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Modelling and Analysis of Propeller Blade with CFRP and GFRP for Material Strength

Aarif Dahi¹, Rakeshkumar Prajapati²

P.G. Student, Department of Mechanical Engineering, Parul Institute of Technology, Gujarat, India¹

Assistant Professor, Department of Mechanical Engineering, Parul Institute of Technology, Gujarat, India²

ABSTRACT: A ship propeller is a mechanical device like fans that use to produce the propulsion force of the ship motion. It is used to generate the thrust by rotational motion of the propeller. Propeller is used in marine, ships. Torpedoes and submarine etc. which require high strength. The propeller is subjected to an external hydrostatic pressure between face and back surface of the blade. So that the propeller blade modeled and design as its can be with stand the static load and distribution. The present work can be carries out the modeling and analysis of propeller blade for its strength for torpedo. The present study static analysis, dynamic analysis and thermal analysis are carried out. The fiber composite material is used for propeller blade which replaced of aluminum. The fiber composite is light weight, highly corrosion resistance, better strength compare to aluminum material.

KEYWORDS: Strength of Propeller Blades, Torpedo Propeller, Fiber Composite, Strength Analysis.

I. INTRODUCTION

The ship propeller is a key component of the motion mechanism of the ship and its play the main part in propulsion systems. The efficiency of a propeller takes important roles in the design process, because its efficiency and stabilities directly related. In most condition, propellers are designed to absorb as minimal power as possible and to give maximum efficiency with less cavitations and hull vibration characteristics. The rotation of propeller will create the thrust force for ship motion. This is the main reason for the weakness blade structure such as blade surface erode, reduced thickness of the blade and pitched surfaces. These created the high cavitations flow occurred on the blade surface and the potential of unbalanced forced developed at the end of propulsion.

1.1 Types of marine propellers

- 1.1.1 Controllable pitch propeller
- 1.1.2 Skewback propeller
- 1.1.3 Modular propeller

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

1.1.2 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.

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1.1.3 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.

1.2 Principle of Propeller

- Propeller is based on Bernoulli's principle and Newton's third law.
- Propeller works by throwing mass in the opposite direction you want to go, which by Newton's law produces equal and opposite reaction of you moving.
- It based on push and pull concept.

1.3 Propeller number of Blade attached:

The classification of different types of propellers is shown below:

- 1.3.1 2 – Blade Propeller
- 1.3.2 3 – Blade Propeller
- 1.3.3 4 – Blade Propeller
- 1.3.4 5 – Blade Propeller
- 1.3.5 6 – Blade Propeller

1.3.1 The 2 – Blade Propeller: The propeller efficiency will be highest for propeller with minimum number of blades i.e. 2 blade propeller. But to achieve strength factor and considering the heavy loads subjected by the ship, sea and weather two blade propellers are not used for merchant ships.



Fig (a) 2 blade propeller

1.3.2 3 – Blade Propeller:

- The manufacturing cost is lower than other types.
- Are normally made up of aluminium alloy.
- Gives a good high speed performance.
- The acceleration is better than other types.
- Low speed handling is not much efficient.
- If you have to power in to a current every time you go out a 3 or 4 blade is the better choice.
- They have a major advantage when going against heavy winds and seas or a current as they will keep your boat speed by up to 30% better than the two blades.
- Moreover, they will run much smoother and reduce vibrations as it is balanced around 3 or 4 points as opposed to 2.

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Fig (b) 3 blade propeller

1.3.3 4 – Blade Propeller:

- The manufacturing cost is higher than 3 blade propellers.
- 4 blade propellers are normally made up of stainless steel alloys.
- Have better strength and durability.
- Gives a good low speed handling and performance.
- Has a better holding power in rough seas.
- 4 blade propellers provide a better fuel economy than all the other types.



Fig (c) 4 blade propeller

1.3.4 5 – Blade Propeller:

- Manufacturing cost is higher of all.
- Vibration is minimal from all the other types.
- 5 blade propellers have better holding power in rough seas.

1.3.5 6 – Blade Propeller:

- Manufacturing cost is high
- Vibration is minimal from all the other types.
- 6 blade propellers have better holding power in rough seas.
- With six blade propeller, the induced pressure field over the propeller decreases.

