Design and Analysis of Composite Marine Propeller using ANSYS WORK BENCH

S. Abdul Mutalib, S. Suresh, S.Jaya Kishore

Abstract— **Present work progress a methodology to design a propeller with isotropic material such as aluminum and composite materials to analyze its strength and deformation using ANSYS WORK BENCH software. To compare the effectiveness of aluminum metal and composite material such as CFRP and GFRP, static analysis and dynamic analysis are performed on these different materials. The solid model of marine propeller is developed using Solid works. This works approach the substantial improvements in metal propellers. The stress, strain and the total deformation were found out both the aluminum and the composite marine propeller using ANSYS. The stresses obtained are well within the limit of elastic property of the materials. The results are compared with aluminum and Composite marine propeller for the maximum stress and maximum deformation.**

***Index Terms*—structural analysis, dynamic analysis, ANSYS WORKBNCH, Aluminum, Composite material**

I. INTRODUCTION

A propeller is a type of fan that converts rotational motion into thrust by means of power. To maximize the efficiency of the engines, propellers are always rotate at constant velocities. The most common marine propellers are designed to reduce the noise such as three or four bladed marine propellers. The boss is the central part of a propeller to which the blades are mounted.

Fiber Reinforced Plastics are widely used in the manufacturing of different structures like radomes, wingtips, stabilizer tips, antenna covers, flight controls including the marine propellers. The hydrodynamic parts of the design of composite marine propellers have pulled in consideration in light of fact that they are important in anticipating the deflections and execution of the propeller blade. Fibre Reinforced Plastic has a high strength to weight ratio and is resistant to mildew and corrosion. As it is easy to fabricate, it is possible to manufacture the other parts of the marine propeller.FRP is a sandwich type material made up of two outer facing and a central layer. If the central layer which consists of a carbon then it is called Carbon Fiber Reinforced Plastic (CFRP).

Manuscript received Sep , 2015.

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Table 1
Aluminum mechanical properties:

Young's Modulus	7000MPa
Poisson ratio	0.34
Mass density	2700 gm/cc
Damping coefficient	0.03

Properties of CFRP:

- High flexibility
- High tensile strength
- Low weight
- High resistance
- Low thermal expansion
- High strength-to-weight ratio

Characteristics of CFRP:

- Specific gravity
- Tensile strength and modulus
- Compressive strength and modulus
- Damping
- Electrical and thermal conductivities
- High cost

Table 2
Mechanical properties of CFRP:

Young's Modulus	116.04 MPa
Poisson ratio	0.28
Mass density	16 gm/cc
Damping coefficient	0.018

II. LITERATURE REVIEW

Dunna Sridhar [2010] [1] conducted propeller open water test frictional resistance and propulsion performance using CFD techniques. For geometric modeling and mesh generation CATIA-V5 is used for four bladed propellers at a thrust force of 346Kn at 30 rps. The computational results are compared with the existing experimental data. Dr. Y .SeetharamaRao [2012] [2] studied stress analysis of composite propeller to design a propeller with aluminium and composite material to analyse its strength and deformation using ANSYS software. Focused on these materials to reduce the stress levels with different

ISSN: 2278 – 7798

materials. Experimental values are compared with the theoretical values. The comparison analysis of metallic and composite propeller was made for maximum deflection and normal stresses. B.Sreedhar Reddy [2012] [3] the comparison had made for analysis of metallic and composite propeller for the natural frequencies. The model analysis is done on both the materials using ANSYS software. By the results of study to overcome the resonance phenomenon composite propellers are safest mode compared to aluminium. M.Suneetha [2013] [4] design and analysis of a surface propeller using ABACUS. CATIA is a 3D modeling software used to generate the blade model and tool path on the computer. Later the model is exported to ABACUS for finite analysis. The different materials such as Aluminium and Carbon UD are taken. Finally its concluded that carbon UD/EXPOXY material can give a better performance with respect to static analysis. Mohammed Ahamed Khan [2013] [5] In this work the propellers are used to propeller the vehicles at its operational speed and RPM. Propeller with conventional isotropic materials creates more noise and vibrations in its rotation. It is undesirable in stealth point of view. To reduce these parameters and also the increase the need for light weight structural elements with acoustic insulation has led to use of Fiber Reinforced multi layered composite propeller. The dynamic analyses are carried out on Aluminium, CFRP and GFRP. M.L. Pavan Kishore [2013][6] Compare the results of experimentally and theoretically with NAB propeller and composite propeller. The modelling is developed in CATIA-V5 R17. Hexahedral solid mesh is generated using HYPER MESH. Static and Model analysis of both NAB and composite are carried out in ANSYS software. From the study of this thesis the composite materials can be made much stiffer than Nickel Aluminium Bronze (NAB) propeller.

