MODELING OF PROPELLER BLADE OF MARINE SHIP SUBJECTED TO STATIC LOADING CONDITIONS

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ABSTRACT

Fiber reinforced composites 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 multilayer composite propeller. The present work carries out the structural analysis of a CFRP KELVER material propeller blade which proposed to replace the Aluminium 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 deflections for both aluminium and 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 modal analysis and static structural analysis were carried out for both aluminium and CFRP

Keyword: *Propeller blade, CATIA, ANSYS, Static loading.*

1. INTRODUCTION

Marine propeller is a component which forms the principal part of ships since it gives the required propulsion. Fiber reinforced plastics are 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 FRP 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. Traditionally marine propellers are made of manganese-nickel-aluminum-bronze (MAB) or nickel-aluminum-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 cavitations 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

1.1 Types of marine propellers

1) Controllable pitch propeller
2) Skewback propeller
3) Modular propeller

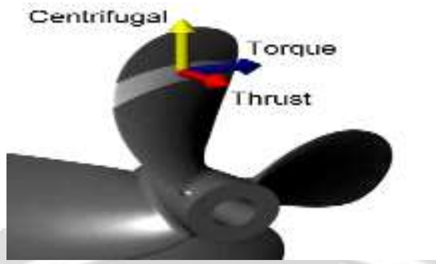


Figure 1.1:Marine propeller

a) 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).

b) 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 cavitations, and thus makes for a quiet, stealthy design.

c) 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 Propeller Geometry

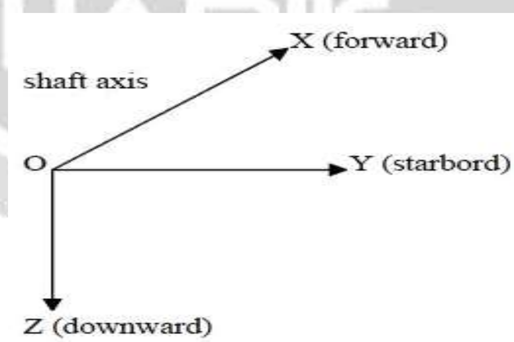


Figure 1.2:Propeller Geometry

1.3.1..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.

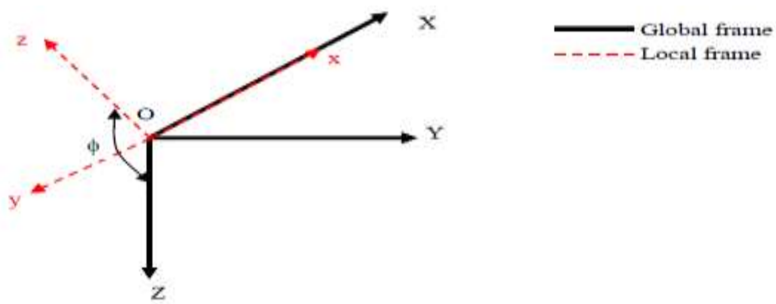
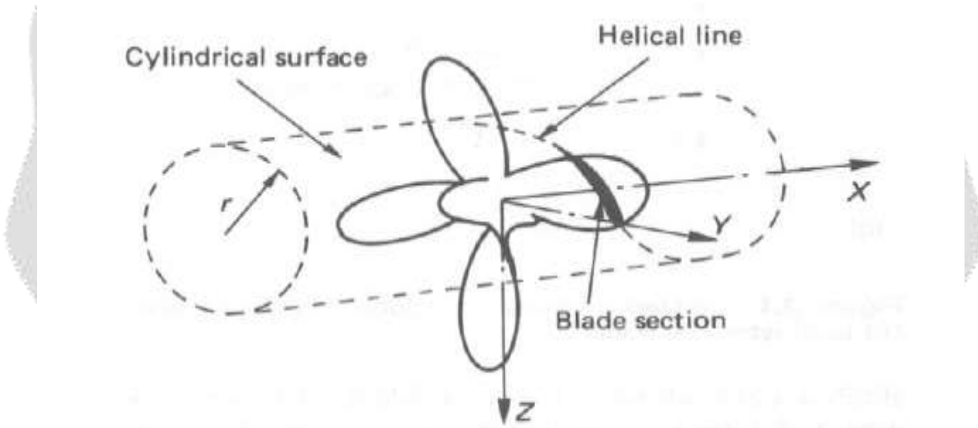


