle and the distance p is the pitch.

There are several pitch definitions.

Nose-tail pitch: The straight line connecting the extremities of the mean line or nose and tail of a propeller blade is called nose-tail pitch line. The section angles of attack are defined to the nose-tail line.

Face pitch: The face pitch line is basically a tangent to section's pressure side surface and you can draw so many lines to the pressure side. It is rarely used but it can be seen in older drawings like Wageningen B series.

Effective or no-lift pitch:

It is the pitch line of the section corresponding to aerodynamic no-lift line which results zero lift.

Hydrodynamic pitch:

The hydrodynamic pitch angle (βi) is the pitch angle at which the incident flow encounters the blade section. Effective pitch angle (θ0) = Noise-tail pitch angle (θ, θnt) + 3-D zero-lift angle where 3-D zero lift angle is the difference between θ0 and θ.

θ0 = Hydrodynamic pitch angle (βi) + Angle of attack of section (α) + 3-D zero lift angle and Pitch values at different radii are called radial pitch distribution.

Slip Ratio

If the propeller works in a solid medium (has no slip), i.e. if the water which the propeller "screws" itself through does not yield (i.e. if the water did not accelerate aft), the propeller will move forward at a speed of $V = p \times n$, where n is the propeller's rate of revolution, as seen in the below figure. The similar situation is shown for a corkscrew, and because the cork is a solid material, the slip is zero and, therefore, the cork screw always moves forward at a speed of $V = p \times n$. However, as the water is a fluid and does yield (i.e. accelerate aft), the propeller's apparent speed forward decreases with its slip and becomes equal to the ship's speed *V*, and its apparent slip can thus be expressed as $p \times n - V$.

Skew

It is the angle between the mid-chord position of a section and the directrix (θs).

The propeller skew angle (θsp) is defined as the greatest angle measured at the shaft centre line which can be drawn between lines passing from the shaft center line through the mid chord position of any two sections.

The skew can be classified into two types:

Balanced skew: Directory intersects with the mid-chord line at least twice.

Biased skew: Mid-chord locus crosses the directrix not more than once normally in the inner sections.

Rake

The displacement from the propeller plane to the generator line in the direction of the shaft axis is called rake. The propeller rake is divided into two components: generator line rake (iG) and skew induced rake (is) which are defined as

Propeller Outlines and Areas

There are five different outlines and associated areas of propeller in use these are:

Disc outline (area) (A0)
Projected outline (Ap)
Developed outline (AD)
Expanded outline (AE)
Swept outline (AS)

Disc area: The area of the circle swept out by the tips of the blades of a propeller diameter.

Projected outline: It is the view of the propeller blade that is actually seen when the propeller is viewed along the shaft centerline normal to y-z plane where Z is the number of blades. rh is the hub radius of the propeller.

R is the tip radius of the propeller.

Developed outline: It is a helically based view, but the pitch of each section has been reduced to zero. The intersection of the blade with the axial cylinder is rotated along the blade reference line into a plane parallel to the propeller. The amount of rotation is equal to the pitch angle at every radius.

 V. Ganesh, K. Pradeep, K. Sreeninivasulu [2014] [1] reported on the two distinguished materials for its strength. Aluminum and CFRP are considered for model and static analysis. The high end software for modeling was chosen CATIA and for analyzing ANSYS software was used. The results are compared with the experimental values. By the results the CFRP gives the best one.

 RaminTaheri, Karim Mazaheri [2013] [2] to optimize the shape and efficiency of two propellers. The design methods based on Vortex Lattice algorithm is developed and two gradients based and non-gradient based optimization algorithms are implemented. By implementing a computer code, vortex lattice method was used. From the analysis , approximately 13% improvement in efficiency and approximately 15% reduce in torque coefficient for first propeller and approximate 10% improved for efficiency of the next propeller can be possible.

 N. Balasubramanyam [2015] [3] carried out ANSYS test on both Aluminum and composite propeller. The composite propeller is GFRP. Static and Dynamic analysis are carried out on both the materials. For solid modeling and meshing CATIA-V5 R17 software is used and for analysis ANSYS is used. The results are compared with the Tsai-Wu failure theory and concluded that they are within the safe limits.

 Aditya Kolakoti, T.V. Bhanupraksh, H.N. Das [2013] [4] analyzed on a controllable pitch propeller using CFD. For hydrodynamic designs CFD becomes more encouraged software. For modeling and meshing CATIA – V5 is used. The flow analyses are carried out in three stages. (1) CFD analysis of bare hull (2) open water analysis (3) flow characteristics of propeller when fixed back of the ship hull. Experimental values and CFD results are compared and got approximate variation in results.

Terge sont vcdt et al [3] has focused on the application of finite element methods for frequency response and improve to the frozen type of hydrodynamic loading The thin shell element of the triangular type and the super parametric shell element are used in the finite element model it presents the realistic an dynamic stresses in marine propeller blades. Stresses and deformations calculated for ordinary geometry and highly skewed propellers are compared with experimental results. Chang suppler et al [4] have investigated the main sources of propeller blade failures and resolved problem systematically. An FEM analysis is carried out to determine the blade strength in model and full-scale condition and range of safety factor for the propeller under study is determined. S.javed jalali and farid Taheri et al [5] Carbon fiber reinforced plastics properties were taken from journal of composite materials. A new test method for the simultaneous evaluation of the longitudinal and the shear module of CFRP was introduced under the proposed method, specimens with different span to depth ratios are subjected to three point bending method. Therefore, we name the method the varying span method. The method builds on the inherent low shear modulus characteristics of CFRP. This characteristics leads to a flexural modules which is a function of L/H. Charles A. Harper et al [6] Aluminum material property taken from the hand book of material and process. The non-ferrous metals and alloys offer a wide variety of physical and mechanical properties for using the many industries. Aluminum and its alloys posse's properties which find wide use in the many industries. Favorable physical properties good strengthweight properties, good corrosion resistance, and low density. Combined with economy in material cost and fabrication cost, make this alloy family a basic material of construction for mechanical assemblies

