CAE ANALYSIS – PROPELLER BLADE

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Abstract - *Basically propeller design aims at achieving high propulsive efficiency at low levels of vibration and noise, generally with minimum cavitations. Achieving this aim is quite difficult with conventional propellers, as we know in modern world vessels have become faster and larger, that is why propeller diameters have remained limited by draught and other factors. Nowadays fiber reinforced composites are getting wide spread use in naval applications in recent times. Vessels and submarines like torpedoes, container ships, etc. and these huge bodies require propeller to drive them. Their performance mainly depends upon the efficiency of the propeller. Its surface finish and geometric properties will ultimately decide the efficiency of the propeller, which are designed for deeper and moderate depth which is required for minimizing of structural weight for increasing payload, Execution and operating range for thatpurpose Al alloy casting comes in use for fabricating propeller blades. In recent years the increased demand for the low weight structural element with acoustic insulation has resulted to take fiber reinforced multi-layer composite in account for propeller. This study carries out the structural analysis of a carbon fiber reinforced plastic aka CFRP propeller blade which is likely to replace the Aluminum propel blade. Further propeller is applied to an external hydrostatic force on alternate side of the blades based on the operating depth and water current around the propeller which also results in differential hydrodynamic pressure between front and back surfaces of blades. For developing the fine mesh model HYPERMESH is imported from SOLIDWORKS by converting it into IGES file. By varying material propertiesin pre-processing stage static structural testing was conducted. And then by importing IGES file, further analysis was done using ABAQUS.*

Key Words: Analysis, Corrosion, Stress, Strain.

1. INTRODUCTION

A propeller converts rotary motion from an engine or other power source into a swirling slipstream which pushes the propeller forwards or backwards. It comprises a rotating power-driven hub, to which are attached several radial airfoil-section blades such that the whole assembly rotates about a longitudinal axis. The blade pitch may be fixed, manually variable to a few set positions, or of the automatically-variable "constant-speed" type.

1.1 Project background

A Propeller is fan like rotating structure which is used to propel the ship by using the power generated by the main engine of the ship. The transmitted power is converted from rotational motion to generate a thrust which imparts momentum to the water, resulting in a force that acts on the ship and pushes it forward.

A ship propels on the basis of Bernoulli's principle and Newton's third law. A Pressure difference is created on the forward and the side of the blade and water is accelerated behind the blades.

1.2 Organization of Report

Chapter 1: Introduction includes fundamental information about the propeller of Ship. The position of the propeller which may vary. The motion which ship propeller imparts with in water to possibly push the water in order to move forward. Some information regarding its power source. The laws on which its motion and other things depends such as Bernoulli's Principles, continuity equation and newton viscosity and motion laws. And the behavior of ship propeller inside the water.

Chapter 2: literature review, In order to be precise in work different data collected which is about different types of propeller. This gave the basic idea about the force and pressure which a propeller blade get act on itself in different scenarios. The size and angle in some areas can change the efficiency of the blade. This majorly helps in reducing formed stress.

Chapter 3: Problem Definition, deals with the problems aroused due to the application of certain propeller in different situation in various type of water level and water pressure. This leads to the failure of the ship propeller which may lead to huge loss. The material used in the process to make the propeller plays the crucial role in stress distribution along it. After defining the problem the methodology works on material of propeller.

Chapter 4: In methodology the process of analyzing the stress on software is defined. The different important parts are mentioned and defined. The materials which possibly can be use to make the propeller blades are mentioned and then filtered to nickel aluminium bronze (NAB) to be the fittest. Then the design aspects are considered in order to make the model in software. Then the analysis carried out in other software by putting the required entities.

Chapter 5: Results and Discussion, Here are the main four results which were produced from the software. Deflection analysis and other three main stress like von and mises stress is shown. All of them are in limit and the deflection is minimum. Every result have their specifications and those are in proper zone of safety of overall propeller.