Figure1.3: Frames of reference

1.3.2. Propeller Reference Lines

a) 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.
b) Generator line: The line formed by intersection of the pitch helices and the plane containing the shaft axis and propeller reference line.
c) The aerofoil 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 ahead 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 ahead 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
.

1.3.3.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 creates a helix.
• When the point P has completed one revolution of helix that means the angle of rotation: $\varphi = 360^o$ *or* 2π the cylinder intersects the X-Z plane and moves forward at a distance of P.
• If the cylinder is opened out the locus of the point P lies on a straight line.
• In the projection one revolution of the helix around the cylinder measured normal to the OX axis is equal to $2\pi r$.
• The distance moved forward by the helical line during this revolution is p andthe helix angle is given by: θ
• The angle θ is termed the pitch angle and the distance p is the pitch.

Several pitch definitions where:

- θ0 is the effective pitch angle of the propeller
- θnt or θ is the geometric pitch angle of the propeller
- βi is the hydrodynamic pitch angle
- α is the angle of attack of section

i) 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.

ii) 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. Therefore its definition not clear. It is rarely used but it can be seen in older drawings like Wageningen B series.

iii) Effective or no-lift pitch:

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

iv) 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 zerSo 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.

2. DESIGN AND ANALYSIS SOFTWARES

It also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixelated) environments.

CADD environments often involve more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) objects.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

CAD is used in the design of tools and machinery and in the drafting and design of all types of buildings, from small residential types (houses) to the largest commercial and industrial structures (hospitals and factories).

CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. It can also be used to design objects. CAD has become an especially important technology within the scope of computer-aided technologies, with benefits such as lower product development costs and a greatly shortened design cycle. CAD enables designers to lay out and develop work on screen, print it out and save it for future editing, saving time on their drawings.

2.1 Types of CAD Software:

2D CAD:

Two-dimensional, or 2D, CAD is used to create flat drawings of products and structures. Objects created in 2D CAD are made up of lines, circles, ovals, slots and curves. 2D CAD programs usually include a library of geometric images; the ability to create Bezier curves, splines and polylines; the ability to define hatching patterns; and the ability to provide a bill of materials generation. Among the most popular 2D CAD programs are AutoCAD, CADkey, CADDS 5, and Medusa.

3D CAD:

Three-dimensional (3D) CAD programs come in a wide variety of types, intended for different applications and levels of detail. Overall, 3D CAD programs create a realistic model of what the design object will look like, allowing designers to solve potential problems earlier and with lower production costs. Some 3D CAD programs include Autodesk Inventor, CoCreate Solid Designer, Pro/Engineer Solid Edge, Solid Works, Unigraphics NX and VX CAD, CATIA V5.

Solid Modeling:

Solid modeling in general is useful because the program is often able to calculate the dimensions of the object it is creating. Many sub-types of this exist. Constructive Solid Geometry (CSG) CAD uses the same basic logic as 2D CAD, that is, it uses prepared solid geometric objects to create an object. However, these types of CAD software often cannot be adjusted once they are created. Boundary Representation (Brep) solid modeling takes CSG images and links them together. Hybrid systems mix CSG and Brep to achieve desired design

2.2 INTRODUCTION TO ANSYS

Dr. John Swanson founded ANSYS. Inc in 1970 with a vision to commercialize the concept of computer simulated engineering, establishing himself as one of the pioneers of Finite Element Analysis (FEA). ANSYS inc. supports the ongoing development of innovative technology and delivers flexible, enterprise wide engineering systems that enable companies to solve the full range of analysis problem, maximizing their existing investments in software and hardware. ANSYS Inc. continues its role as a technical innovator. It also supports a process-centric approach to design and manufacturing, allowing the users to avoid expensive and time-consuming "built and break" cycles. ANSYS analysis and simulation tools give customers ease-of-use, data compatibility, multiplatform support and coupled field multi-physics capabilities.

