DESIGN AND STRESS ANALYSIS OF A FOUR BLADE MARINE PROPELLER

A project report submitted in partial fulfilment of the requirement for the award of the degree of

BACHELOR OF
TECHNOLOGY IN
MECHANICAL ENGINEERING

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ABSTRACT

Marine propellers, although submerged in water aft of the ship, form an integral part of a ship and play a vital role in ship propulsion. Much has been said and published on the development of the marine propeller from the time of antiquity to the present age, but there is more to be done. Therefore, this paper focuses on the design procedure of four bladed marine propellers with specific interest on engines with 85Bhp and ship speed of 30knots for the design of the fixed pitch propeller. this work used the Bp standard chart using the optimum design line to carry out the design analysis of propellers for a ship with a detailed calculation of the various stages involved in the derivation of the basic propeller. The optimal design parameters are taken and modelling is done in CATIA v5 which is a high end modelling software and FEM procedure is adopted for conducting structural analysis in AUTODESK INVENTOR simulation software. Aluminum 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 multi layer composite propeller. The present work carries out the structural analysis of a CFRP (carbon fiber reinforced plastic) propeller blade which proposed to replace the Aluminum propeller blade. The propeller blade is modelled and designed such that it can withstand the static load distribution and finding the stresses and deflections for both aluminum and carbon fiber reinforced plastic materials. By using Autodesk Inventor software static structural analysis is carried out for both aluminum and CFRP.

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CHAPTER - 1

INTRODUCTION

1.1INTRODUCTION TO SHIP PROPULSION

Ships and under water vehicles like submarines, torpedoes and submersibles etc., uses propeller as propulsion. The blade geometry ant its design is more complex involving many controlling parameters. The strength analysis of such complex 3D blades with conventional formulas will give less accurate values. In such cases numerical analysis (Finite Element Analysis) gives comparable results with experimental values. In the present project the propeller blade material is converted from aluminum metal to fiber reinforced composite material for underwater vehicle propeller. Such complex analysis can be easily solved by finite element method techniques.

1.2 PROPELLER

The movement of a ship through water is achieved by the power so developed in the engine via the propeller shaft to the propeller in water. The distance or forward motion depends mainly on the propeller pitch which is defined as how far the propeller can travel for one revolution of the shaft.

A propeller is a rotating fan-like structure which is used to propel the ship by using the power generated and transmitted by the main engine of the ship which transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and the rear surfaces of the air foil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. A propeller is sometimes also known as screw.