II. LITERATURE REVIEW

[1] M. A Ishak, Sulaiman S., Baharudin B. T. H. T., and Syajaratunnur Y “RESEARCH ON THE SHIPP ROPELLER BLADE TO DETERMINECHANGES IN THE MECHANICAL PROPERTIES BASED ON THE FORCES PROJECTION”, [2017]

Research that the existing ship propeller and the effects of casted specimen on the changes of mechanical properties of the propeller structure. The specimen prepared is referred to ASTM E8 2008 standard and including two projections is Longitude and Latitude projected, according to the forces analysis exerted on blade structure. The experiments perform

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on the used propeller by cutting into pieces of specimen and casted specimen of copper alloy of Nickel Aluminium Bronze (Ni-Al-Br). The mechanical testing is conducted on tensile test, tensile strength and hardness test. They conclude that the latitude projection shows greater compared to longitude projection. An experimental result for the casted specimen showed a reading of mechanical properties is 3% to 5% difference compared to the cutting specimen. From the results of these experiments have found that fixing projections in this study are reasonable and can be used in subsequent studies and mechanical properties of the material are not homogenous across the blade structure.

[2] PALLE PRASAD, LANKA BOSU BABU ,“DESIGN AND ANALYSIS OF THE PROPELLER BLADE”, [2017]

They work on the structural analysis of a CFRP (carbon fiber reinforced plastic) propeller blade which proposed to replace the Aluminium propeller blade. Also finding the stresses and deflections for both aluminium and carbon fiber reinforced plastic materials. After the study they conclude the stresses and deflections for both aluminium and carbon fiber reinforced plastic materials and also finding its strength.

[3] A. Satya Dinesh, G. V. Naga Mani, “Modelling and Analysis of a Shaft Blade for its Strength”, [2016]

They examine the structural analysis of CFRP propeller blades which in future replaces the aluminium propeller blade. And this study basically deals with modelling and design analysis for propeller blade for torpedoes application.

[4] G.Rajesh et al ,“Modelling and Analysis of Propeller Blade with Different Materials Using FEA”, [2016]

They studied the structural analysis of a propeller blade which proposed to replace the Aluminium propeller blade for torpedoes application and this work basically deals with the modelling and design analysis of the propeller blade of a torpedo for its strength and they findings the stresses and deflections for both materials.

[5] Y.Venkatesh et al, “MODELLING AND ANALYSIS OF COMPOSITE TORPEDO PROPELLER”, [2016]

Work on metal and composite strength analysis of propeller carried out by using the finite element method for torpedoes application and findings the structural and vibration analysis for both aluminium and composite material.

[6] S. Abdul Mutalib, S.Suresh, S.Jaya Kishore, “Design and Analysis of Composite Marine Propeller” using ANSYS WORK BENCH, [2015]

They were work on the isotropic material such as aluminium and composite materials to analyse its strength and deformation using ANSYS WORK BENCH Software. Static analysis and dynamic analysis are performed on these different materials and findings the stress, strain and the total deformation for both the aluminium and the composite marine propeller using ANSYS.

[7] Jaya Kishore.S,B.Siddeswara Rao, P. Kumar Babu, “FEM Analysis on Submarine Propeller Blade for Improved Efficiency by using Solid Works and ANSYS-Workbench”[2015]

They work on the FEM analysis for underwater vehicle for its strength for propeller blade. The materials used are aluminium and composite. And findings the Interlaminar stress for both material.

[8] Esukapatla Pratyush Kumar et al, “Modelling and Analysis of Propeller Blade with Different Materials Using FEA”, [2015] work carries out the structural analysis of a propeller blade which proposed to replace the Aluminium propeller blade and findings that the Metal matrix composite propellers have more advantages over the conventional metallic propellers.

[9] P.Durga Neeharika ,P. SureshBabu ,“DESIGN AND ANALYSIS OF SHIP PROPELLER USING FEA”, [2015]

They work on the modelling and analyzing the aluminium propeller blade of an underwater vehicle for its strength. They used the aluminium material for propeller blade. And they conclude the Metallic propellers can be replaced by composite propellers for enhanced performance with regard to the operating range.