Analysis types available:

- Structural static analysis.
- Structural dynamic analysis.
- Structural buckling analysis.
- Linear buckling
- Non-linear buckling
- Structural non linearity's
- Static and dynamic kinematics analysis.

2.3. STATIC STRUCTURAL ANALYS

A Static structural analysis determines the stress, displacements, strains, forces in structures or components caused by loads that do not induced significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

1. Add a static structural analysis template by dragging the template from the tool box into the project schematic or by double clicking the template in the tool bars.
2. Load on the geometry by right clicking on the geometry cell and choosing import geometry.
3. View the geometry by right clicking on the modeling cell and choosing edit or double clicking the model cell alternatively you can right click the set up cell and select edit. This step will touch the mechanical application.
4. The mechanical application window, complete static structural analysis using the mechanical applications tools and features.

3. DESIGN AND ANALYSIS OF PROPELLER BLADE

3.1. PROCEDURE FOR PROPELLER BLADE:

- Open CATIA V5 R16
- Close the Product Window
- Start – Mechanical Design – Wireframe and Surface Design – Enter Part Name as **Propeller Blade –** OK

- Now we are in a surface modeling - Select Top (XY) plane – Sketch tool
- Now we are in sketcher workbench - Draw a circle with 60 dia – Exit workbench
- Extrude it with 50 mm on both sides total 100 mm height as shown in

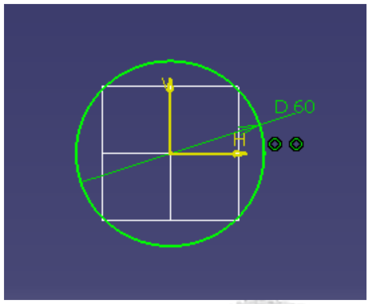


Fig 3.1:60 dia circle in workbench

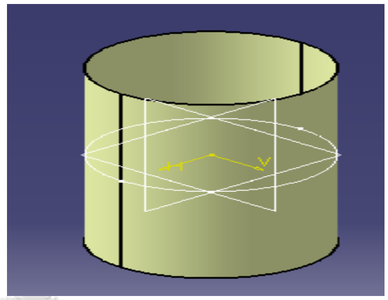


Fig:3.2 Extrude dimensions of circle

- Create a point on the right plane at a distance of 30 mm from vertical 4 mm from horizontal
- Create the helix with 92 mm height and 276 pitch

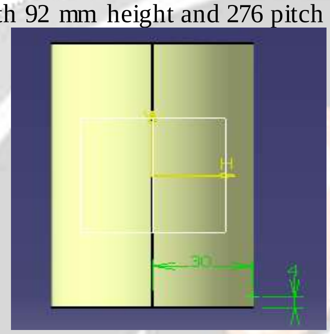


Fig:3.3: Dimensions of helix

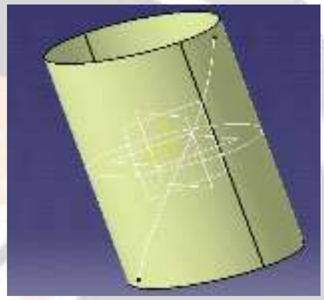


Fig:3.4:helix

- Create the blade as shown below in Fig:5 by using sweep tool, round the corners with corner tool with R 80 and R 40 as shown below in

