Design and Analysis of Composite Marine Propeller

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Abstract- *In this work a structural analysis of the propeller blade made of carbon fiber (carbon fiber) is carried out, which is to be replaced by a propeller blade made of aluminum. This work is mainly concerned with modeling and calculating the design of a torpedo propeller blade for its strength. The propeller is a complex 3D model. This requires high performance simulation. The CATIA software is used to create the blade model. This report provides a summary of the fiber reinforced plastic materials and the benefits of using a composite propeller over a traditional metal propeller. The modal analysis and the static structure analysis were carried out using the ANSYS software for both aluminum and CFRP.*

I. INTRODUCTION

Conventional ship propellers are still the standard propulsion system for surface vessels and submersibles today. In general, a propeller is the component on a ship that converts engine power into propulsion for the ship. Changes to the basic geometry of the propeller in water jets and engines of an alternative type on submersible boats have not been significantly changed in order to determine and analyze the properties of the propeller. However, the propellers must provide sufficient thrust to propel the boat at a specified design speed and achieve “reasonable” propulsion efficiency. It is necessary to take into account the engine power and the shaft speed as well as the size of the ship and its operating speed with a propeller of suitable design. The above conditions are interdependent and a knowledge of the desired operating speed for a particular ship is required. However, the complexity of the flow field in which the propeller must operate efficiently forces the designer to design the propeller to overcome most of the dilemma. Another difficulty that arises when operating a propeller is the change in the inflow, which has a great impact on the propellers.

Experimental details:

In this work Carbon Fiber Reinforced Plastics(CFRP), Glass fiber reinforced plastic (GRP) and Aluminum5052 materials are used to analyse and found Stress determination of metallic and composite marine propeller. Linear static analysis to determine the tension and deflection of metal and composite propellers. Free vibration analysis for both composite and metallic propeller. The above observations are done by using CATIAV5,Hyper Mesh and ANSYS Workbench R20a.

Procedure for propeller blade:

Browse and open CATIA V5R16 and Clear all the Product Windows. Start - Mechanical Construction wire Frame and Surface Construction – select the part name as "Propeller Blade" - OK. We're into surface modeling now - select the top (XY) plane - the sketch tool. We are now in the sketch workbench - draw a circle with a diameter of 60 mm - close the workbench Fig. (a). Extrude it 50mm on both sides. Total height 100 mm as in Fig. (b).

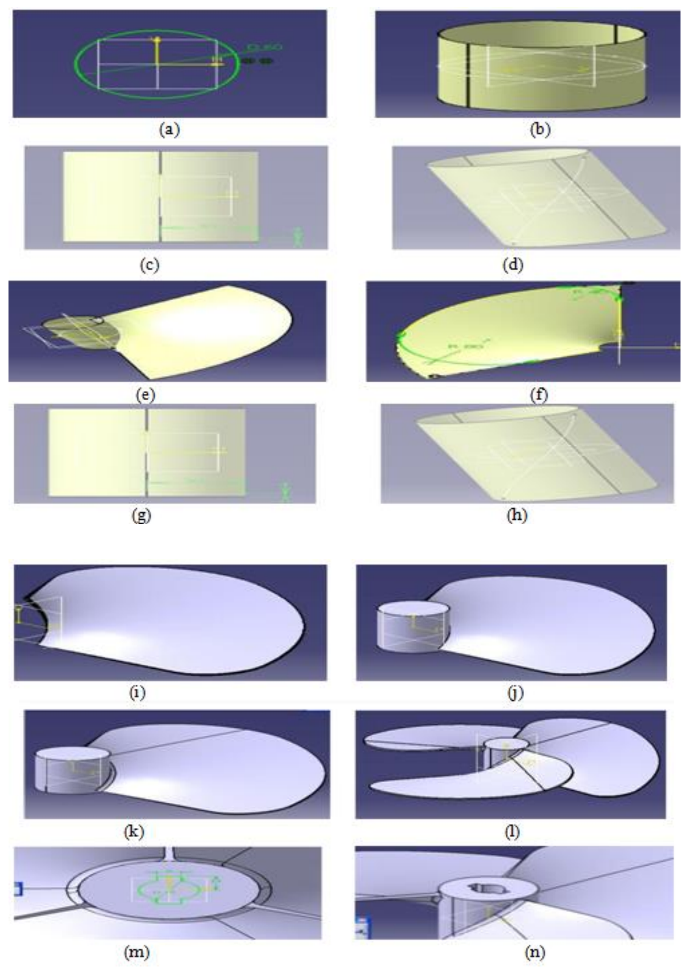


Figure. 1 design steps

Create a point on the right plane at a distance of 3 mm from vertical 4 mm from horizontal as shown in Fig.(c). Create the helix with 92 mm height and 276 pitch as shown in Fig. (d). Create the blade as shown below in Fig. (e) by using sweep tool.