Chapter 6: It is concluded that the material selection is perfect and its properties are suitable in order to make the propeller so that it can withstand greater pressure forces. The deflection, non mises stresses are in safe band in such given condition. Also the future scope describes that the analysis is of hydrostatic force but the hydrodynamic analysis can also be done by changing or carrying forward these parameters to analyze different aspects like water turbulence stress analysis.

2. LITERATURE RIVIEW

I**W.Y.San, 2017 [1]** for a given a numerical prediction based on CFD, FEM and BEM for submarine body or vessel about its propeller excited acoustic response. Unique solutionacquired by applying boundary condition in Refined Integral Algorithm and pointing the CHIEF points normal to the inner field. And Field point is acquired by calculating by global mesh refinement scheme considering QUAD8 as a boundary element. Errors refining have done up to 10-4 maximum limiting point. Further, In BEM model of sphere RIA applied forit's HIE integral calculation. Open water characteristic of 4381 propeller investigated bycomputational fluid dynamics and experimental outcome compare with achieved yield. "Sub marine with addition propeller" system were simulated by computational fluid dynamics to get propeller variation of thrust and torque. SST turbulent model produced to analyze flow details in boundary of the submarine

Jaya Kishore, S. B. Siddeswara Rao, P. Kumar Babu, 2015 [2] they work on the fluid element method analysis for underwater vehicle for its fortitude for propeller blade. The elements used are aluminium and composite. And also findings are inter-laminar stress for both of material. The work carries out the structural analysis of a propeller blade which has proposed to replace the Al propeller blade and findings that the Metal matrix composite propellers have moreover advantages over the conventional metallic propellers. They work onthe modelling and analyzing the al propeller blade of an underwater vehicle for its fortitude. They used the al material for propeller blade. And they conclude the Metallic propellers can be replaced by composite propellers for enhanced performance with regard to the operating limit. They select the fiber reinforced composite material which has replaced of the al material for under water vehicle for the analysis. They utilize the fluid element method for analysis. And the finally findings of the deflection, frequency, Inter-laminar shear stress.

S. Abdul Mutalib, S.Suresh, S.Jaya Kishore, 2015 [12] "Design and Analysis of Composite Marine Propeller" using ANSYS WORK BENCH, [2015] They were work on the isotropic material such as metal AL and composite materials to analyze its strength and distortion using ANSYS WORK BENCH Software. Dynamic analysis and static analysis are carried out on these various materials and findings the stress, strain and the total deformation for both the al and the composite metals marine propeller using ANSYS software.

3. PROBLEM DEFINITION

3.1 Problem Statement:-

After reading research papers which were proposed for analyzing the stress on propeller blade we come to one sub conclusion that many ships and naval vessels meet with the accidents due to the propeller failure which is ultimately caused by improper load distribution on surface propeller blade also main cause is due to improper analyzing of stress which going to get applied by varying hydro pressure which is caused due to the high turbulent flow of waves that are caused in ocean bed.

Selection of material in manufacturing of propeller plays a crucial role for analyzing the stress on it. As there are few materials which comes to the failure over the course of time and due to high turbulent flow of water current. Hence we can use different types of composite material to overcome this issue.

4. METHODOLOGY

By referring different research papers which have proposed analysis over a propeller blade, concluding the important points and we proceed to the further process. For the ease of the overall procedure, we consider suitable properties of the material, geometry and dimensions for smoothening its further analysis. Hence it can function suitably. Specific metals or composite material scan only be used for propeller. Selecting improper material may lead to ultimate failure. Hence selection of material plays a crucial role in the functioning of the propeller. We design a 3D propeller model on Solidworks, by giving it approximate dimensions and angles, so that it can mimic the actual propeller. Thereafter, we import it tothe desirable FEA software i.e. ABAQUS. Then the model is assigned proper material. In the final step, as per the finite element analysis, we impose the boundary conditions and proper directed pressure. Henceforth, the results are generated.