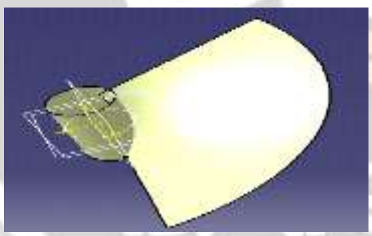


Fig:3.5: propeller blade

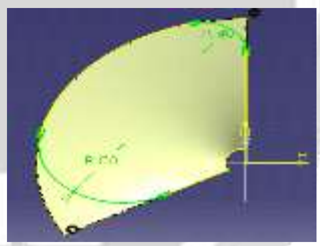


Fig:3.6:Dimensions of the propeller blade

- Extrude the rounded sketch with supports as shown below in Fig:7, split it with split tool as shown below in

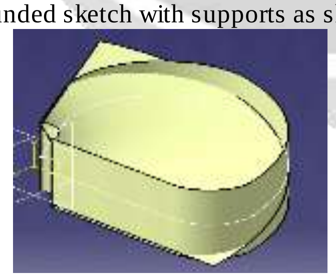


Fig:3.7:Extrude the propeller blade

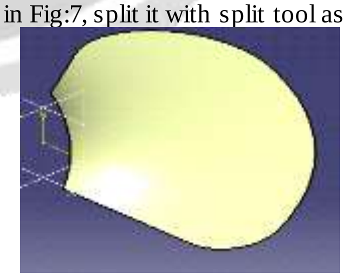


Fig:3.8:split tool used .

Now enter into part modeling to add thickness to the blade, by using thick surface tool add the thickness 4 mm (Fig:9), Convert fig:3 surface into solid using close surface tool (Fig:10).

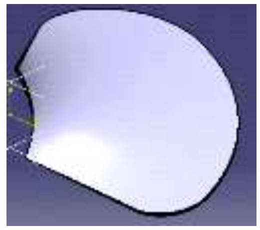
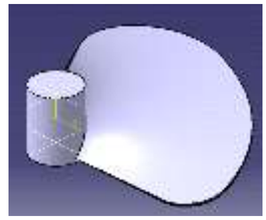



Fig:3.9:Part modelling to the blade **Fig:3.10:Surface tool used in the blade**

- Using edge fillet tool add round at joining location of blade and hub Fig:11
- Pattern blade as shown in Fig:12

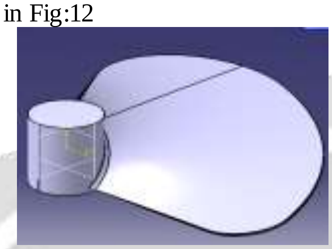
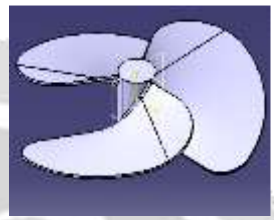



Fig:3.11:Joing the locations **Fig3.12:Pattern blade**

- Remove the material as shown in fig:13 and Fig:14 by using pocket tool

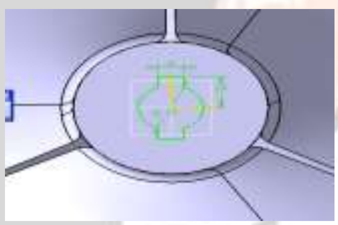
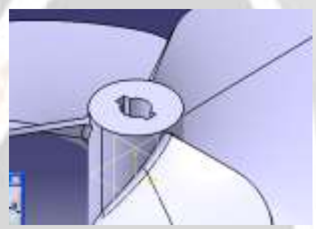