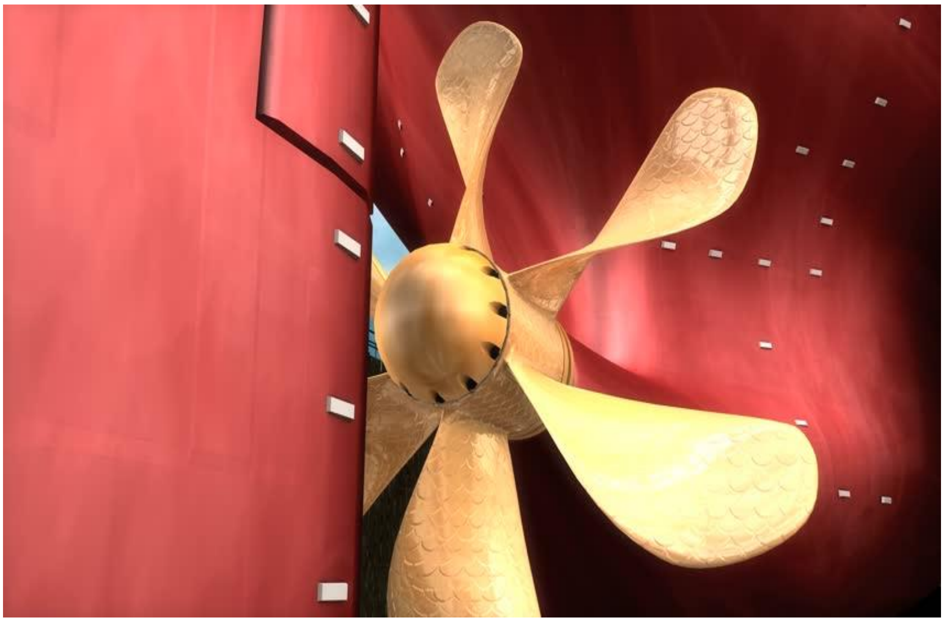


Fig 1. 1 Marine propeller

The thrust from the propeller is transmitted to move the ship through a transmission system which consists of a rotational motion generated by the main engine crank shaft, intermediate shaft and its bearings, stern tube shaft and it's bearing and finally by the propeller itself.
A ship can be fitted with one, two and rarely three propellers depending upon the speed and requirements of the vessel.

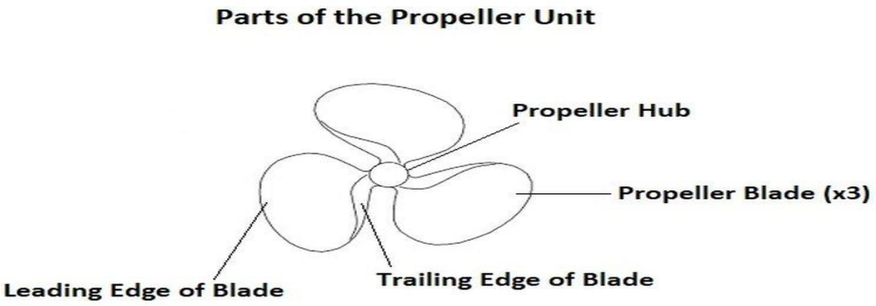


Fig 1. 2 Parts of propeller unit

1.3 PRINCIPLE OF PROPELLER

- Propellers are 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 newtons law produces equal and opposite reaction of you moving.
- It based on push and pull concept.

1.4 MARINE PROPELLER

Propeller blades displace water, to create the forces that move a boat forward. . The propeller works by turning torque into thrust. In other words, it converts power from the engine into an action. The action of turning the propellers creates force, by moving the flow of water downward and behind the blades.

Today, conventional marine propellers remain the standard propulsion mechanism for surface ships and underwater vehicles. Modifications of basic propeller geometries into water jet propulsors and alternate style thrusters on underwater vehicles has not significantly changed how we determine and analyse propeller performance.

We still need propellers to generate adequate thrust to propel a vessel at some design speed with some care taken in ensuring some “reasonable” propulsive efficiency.

Considerations are made to match the engine’s power and shaft speed, as well as the size of the vessel and the ship’s operating speed, with an appropriately designed propeller. Given that the above conditions are interdependent (ship speed depends on ship size, power required depends on desired speed, etc.) we must at least know *a priori* our desired operating speed for a given vessel. Following this we should understand the basic relationship between ship power, shaft torque and fuel consumption.

Fig 1. 3 Marine propeller under water

1.5 CLASSIFICATION OF MARINE PROPELLERS

Propellers are be classified on the basis of several factors. The classification of different types of propellers is shown below:

1.5.1 Classification by Number of Blades

Propeller blades may vary from 3 blade propeller to 4 blade propeller and sometimes even 5 blade propeller. However, the most commonly used are 3 blades and 4 blade propellers. The propeller efficiency will be highest for propeller with a 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.

3 BLADE PROPELLER

A 3 blade propeller has the following characteristics:

- The manufacturing cost is lower than other types.
- Are normally made up of aluminum alloy.
- Gives a good high-speed performance.
- The acceleration is better than other types.
- Low-speed handling is not much efficient.

Fig 1. 4 3 bladed marine propeller

4 BLADE PROPELLER

A 4 blade propeller has the following characteristics:

- The manufacturing cost is higher than the 3 blade propellers.
- 4 blade propellers are normally made up of stainless steel alloys.
- Have better strength and durability.
- Gives 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 1. 5   4 bladed marine propeller

5 BLADE PROPELLER

A 5 blade propeller has the following characteristics:

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

6 BLADE PROPELLER

A 6 blade propeller has the following characteristics:

- 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

Large container ships are mainly fitted with 5 or 6-bladed propellers.