Round the corners with corner tool with R80 and R40 as shown below in fig. (f). Extrude the rounded sketch with supports as shown below in Fig. (g). Split it with split tool as shown below in fig. (h). Now enter into part modelling to add thickness to the blade, by using thick surface tool add the thickness 4mm [Fig. (i)] Thickness to the blade. Convert fig. (c) surface into solid using close surface tool [Fig. (j)] Solid model of the blade. Using edge fillet tool add round at joining location of blade and hub Fig. (k). Pattern blade as shown in Fig. (l). Remove the material as shown in fig. (m). By using pocket tool as shown in fig. (n).

Model of a Propeller:

The propeller was simulated with CATIA V5. To model a blade, you will need sections of the propeller with different radii. These sections are drawn and rotated at the appropriate angles. Then all rotated sections are projected into the right circular cylinder of the corresponding radii. Finally, the torpedo propeller is first modeled with a quadrangular square shell element, two models are aluminum and composite material.

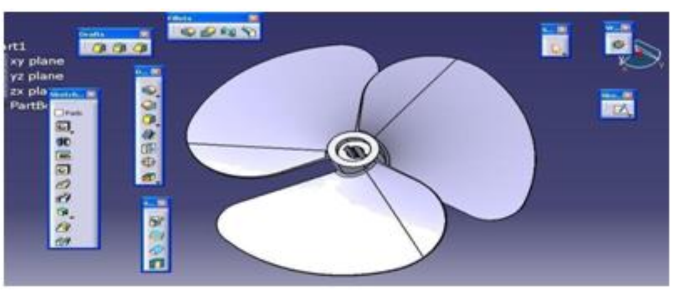


Figure. 2 model of a propeller

Hyper mesh is a very versatile software to perform meshing for complex shapes easily. It is capable of producing meshes that are high quality made with no complexity. Attain accurate and high quality meshes infractions of seconds, since it supports batch meshing which makes it possible to develop several meshes at once. Import the model by using File – Import – Model – Select the saved model fromCATIAV5. After importing change to “By Topo” for topology repair as shown in fig:3 (a).

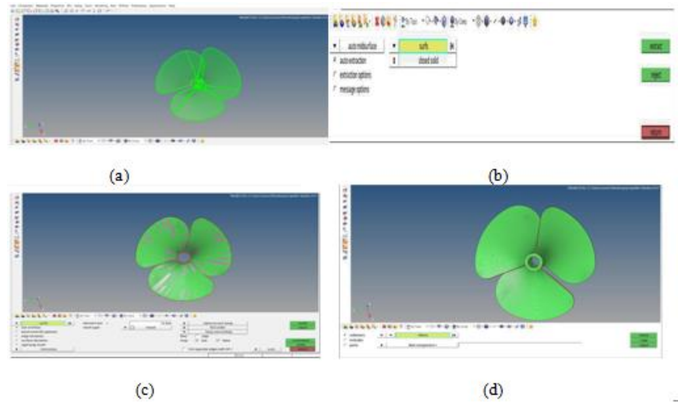


Figure. 3 meshing

Import the model by using File – Import – Model – Select the saved model fromCATIAV5. After importing change to “By Topo” for topology repair as shown in fig. 3 (a). Check for any geometrical repairs and correct them by F11 command window. Then extract the mid surface by Geom – mid surface – auto mid surface – select the propeller– extract as shown in fig. 3 (b). Hide the part model by using display “D” command window. Start the meshing by creating a new mesh component and by usingtheF12commandwindowas shown in fig.3 (c). The element size of used mesh is 5mmand the type of mesh is quads. After completion of meshing apply thickness components to wings and hub of thickness 4 mm and 10 mm respectively. Move the elements to the thickness components by using SHIFT+F11 command as shown in fig. 3 (d). And finally Save and Export the mesh file to ANSYS WORKBENCH in “.bdf ” format.