4. RESULTS

4.1. CFRP MATERIAL:

Here the stresses, strains, deformations are obtained by analyzing the marine propeller by using cfrp material, as shown in below figures

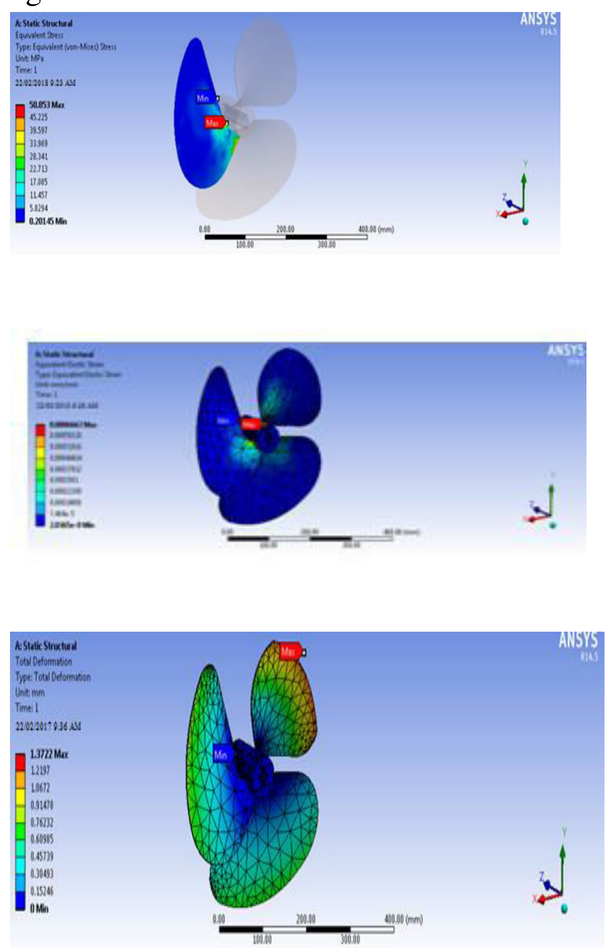


Figure 2 Von-mises stress of CFRP material

4.2. GRAPHS

4.2.1 Graph between von-mises stresses :

This graph shows the different stress values in different materials, GFRP,CFRP,AL-6061, Nibral, materials have least stress values compared to these fours materials as shown below graph

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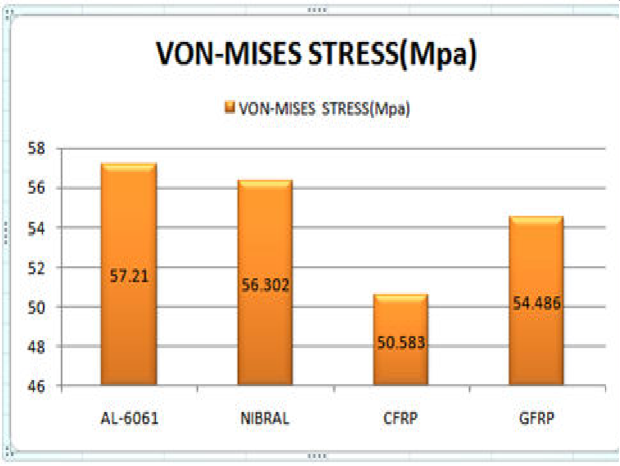
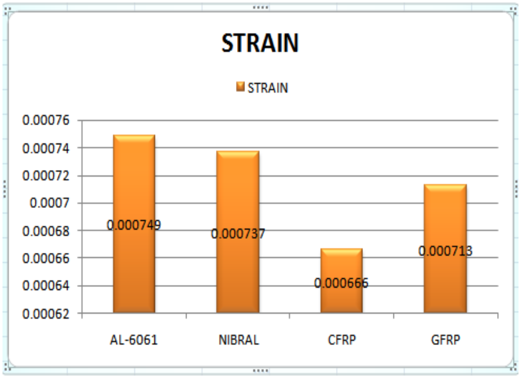


Graph 1 VON-MISES STRESSES

4.3 Graph between Strains:

This graph shows the different stress values in different materials, GFRP,CFRP,AL-6061,NIBRAL materials have least strain values compared to these four materials as shown below graph



Graph 2 strain

CONCLUSION

Modeling and simulation of marine propeller has done using catia software. After observing the static analysis values, modal analysis values we can conclude that GFRP, CFRP, better stress bearing capacity compared with the other materials and its showing better strength values when loads are applied . On doing static analysis of marine propeller it is clear that, the maximum Stress, strains and deformations are induced in Nibral , Al-6061, materials compared to other materials(composites) Cfrp,gfrp. If we compare stress, strain corresponding deformations of the material composites (GFRP,CFRP,) above result finally GFRP and CFRP is concluded as suitable material For marine propeller and manufacturing the marine propeller we can proceed with GFRP,CFRP materials because it has high stress bearing capacity and reasonable manufacturing cost.

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