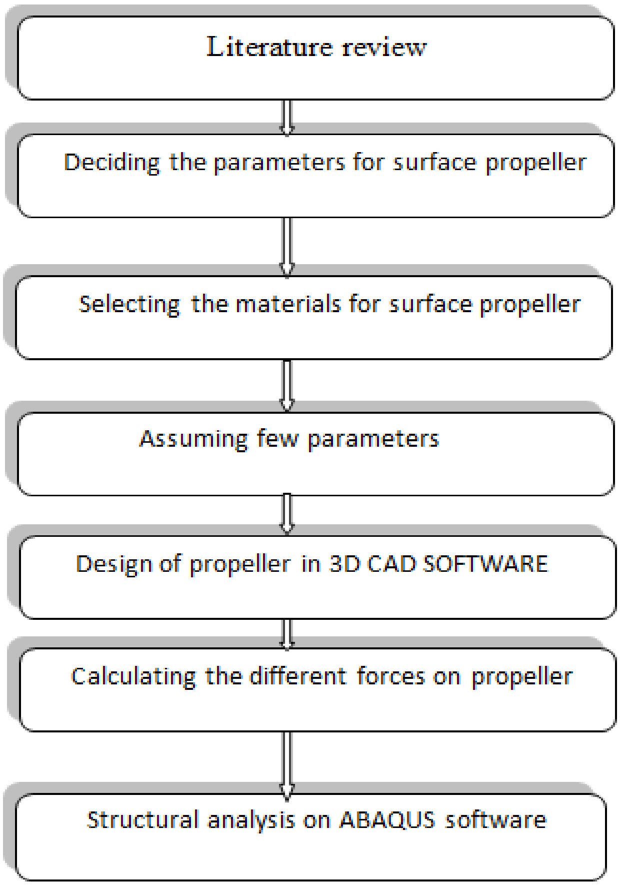

Fig - 4.1: Methodology Flow Chart

4.1 Propeller Parts

4.1.1 Blade Tip:- The maximum reach of the blade from the center of the propeller hub. It separatesthe leading edge from the trailing edge.

4.1.2 Leading Edge:- That part of the blade nearest the boat, which first cuts through the water. It extendsfrom the hub to the tip.

4.1.3 Trailing Edge:- That part of the blade farthest from the boat. The edge from which the water leaves the blade. It extends from the tip to the hub (near the diffuser ring on through-hub exhaust propellers).

4.1.4 Blade Face:- Side of the blade facing away from the boat, known as the positive pressure side of the blade.

4.1.5 Blade Back:- Side of the blade facing the boat, known as negative pressure (or suction) side of the blade.

4.1.6 Inner Hub: - The forward end of the inner hub is the metal surface which generally transmits the propeller thrust through the forward thrust hub to the propeller shaft and in turn, eventually to the boat.

4.1.7 Outer Hub:- For through-hub exhaust propellers. The exterior surface is in direct contact with the water. The blades are attached to the exterior surface. Its inner surface is in contact with the exhaust passage and with the ribs which attach the outer hub to the inner hub.

4.1.8 Skew Angle:- The term angle skew or skew angle is generally applied to the difference between the alignment of an intermediate or end support and a line square to the longitudinal axis of the blade above. Thus, on a straight bridge, the skew angle at all supports would normally be the same and the term skew angle can be applied to the bridge as a whole.

Fig - 4.2: Propeller Blade

4.2 Material Considered

There are few materials which can be considered for the design of the ship propeller. Several physical properties such as stress, tensile strength, modulus of elasticity, hardness number, specific gravity are taken into account for designing of the propeller. Some of the materials with their physical properties are given as follows.

Table -1: Material Properties

Material	Stress (MPa)	Tensile strength	Modulus of elasticity
Manganese bronze	200	510	107
Chromium Stainless steel	450	680	200
Low carbon steel	250	450	200
Austenitic cast iron	235	435	105
NAB	295	635	125
Nikalium	270	680	124
Novoston	305	685	117
Superston seventy	345	725	117
Sonoston	285	565	77