III DESIGN OF MARINE PROPELLER IN SOLID WORKS

Modeling of the propeller is done using SOLID WORKS. 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.

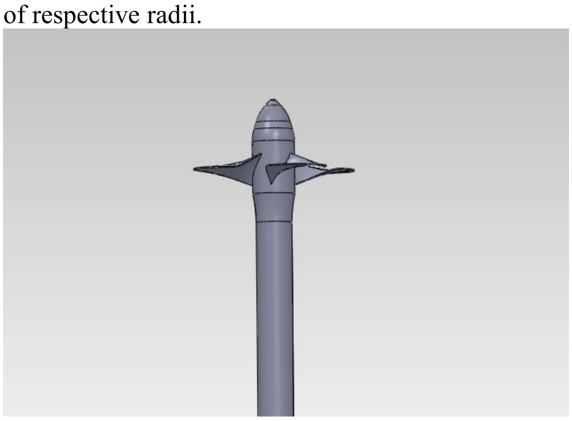


Figure1: designed in solid works of a marine propeller

IV MESH GENERATION

The solid model of the marine propeller blade along with the hub is imported to ANSYS WORK BENCH. The solid mesh is generated with the fine number of nodes and elements. The boundary conditions are applied to the meshed model. The contact surfaces between hub and shaft is fixed in all degrees of freedom. The Tetrahedral meshes are generated because the composite materials are used for the analysis. The thrust force of 2102.1 N is uniformly distributed on face side of blade and since it is the maximum loading condition on each blade. The number of nodes are generated are 13455 and the number of elements are generated are 13464.

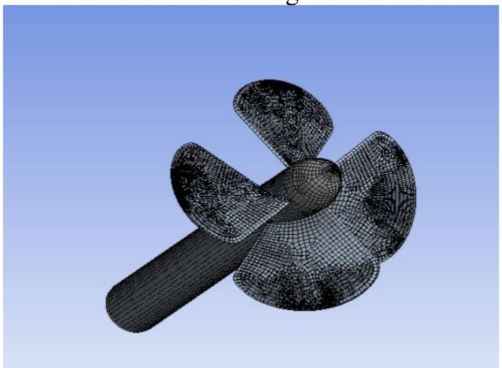


Figure2: Tetrahedral mesh generated on a marine propeller

V ANSYS RESULTS

The Aluminum propeller and composite propellers are considered for Finite Element Analysis. In effective software the results of static analysis and dynamic analysis are represented in the form of graphs and figures.

Static analysis of Aluminum propeller:

The thrust of 2102.1 N is applied to the propeller blade. The intersection of hub and shaft points in all direction is fixed. The thrust force is produced because of the pressure difference between the front side and back side of the propeller blades. The propeller blade is considered as cantilever beam i.e. one end is fixed and the other end is free end. The maximum vonmises stress is induced 658.3 MPa, the maximum vonmises strain is 0.028716 and the maximum total deformation is 17.451 mm.

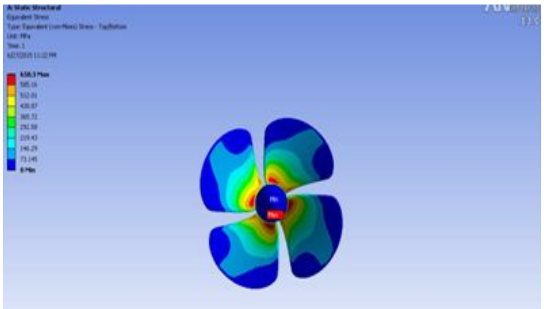


Figure3: Maximum vonmises stress of aluminium propellr

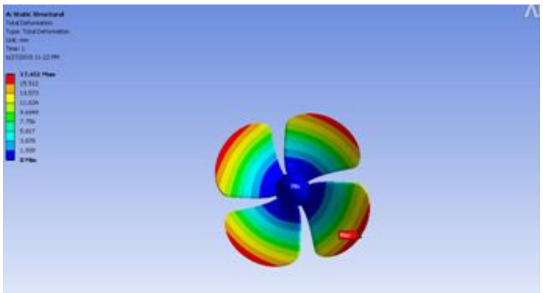


Figure4: Maximum total deformation of aluminium propeller

ISSN: 2278 – 7798

Static analysis of CFRP:

For the same force applied on the CFRP material the maximum vonmises stress is induced as 642.99 MPa, the Vonmises strain is induced as 0.0089965 and the total deformation as 5.1022 mm.