Fig:3.13:Removing material **Fig:3.14:Using pocket tool**

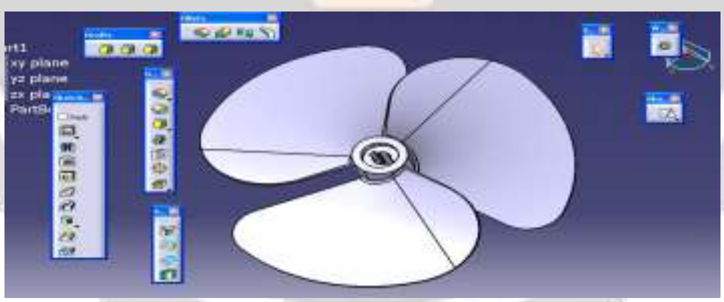


Figure3.15:Model of propeller

WEIGHT COMPARISION OF THREE MATERIALS

Table 3.1: Weight comparison of three materials

MATERIAL	WEIGHT
KEVLER	0.358
ELGLASS	0.486
ALUMINIUM	0.709

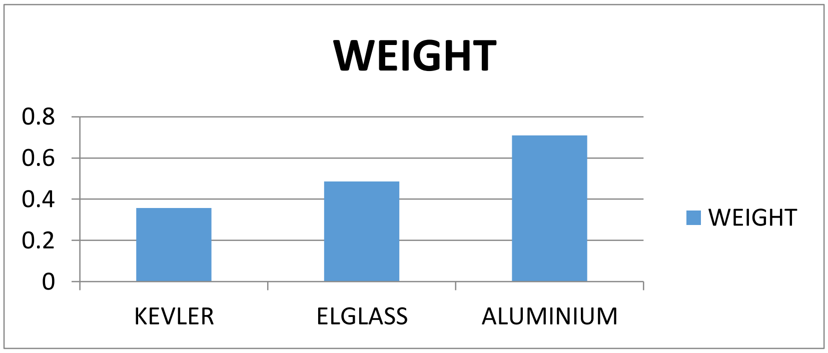


Figure 3.16: weight comparison of three materials

DEFORMATION TABLE

Table3.2: Deformation of different materials with different loads

LOAD	KEVLAR	ALUMINIUM	E-GLASS
500	4.9703	5.3094	10.18
1000	9.9407	10.619	20.37
1500	14.911	15.928	30.56
2000	19.981	21.238	40.74

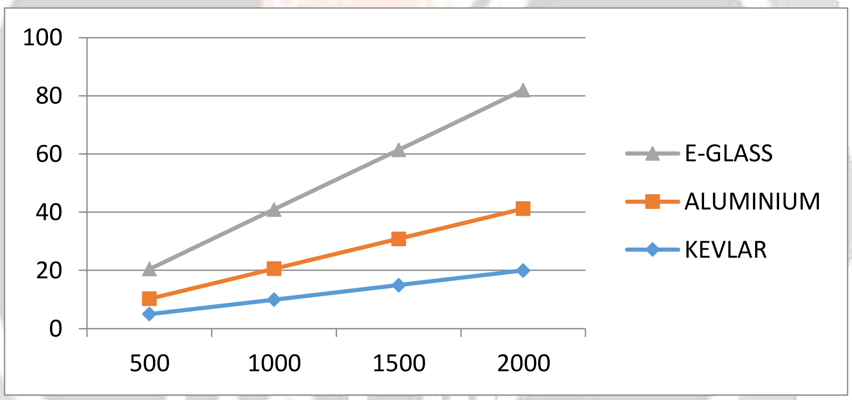


Figure3.17: Deformation of different materials with different loads

STRESS :

Table 3.3:Stress of different materials with different loads

LOAD	KEVLAR	ALU	E-GLASS
500	115.57	116.17	119.28
1000	231.15	232.35	238.5
1500	346.72	348.52	357.83
2000	462.29	446.69	477.11

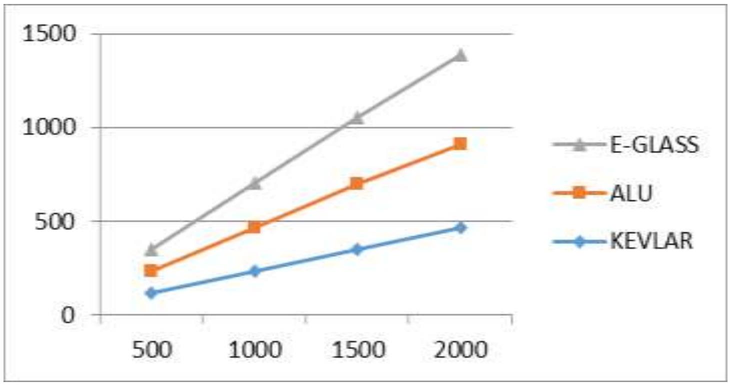


Figure 3.18:Stress of different materials with different loads

STRAIN

Table 3.4:Strain of different matterials with different loads

LOAD	KEVLAR	ALU	E-GLASS
500	0.001541	0.001636	0.002982
1000	0.003882	0.003273	0.005964
1500	0.004623	0.004909	0.008946
2000	0.006164	0.006545	0.011928