Among all above materials NAB (Nickel Al Bronze) is chosen for propeller blade due to its high tensile enduringness and moderately high modulus of elasticity Propellers being rotating devices need to be withstand terribly high hydrodynamic force, centrifugal force, torsion and hydrodynamic lift. Thus NAB is appropriate according to the design parameters. There's an outsizes market for nickel, aluminium, bronze in naval applications, significantly for the submarine fleets of the globe. The most applications are in seawater piping and valve systems, weapons handling, versatile couplings, sonar equipment, seawater external hatches, hydraulic valves and bearings, fasteners and waterproofing flanges, low noise propellers, propulsion equipment and periscope assemblies. These applications make use of some of the important properties of the nickel aluminium bronzes: good corrosion resistance, non-sparking, wear resistance, high strength and good impact properties. The alloys also exhibit good anti- damping properties twice that of steel, which is important in submarines in suppressing soundfor silent operations. Non-sparking and wear resistance become particularly important in weapons' handling systems. The various grades with lower iron and nickel contents can be manufactured with magnetic permeability below 1.03 μ

4.3 Corrosion Resistance

Nickel, aluminium, bronze relies on the formation of a thin adherent copper/aluminium- rich oxide film of Cu_2O and Al_2O_3 which is self-repairing even in media containing low oxygen levels. The oxide layer also contains iron and nickel oxides which tend to form under longer exposure and, the greater the concentration of oxygen, the more protective is the film. It is vitally important in the commissioning of equipment, particularly in seawater applications, that the system is flushed through with clean aerated seawater for several hoursto assist in building up the protective layer and this is important for long-term corrosion resistance. On occasion, new marine vessels in dock are flushed through with contaminated water and this has proved to be problematic if the water contains high sulphide levels.

4.3.1 Pitting

Fig - 4.3: Pitting

Pitting can occur through a process termed differential aeration due to localized damage of the oxide film or internal defects uncovered by machining or fettling. Examples of defects are oxide inclusions, slag inclusions, porosity and foreign deposits. Pitting can also be caused by attack of less noble phases within the structure. Such attack is more likely to occur in an „as cast" structure than wrought products where the internal integrity of the metal ismore uniform and finer grained through hot working and heat treatment. Pitting corrosion in all metals is an important consideration, particularly in thin-walled components such as pipework where, because of the localized nature of the corrosion, perforation can occur. Nickel aluminium bronze has good resistance to pitting corrosion, particularly in the wrought condition. Cathodic protection, e.g. coupling to a less noble alloy, can help reduce the risk of this type of corrosion but has the disadvantage of suppressing the natural ability of this alloyto resist marine growths.

4.4 Propeller Design

4.4.1 Deign of Propeller in 3D CAD Software

After considering NAB as material for propeller, its 3D model is prepared from 3D CAD software (Solidworks) by considering design dimensions as per requirement of the ship. In this design blade length, hub diameter (inner and outer), skew angle, fillet radius, blade thickness, hub length etc. are considered as per the proper functioning of propeller so that it can propel within sea water with minimum stress bending also the design is such that hydrostatic resistance.

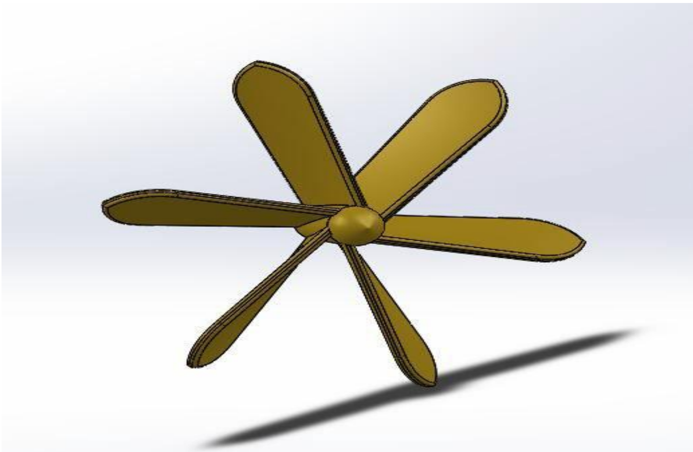

Fig – 4.4: CAD Model

Table – 2: Dimensions of Propeller Blade

Sr. No.	Entity	Dimensions
01	Hub Diameter	1 meter
02	Hub Diameter(Inner)	0.8 meter
03	Hub Length	2 meter
04	No. of Blade	06
05	Blade Length	4 meter
06	Blade Width	1.5 meter
07	Blade Thickness	0.2 meter
08	Blade Fillet Corner	0.1 meter
09	Blade Area	6 meter^2
10	Skew Length	15^0

4.4.2 Design Calculations

Calculations of pressure on blades

Propeller Blades are always under the constant pressure of sea water. Generally propeller blades are located 10 to 20 meter under sea level. Hence average pressure on the propeller can be calculated as follows.