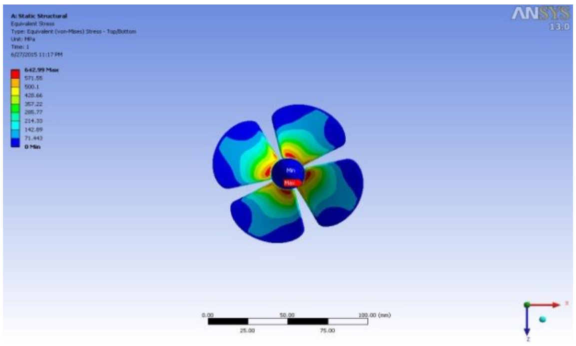


Figure6: Maximum vonmises stress of CFRP propeller

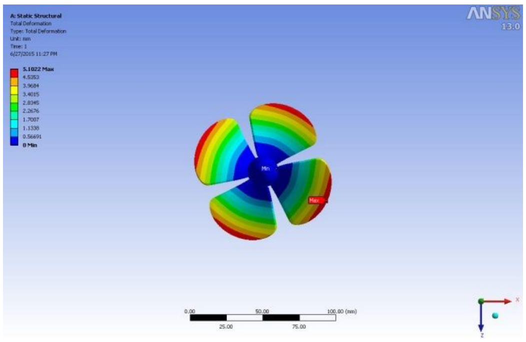


Figure:5 Maximum total deformation of CFRP propeller

Static analysis of GFRP:

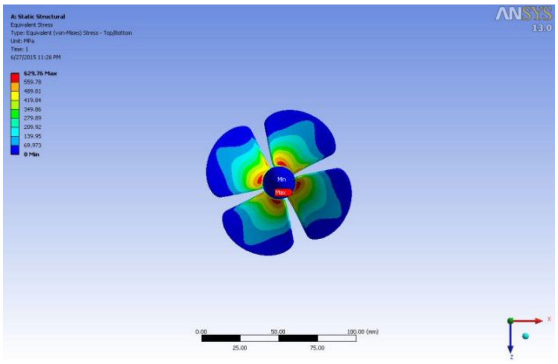


Figure6: Maximum vonmises stress of GFRP propeller

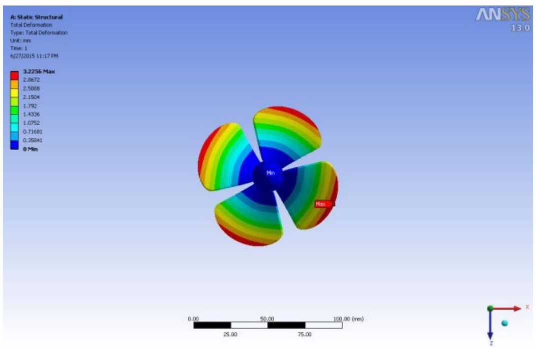


Figure 7: Maximum total deformation of GFRP propeller

VI RESULTS AND DISCUSSION

Table3

Static analysis of a marine propeller

Material	Vonmises stress MPa	Total deformation (mm)
Aluminum	658.3	17.451
CFRP	642.99	5.1022
GFRP	629.76	3.2256

Table4

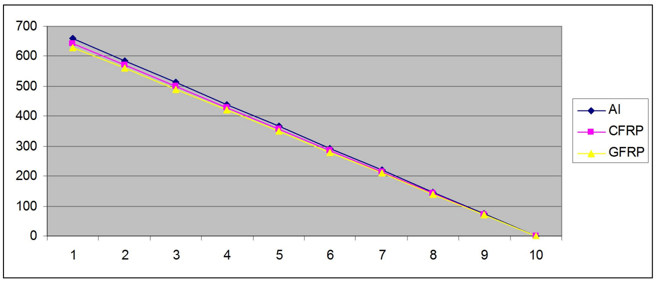
Dynamic analysis of a marine propeller

Material	Vonmises stress MPa	Total deformation (mm)
Aluminum	5.5924	0.013145
CFRP	4.7777	0.0033667
GFRP	4.463	0.00205757