[10] P. NARASIAH, “Analysis of Composite Propeller of Ship using FEA”, [2014]

They choose the fiber reinforced composite material which replaced of the aluminium material for under water vehicle for analysis. They used the FEM method for analysis. And finally findings the Deflection, Frequency, Interlaminar shear stress.

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[11] Ganesh, K. Pradeep, K. Srinivasuluc, “Modelling and Analysis of Propeller Blade for its Strength”, [2014]

They work on the structural analysis of a CFRP (carbon fiber reinforced plastic) propeller blade which proposed to replace the Aluminium propeller blade for torpedoes application. And they find the deformation, maximum displacement and Frequency.

[12] M.L.Pavan Kishore, R.K.Behera, Sreenivasulu Bezawada, “Structural Analysis of NAB Propeller Replaced With Composite Material”, [2013]

They work on the modelling and analyzing the propeller blade of a underwater vehicle for their strength. And they conclude the stresses obtained are well within the limit of elastic property of the materials.

[13] MOHAMMED AHMED KHAN, Khaja shahnawaz uddin, Bilal Ahmed, “Design and Dynamic analysis on composite propeller of ship using FEA”, [2013]

They examine the dynamic analysis of aluminium, composite propeller which is a combination of GFRP (Glass Fiber Reinforced Plastics) and CFRP (Carbon Fiber Reinforced Plastics) materials and finds the inter laminar shear stresses for composite propeller by varying the number of layers. The stresses obtained are well within the limit of elastic property of the materials.

[14] Dr.Y.SEETHARAMA RAO, Dr.K. MALLIKARJUNA RAO, B.SRIDHAR REDDY, “STRESS ANALYSIS OF COMPOSITE PROPELLER BY USING FINITE ELEMENT ANALYSIS”, [2012]

They Work on the stress analysis of propeller blade with aluminium and composite material using finite element Analysis. And they conclude that the effectiveness of composite over metals, stress analysis is performed on both composite and metal propeller using ANSYS.

III. MODELLING DESCRIPTION

CFRP Material Properties

Young’s Modulus: 1160.64 MPa

Poisson’s Ratio: 0.28

Density: 1600kg/m³

Calculations

Diameter = 227.27 mm

Number of blades = 4

Propeller Model = INSEAN E779A

Type of propeller = Controllable pitch propeller

Material = Aluminum and CFRP

Total area of the circle = πr^2

= 40567.113mm²

Total blade area = total area of the circle X disc area ratio

Given disc area ratio = 0.689

Total blade area = 40567.113 x 0.689

= 27950.66mm²

Relation between pitch & pitch angle

Formulae; pitch (p) = $2\pi r \times \tan a$

Where @ = pitch angle and r = radius and π

Pitch angle = 120

Pitch = $2 \times \pi \times 113.635 \times \tan 120$

= 1236.66

= 1237mm

Speed = (RPM/Ratio) x (pitch/c) x (1-s/100)

= [(1000/0.5) x (1237/1) x (1-0/100)]

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Assume Ratio=1/2; gear ratio(c)=1;slip=0

=762636 x 60/106

=45.75816km/hr

Boat speed = $V_b = 45.75186/1.6093$ mile/hr

= 28.4328 mile/hr

Mass flow rate/hr = total blade area* speed of the boat

The thrust (T) is equal to the mass flow rate (m) times the difference in the velocity (v)