P = ρgh

ρ=Density of sea water=1025 Kg/m^3

g=acceleration due to gravity=9.81 m/s^2

h= average depth of propeller from sea level=14.5 meter

P = 1025 × 9.81 × 14.5
P = 145801.125 N/m^2

Calculations of average force on blades

Length of blade = 4 meter
Breadth of blade = 1.5 meter
Blade area on rectangular contour = Length × Breath
= 4 × 1.5
= 6 m^2

Average Force = Average Pressure × Area
= 145801.125 × 6
= 874806.75 N

Factor of safety
Generally factor of safety for propeller blade in marine applications is considered as 2.
Hence,
Shear yield force of material is calculated as follows:-

Shear Yield Force = Factor of Safety × Work Force
= 2 × 874806.75
= 1749613.5 N

Average bending of bade at center of mass

Average Force (F) = 874806.75 N
Length of blade (L) = 4 m
Breadth of blade = 1.5 m
Depth (Thickness of blade) = 0.2
Young's Modulus = 110 GPa

Equation of bending can be given as follows:-
Moment of inertia of blade
= ML^2/12
= 9108 × 16/12
= 12144 Kg-m^2

$$\delta = \frac{FL^3}{3YI}$$

$$= \frac{874806.75 \times 4^3}{3 \times 12144 \times 110 \times 10^9}$$

$$= 4.25 \times 10^{-2} \text{ mm}$$

4.4 Structural Analysis on ABAQUS Software

Design of the propeller blade is ported in ABAQUS software from SOLIDWORKS.

In this process following steps are followed:-

1. Material was created by providing input property like density, elastic properties like Young's modulus, poisson's ratio, plastic properties like plastic strain, Yield stress etc. and the created material was Nickel, Aluminum Bronze (NAB).
2. Then the created material was assigned to the imported part i.e. propeller blade by assigned material command
3. In assembly mounting the center axis was selected at center of propeller hub.
4. The required result stress, strain and deflection parameter were selected.
5. Then according to the finite analysis method the boundary conditions were applied by keeping all degrees of freedom zero for inner diameter of hub. i.e. fixing the hub at point in a space.
6. After this, design steps are created as follows:-
   a. Selection of mechanical steps.
   b. Pressure was selected as input parameter
   c. Value of pressure is created
   d. The pressure amplitude is created for 0 to 0 and 1 to 1

e. Then by selecting propeller blade faces the pressure were equally distributed over it.

7. By following above process, for accurate results the mesh is created by keeping the seed size as 0.03 for accurate results.

   The elements are quadratic tetrahedral elements of inserted seed size 2221294 quadratic tetrahedral elements are formed. The total number of nodes are 3174938 formed on propeller design. This was obtained by query tool from the toolbar. This increases the accuracy of result.

8. In Post processing the job were created for analysis purpose. First the job was submitted for data check the result were obtained.