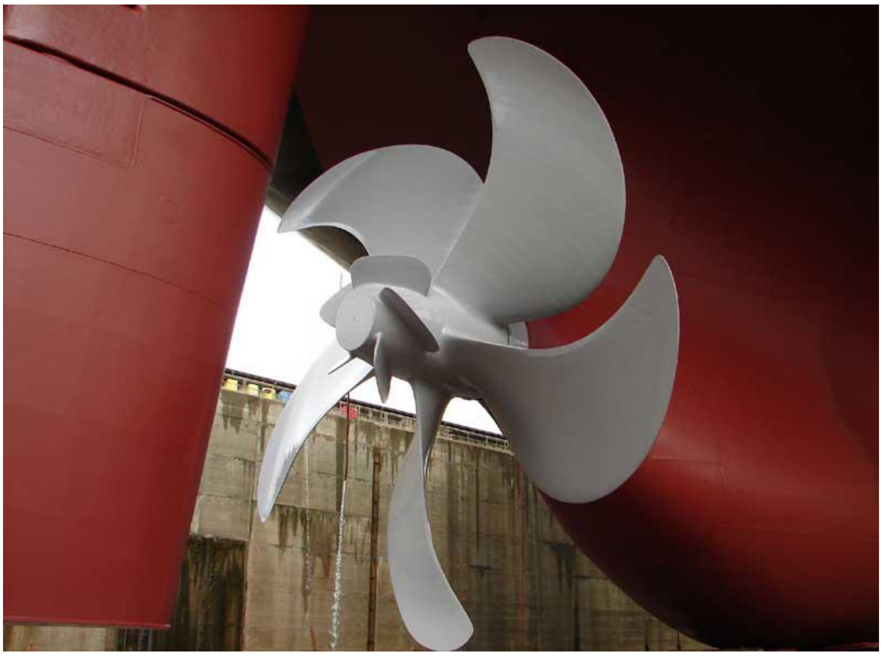


Fig 1. 6 5 bladed marine propeller

1.5.2 Classification by pitch of the blade

Pitch of a propeller can be defined as the displacement that a propeller makes for every full revolution of 360˚. The classification of the propellers on the basis of pitch is as follows.

A)FIXED PITCH PROPELLER (FPP)

The blades in fixed pitch propeller are permanently attached to the hub. The fixed pitch type propellers are casted and the position of the blades and hence the position of the pitch is permanently fixed and cannot be changed during the operation. They are normally made from copper alloy.

Fixed pitch propellers are robust and reliable as the system doesn’t incorporate any mechanical and hydraulic connection as in Controlled Pitch Propeller (CPP). The manufacturing, installation and operational costs are lower than controlled pitch propeller (CPP) type. The manoeuvrability of fixed-pitch propeller is also not as good as CPP. This type of propellers are fitted in a ship which does not have good manoeuvrability requirements.

B)CONTROLLABLE PITCH PROPELLER (CPP)

In Controlled Pitch type propeller, it is possible to alter the pitch by rotating the blade about its vertical axis by means of mechanical and hydraulic arrangement. This helps in driving the propulsion machinery at constant load with no reversing mechanism required as the pitch can be altered to match the required operating condition. Thus the manoeuvrability improves and the engine efficiency also increases.

This drawback includes the possibility of oil pollution as the hydraulic oil in the boss which is used for controlling the pitch may leak out. It is a complex and expensive system from both installation and operational point. Moreover, the pitch can get stuck in one position, making it difficult to manoeuvre the engine. However, the propeller efficiency for the CP propeller is slightly lower than the same size FP propeller due to the larger hub to accommodate the blade pitch mechanism and pipings.