Boundary Conditions:

In this propeller the hub acts as a fixed support and the force is applied on the blades of the propeller. The propeller blade is considered as can tilever beam i.e. , one end is fixed and the other end is free end. The thrust force applied on the propeller is uniform throughout the blade.

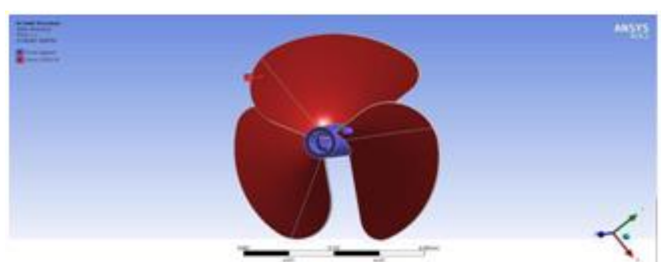
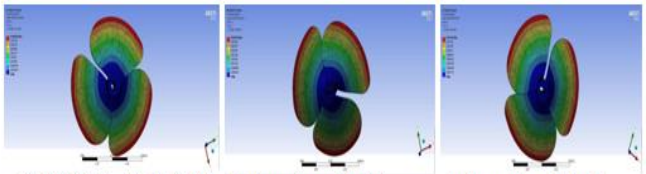


Figure.4 Application of boundary condition

II. RESULTS AND DISCUSSIONS

The deformation of aluminium alloy marine propeller is 0.004209m. The deformation is more at free end because, the Blade act as can til ever beam. The deformation of GFRP marine propeller is 0.0038243m. The stresses are produced around the hub because, the thrust force act son blade surface and the hub is fixed support. The deformation of CFRP marine propeller is 0.0015421m.



Deformation of Al 5052 alloy Deformation of GFRP Deformation of CFRP

Figure. 5 deformation plots

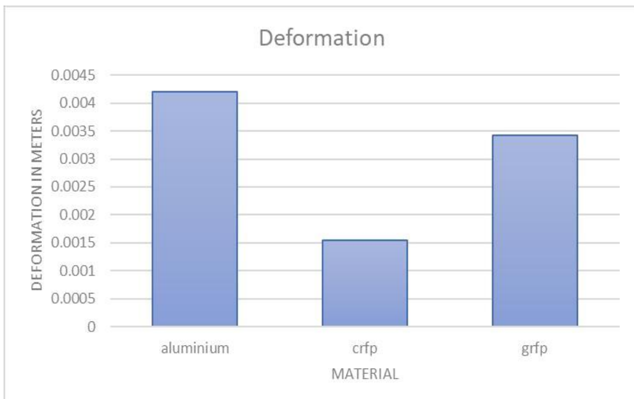
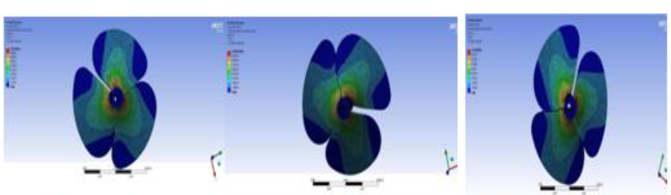


Figure.6 deformation Vs material

The above bar graph compares the deformation of three different materials which are used on marine propeller. The CFRP Material gives the lower deformation than the other two materials. Aluminium (0.004029m) > GFRP(0.0038243m) > CFRP (0.0015421m). The Equivalent (von Mises) Stress of aluminium alloy marine propeller is 106.5 MPa. The Equivalent (von-Mises) Stress of GFRP marine propeller is 108.41 MPa. The Equivalent (von-Mises) Stress of CFRP marine propeller is 105.16 MPa. The stresses are produced around the hub because, the thrust force acts on blade surface and the hub is fixed support.