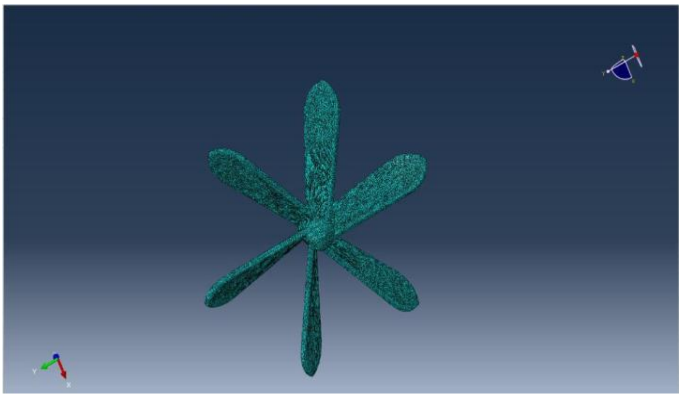

Fig – 4.5: Mesh Model form Software

5. RESULT AND CONCLUSION

Based on above steps from methodology, ABAQUS result were obtained as follows

5.1 Deflection Analysis

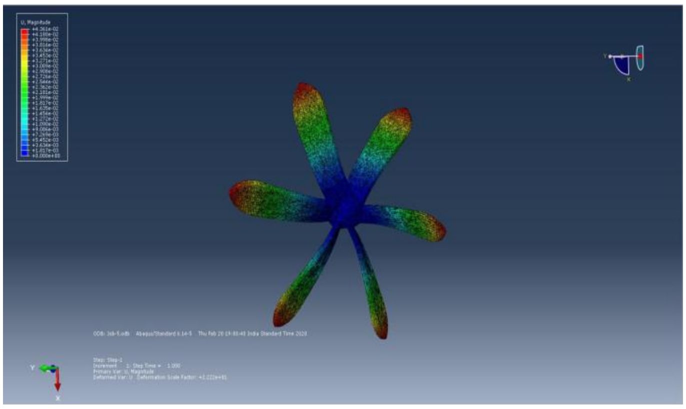

Fig – 5.1: Deflection Analysis

By "U translation and rotations" in ABAQUS software after providing pressure as input parameter above result is obtained for average deflection of the propeller blade. The value of pressure as an input parameter is considered as 145801.125 N/m^2 and the deflection obtained as 4.316×10^{-2} mm. which is close to the calculated value. And the calculated value was approx. 4.25×10^{-2} mm.

5.2 Stress Analysis

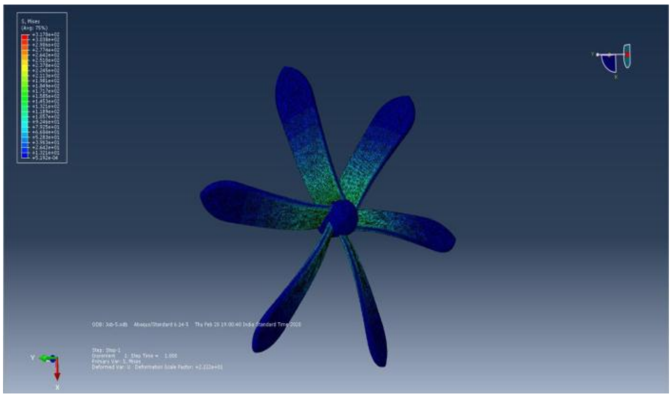

Fig – 5.2: Stress Analysis on Propeller Blade

The shear stress due to sea water on surface area of blade is deforming force per unit area. Byproviding input parameter as pressure above result was obtained where the maximum stress was obtained at root of the blade which is 1.453×10^2 N/mm^2 which is under completely safe category. In ABAQUS result it is under green zone condition hence the design is safe.

5.3 Von MISES Stress Analysis

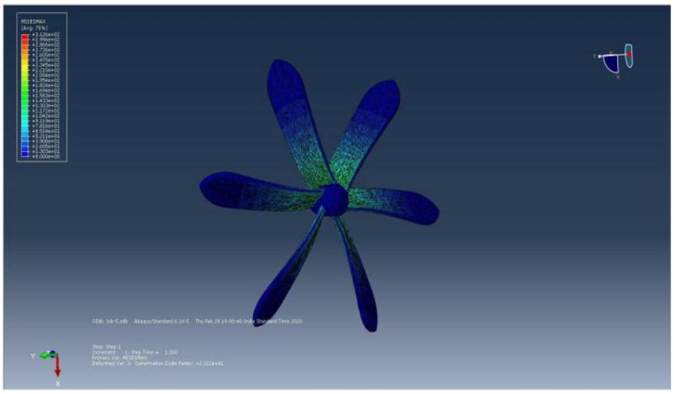

Fig – 5.3: Von Mises Stress Analysis

Von Mises stress also known as equivalent tensile stress beyond which material is said to start yielding that is It starts plastic deformation. Mises stress in important in case of ductility of the material while designing propeller blade stresses must be well below mises stress limit.