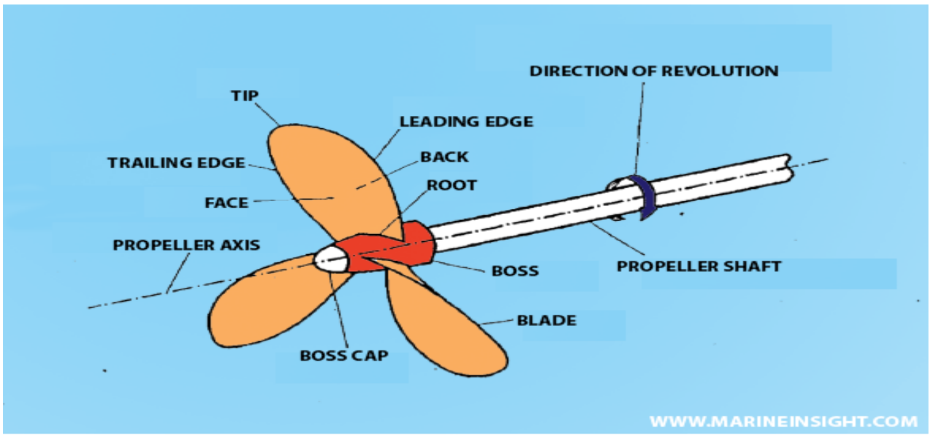


Fig 1. 7 parts of screw propeller

1.5.3 Classification based on direction of rotation (right handed & left handed):

A propeller is called right-handed if it rotates clockwise in forward gear (when viewed from the stern). A right-handed propeller in forward gear will tend to push the stern of the boat to starboard (thereby pushing the bow to port and turning the boat counter-clockwise) unless the rotation is corrected for. In reverse gear, the turning effect will be much stronger and with opposite direction (pushing the aft to port). A left-handed propeller acts analogically to the right-handed but with all rotation directions reversed.

1.6 PROPELLER TERMINOLOGY

a. Diameter – The diameter of the imaginary cycle scribed by the blade tips as the propeller rotates.

b. Radius – The distance from the axis of rotation to the blade tip. The radius multiplied by two is equal to the diameter.

c. Blade face – The pressure side, pitch side. Aft side of the blade surface facing the stern.

d. Blade number – Equal to the number of blades on the propeller.

e. Blade tip – Maximum reach of the blade from the center of the hub separates the leading and trailing edges.

f. Hub – Solid cylinder located at the center of the propeller. Bored to accommodate the engine shaft. Hub shapes include cylindrical, conical, radius and barreled.

g. Blade root – Fillet area. The region of transition from the blade surfaces and edges to the hub periphery. The area where the blade attaches to the hub.

h. Pitch (*P*) – The linear distance that a propeller would move in one revolution with no slippage.