von-MisesStress of Al 5052 alloy von-MisesStress of GFRP von-MisesStress of CFRP

Figure. 7 von-MisesStress plots

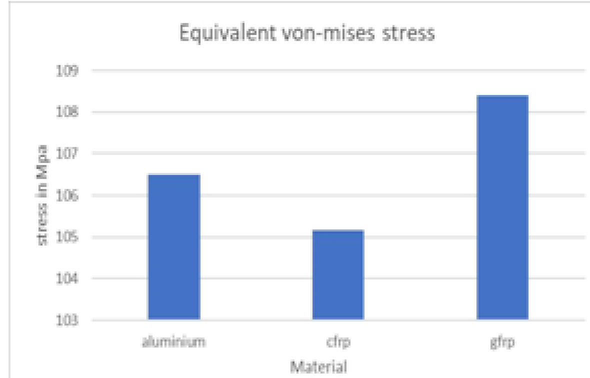


Figure.8 Equivalent von-Mises stress Vs material

The above bar graph compares the equivalent vonmises stress of three different materials which are used on marine propeller. The CFRP Material produce less stress than other two materials.

The maximum shear stress of aluminium marine propeller is 56.9 MPa. The maximum shear stress of GFRP propeller is 56.873 MPa.

The stresses are produced around the hub because, the thrust force act son blade surface and the hub is fixed support. The maximum shear stress of CFRP propeller is 56.98 MPa. The above bar graph compares the maximum shear stress of three different materials which are used on marine propeller.

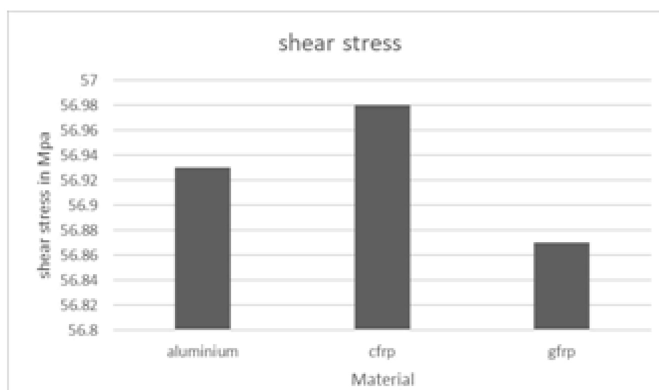


Figure.9 Shear stress Vs material

Modal frequencies bar graph:

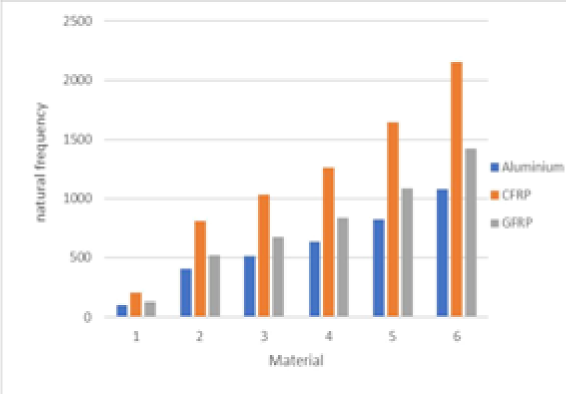


Figure.10 Natural frequency Vs material

The above bar graph compares the modal frequencies of three different materials which are used on marine propeller. The modal frequencies of CFRP material is more than the other two materials. So, it's operational range frequency is more compared to other materials.

III. CONCLUSION

- The above study provides the information on stresses, deformation and frequencies of three different materials. From our study, we have observed that deformation of CFRP material is less than the aluminium and GFRP materials. Aluminium (0.004029m) > GFRP (0.0038243 m) > CFRP (0.0015421m).
- The boundary conditions which were taken correct as per the values of deformations. The deformations for cantilever beam will be maximum at free end and zero at the fixed end. It was assumed that the blade was cantilever beam fixed at the hub end. From the above results the values taken are satisfying the conditions the same blade parameters can be used for the strength analysis of CFRP material propeller.
- The stress produced in CFRP material propeller is less compared with other two materials aluminium and GFRP. Similarly, the modal frequencies of CFRP material are more compared to other two materials.
- Due to the higher natural frequencies of CFRP propeller than aluminum and GFRP propeller, indicates that the operation range of frequency for CFRP Propeller is higher and also reduces noise problems.
- From above compared materials the propeller made with CFRP Material shows better results in natural frequency, stresses developed and deformation than Aluminium and GFRP materials.

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