$T = m (V_b - V_a)$

Thrust = 2102.097 N

IV. MODELLING OF PROPELLER BLADE

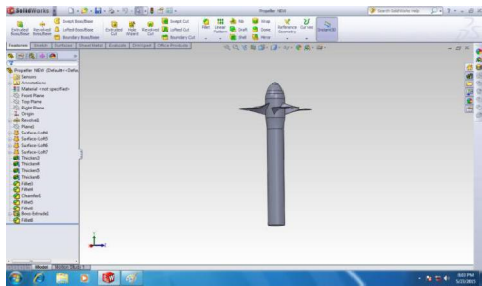


Fig (d) Front view of Solid Model of a propeller

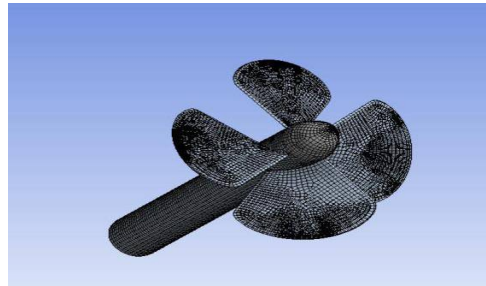


Fig (e) Fine meshed model of propeller

V. PROPELLER ANALYSIS

FEM Analysis of Propeller Blade

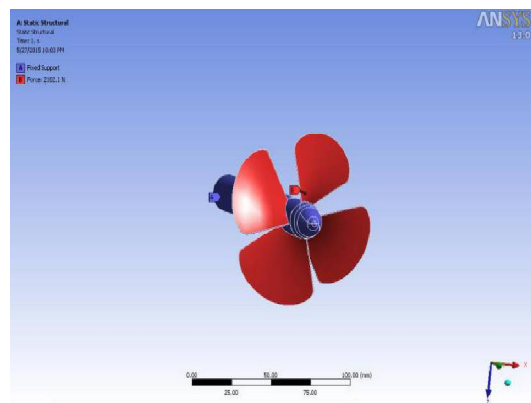
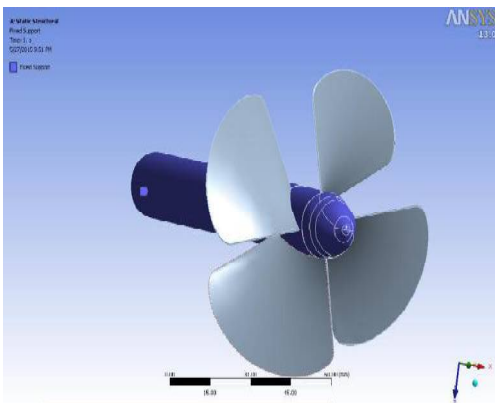


Fig (f) Boundary conditions applied to the marine propeller blade in ANSYS. Applied load=2102.1 N

VI. DYNAMIC ANALYSIS

CFRP Material Properties

Young's Modulus : 1160.64 Mpa

Poisson's Ratio : 0.28

Density : 1600kg/m³

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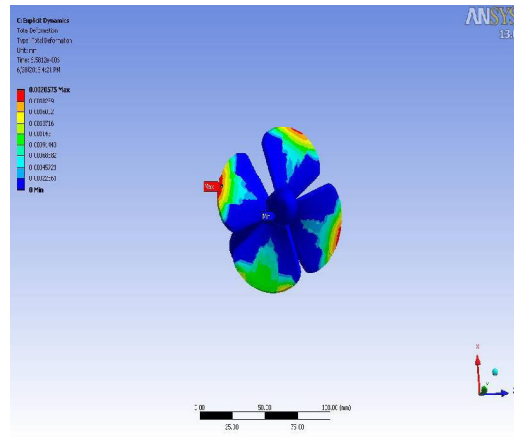
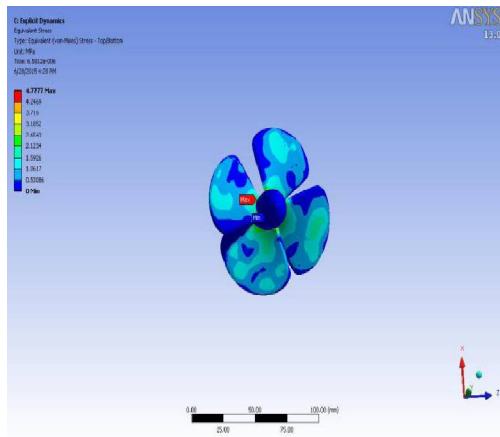


Fig (g) Vonmises-Stress distribution of CFRP marine propeller blade Fig (h) Total Deformation