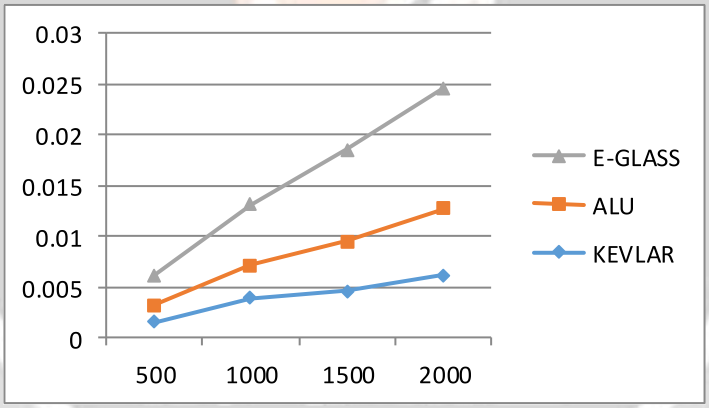


Figure 3.18: Strain of different materials with different loads

4. CONCLUSIONS

Observe from the results

- **Compared to weight :**
  E-glass has high weight, Aluminium has moderate weight, Kelver Has low weight
- **Compared to deformation:**
  E-glass has high deformation, Al has moderate deformation, Kelver has low deformation
- **Compared to stress:**
  E-glass has high stress, Aluminium has moderate stress, Kelver has low stress
- Compared to strain:
  E-glass has high strain, Aluminium has moderate strain, Kelver has low strain

We conclude that composite propellers have more advantages over the conventional metallic propellers. We concentrated on the metal and composite structural analysis of the propeller blade carried out by using the finite element method. By comparing the deformation we can say that kelver will be having more advantages Kelver can with stand more amount of loads stress when compared and by seeing the weight comparison kelver is having less weight when observed with E-glass and Aluminium materials.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] Ajay Baban Pawar(2019)" Design and Simulation of Marine Propeller with Different Blade Geometry" by International Journal of Innovative Science and Research Technology

[2] P. DurgaNeeharika1, P. Suresh Babu (2015) "DESIGN AND ANALYSIS OF SHIP PROPELLER USING FEA" by South Asian Journal of Engineering and Technology

[3] Dervis ozkan(2020)" Carbon Fiber Reinforced Polymer (CFRP) Composite Materials, Their Characteristic Properties, Industrial Application Areas and Their Machinability"

[4] G. P. Nikishkov "INTRODUCTION TO THE FINITE ELEMENT METHOD"

[5] Mohammed Hisham,(2019) "A Research on Kevlar and Hybrid Kevlar Composites"- International Journal of Recent Technology and Engineering (IJRTE) SSN: 2277-3878.

[6]. Engineering material properties and selection by Kenneth G.BudinskiMichael K.Budinski

[7]. Mechanics of composite materials by Robert M.Johnes

[8]. An Accurate Four-Quadrant Nonlinear Dynamical Model for Marine Ralf Bachmayer, Louis L Whitcomb, Mark AGrosenbaugh - 2000 - IEEE JOURNAL OF OCEANIC ENGINEERING

[9]. Nonlinear Output Feedback Control of Underwater Vehicle Propellers.. Thor I Fossen, MogensBlanke - 2000 - IEEE JOURNAL OF OCEANIC ENGINEERING

[10] Properties of engineering materials by RA Higgin, second edition.