In design of propeller blade as per the working pressure condition Mises stress is maximum near root of the blade having value 1.563 x 10^2 N/mm^2. Which is under safe design condition. In ABAQUS design shown in above diagram, entire design is under green zone condition which means design is completely safe Mises stress analysis.

5.4 Stress Analysis

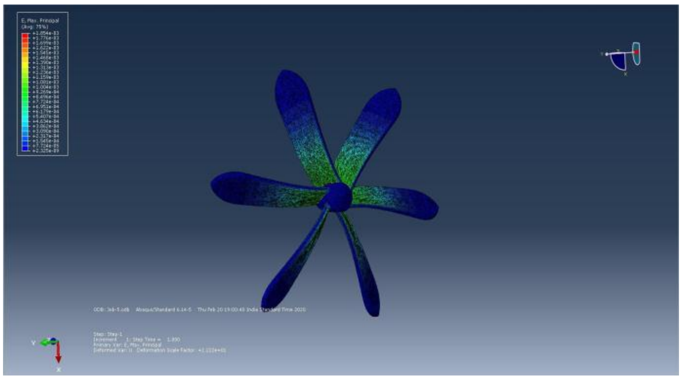

Fig – 5.4: Stress Analysis

Change in dimension per unit original dimension. Here change in dimension is length hence type of strain is longitudinal. Due to hydrostatic stress of sea water on surface of the blade the length of blade slightly increases due elastic properties of the NAB.

Generally for safe design of the blade strain must be as low as possible. In ABAQUS design the obtained result shows that maximum strain occurs at the root of the blade. The region is shown by pale yellow color which is under complete to moderate safe region. The maximum strain value is 1.159 x 10^{-3}.

6. CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

The propeller blades under hydrostatic stress are examined and their results are obtained from ABAQUS software by putting all the values of stresses at the depth of 15 meters from sea level.

Following conclusion are obtained from results:-

1. From stress analysis it is concluded that design of blade is under "completely safe" condition.
2. From deflection of blades analysis design is under "completely safe" condition.
3. From Mises Stress analysis design is under "complete to moderately safe" condition.
4. Material selected for propeller blade i.e. NAB is proven to be efficient for the design of hydrostatic stress condition

6.2 Future Scope

In this project we have considered hydrostatic stress analysis on propeller blades of ships. This project certainly has some future scopes so as to ensure smooth, hustle free and efficient propeller performance.

Some of the future scopes are as follows:

1. Hydrodynamic stress analysis with hydrodynamic lift and drag force consideration.
2. Water turbulence stress analysis.
3. Factor of safety calculation considering miscellaneous stress due to varying aquatic conditions and aquatic bodies.

REFERENCES

[1] Hussain, N. A., Arshad, M. R., and Mokhtar, R. M., "Underwater Glider Modelling and Analysis for Net Buoyancy, Depth and Pitch Angle Control", Ocean Engineering Vol. 38, pp: 1782–1791

[2] M. jourdian, visitor and J.L.Armand. "Strength Of Propeller Blades-A Numerical Approach",IJESC the socity of naval architects and marine engineers,,Page 20-1-21-3, May 24-25

[3] Rao, Y. S., and Reddy, B. S., "Harmonic Analysis of Composite Propeller for Marine Applications", International Journal of Research & Technology (IJERT), Vol.1 Nov-2012 pp: 257-260

[4] Jaya Kishore, B. Siddeswara Rao, P. Kumar Babu, "FEM Analysis on Submarine Propeller Blade for Improved Efficiency by using Solid Works and ANSYS-Workbench", International Journal of Emerging Engineering Research and Technology Volume 3, Issue 11,pp. 144-151, November 2015

BIOGRAPHIES

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