CFRP Material Properties

Young's Modulus :7300 Mpa

Poisson's Ratio :0.28

Density : 1800kg/m3

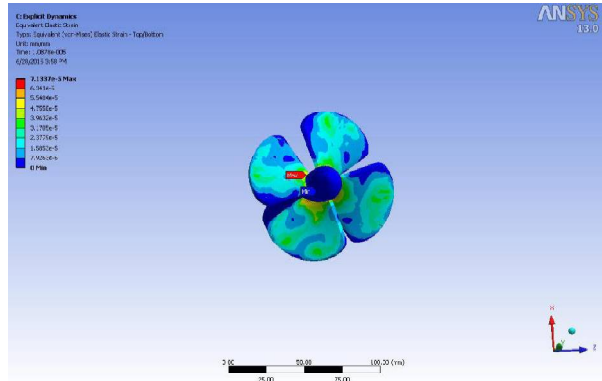
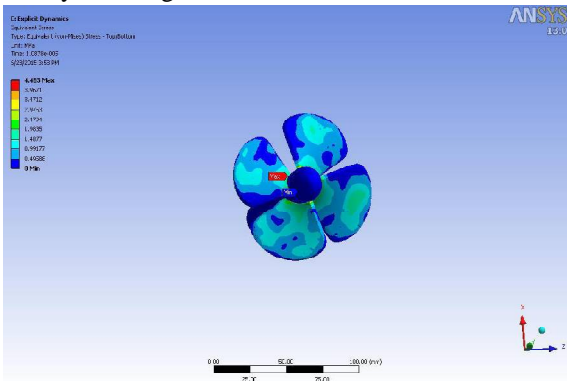


Fig (I) Vonmises-Stress distribution of GFRP marine propeller blade Fig (J) Vonmises-Strain distribution of GFRP

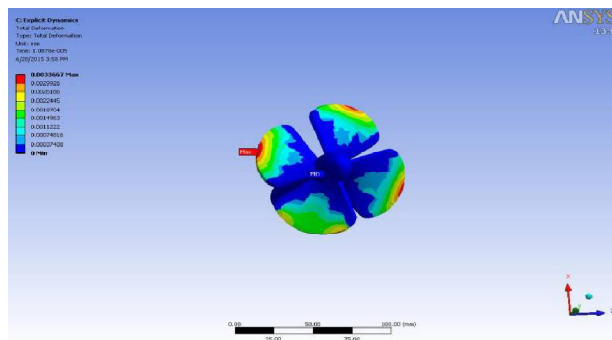


Fig (K) Total deformation over GFRP marine propeller blade in ANSYS.

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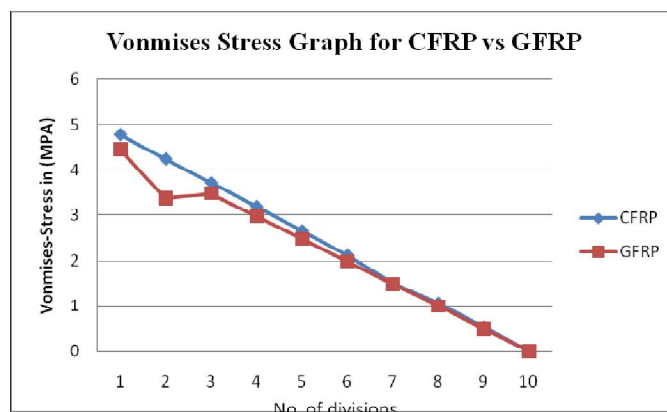
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VII. RESULTS & DISCUSSIONS

Table. I Result for Dynamic Analysis

Sr. No.	Material	Vonmises – stress (Mpa)	Vonmises – Strain	Total Deformation
1	CFRP	4.777	4.3737e-5	0.002857
2	GFRP	4.463	7.8337e-5	0.003366
3	% Difference	31.4%	0.00346%	0.59%



VIII. RESULTS GAP ANALYSIS

Literature shows that the only software base work can be carried out for strength analysis in research work using software. Static analysis, dynamic analysis is carried out by software; Experimental work does not carried out for strength measurement. So we can do experimental work for research work by manufacturing the Propeller Blade and compare the actual result with software result, and also we can perform the thermal analysis for the work.

IX. COCLUSION

From the result analysis vonmises stress and strain is less of GFRP material compare to CFRP material and also total deformation is less in the GFRP material. The %difference of GFRP material is vonmises stress difference is 31.4% and vonmises strain is 0.00346% and total deformation is 0.59%.

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