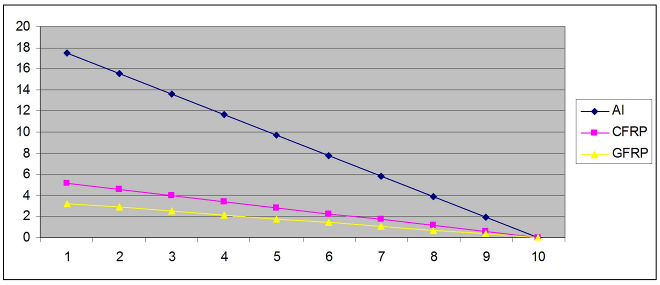
Representation of graphs shows the comparison of the three different materials such as Aluminium, GFRP and CFRP.

Static analysis:

In the below graph the X axis represents the number of iterations and on Y axis the maximum stress when the load is applied on the marine propeller and the maximum deformation occurs on the propeller blades. The different colours show the different materials of a marine propeller.



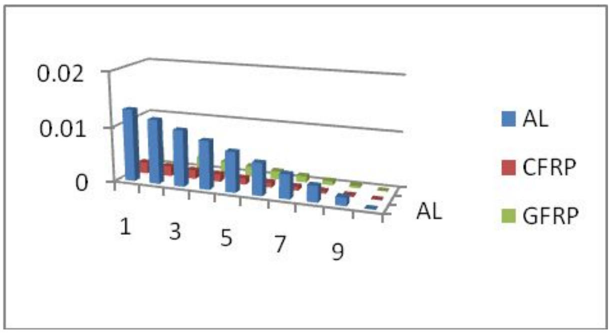
Graph 1: The maximum vonmises stress



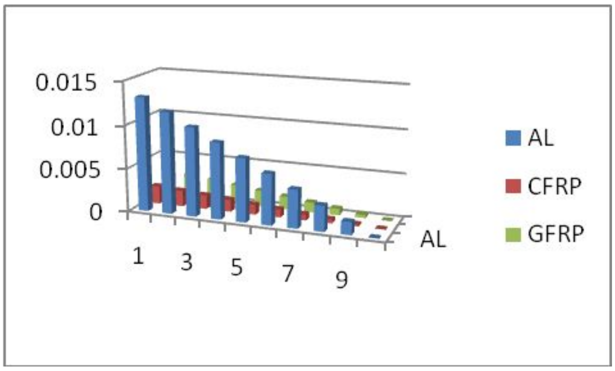
Graph 2: The maximum total deformation

ISSN: 2278 – 7798

Dynamic analysis:



Graph 3: The maximum vonmises stress



Graph 4: The maximum total deformation

The static and dynamic analyses are worked out in ANSYS software. The vonmises stress, strain and total deformation are calculated for aluminium (isotropic), CFRP and GFRP (orthotropic). The above graphs show the static analysis of comparison of the three different materials those are Aluminium alloy, CFRP and GFRP. In that on Y axis we considered the vonmises stress for graph1, Vonmises strain for graph 2 and total deformation for graph 3 then on the X axis we took the number of iterations for to get the maximum values.

VII CONCLUSION

The static analysis and dynamic analysis are carried out for the three different type of materials, those are Aluminium, Carbon Fiber Reinforced Plastic (CFRP) and Glass Fibre Reinforced Plastic (GFRP). Following are the important conclusions are drawn from that analysis:

Static analysis:

1. The vonmises stress acting on the propeller produced from aluminum is 658.3 MPa, and the total deformation is 17.451 mm
2. The vonmises stress acting on the propeller produced from CFRP is 642.99 MPa, and the total deformation is 5.1022 mm
3. The vonmises stress acting on the propeller produced from GFRP is 629.76 MPa, and the total deformation is 3.2256 mm

Dynamic analysis:

1. The vonmises stress acting on the propeller produced from aluminum is 5.5924 MPa, and the total deformation is 0.013145mm
2. The vonmises stress acting on the propeller from CFRP is 4.7777 MPa, and the total deformation is 0.0033667mm
3. The vonmises stress acting on the propeller from GFRP is 4.463 MPa; and the total deformation is0.00205757 mm.

Finally it is concluded that Glass Fiber Reinforced Plastic (GFRP) material can give a better performance with respect to static and dynamic analysis

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ISSN: 2278 – 7798

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ISSN: 2278 – 7798