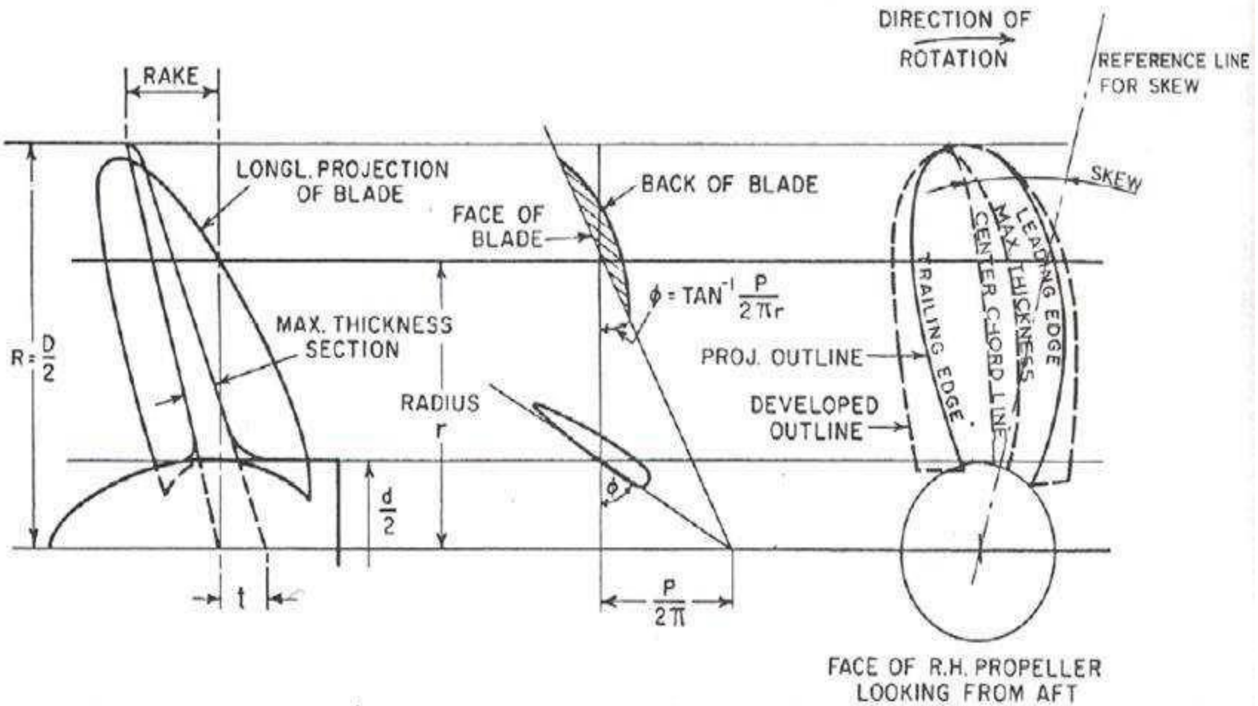
i. Rake – The fore or aft slant of a blade with respect to a line perpendicular to the propeller axis of rotation.

j. wake (*w*) – this explains the overall disturbances created by the motion of the ship as a result of the drag of the hull, the streamline flow past the hull and the wave patterns formed by the ship on the surface water.

k. Developed Area ($_{D}A$) - This is the actual area of driving faces.

l. Projected Area ($P\ A$ **)**-. This is the sum of the blade areas projected into a plane which is perpendicular to the axis of the screw

m. Expanded Area ($E\ A$)-. This is the sum of area of all blades enclosed in an expanded blade outline outside the hub.



Developed area ratio = $DAR = \frac{A_D}{A_O}$

Projected area of blades (on transverse plane) outside hub = A_P

Projected area ratio = $PAR = \frac{A_P}{A_O}$

Blade width ratio = $BWR = \frac{\text{Max. blade width}}{D}$

Mean width ratio = $MWR = \frac{A_D/\text{length of blades (outside hub)}}{D}$

Diameter D Pitch ratio = $\frac{P}{D}$

Pitch P Blade thickness ratio = $\frac{t}{D}$

No. of blades 4 Pitch angle = ϕ

Disk area = area of tip circle = $\frac{\pi}{4} D^2 = A_O$

Developed area of blades, outside hub = A_D

Fig 1. 8 Typical propeller drawing

1.7 MATERIAL SELECTION:

The stress-strain curve for a composite lies in between the stress-strain curves of the fibers and matrix. The actual location of the composite stress strain curve will depend upon the relative volume fraction of the constituents. If the fiber volume fraction is high the composite stress strain curve will be close to the fiber stress-strain curve. On the other hand the composite stress–strain curve may be closer to the matrix stress-strain curve for a higher matrix volume fraction. Marine propellers are made from corrosion-resistant materials as they are made operational directly in seawater which is a corrosion accelerator. The materials used for making marine propeller are an alloy of aluminium and stainless steel. Other popular materials used are alloys of nickel, aluminum and bronze which are 10-15 % lighter than other materials and have higher strength.

1.8 CONSTRUCTION

The construction process of the propeller includes attaching a number of blades to the hub or boss by welding or forging in one piece. Forged blades are highly reliable and have greater strength but are expensive as compared to welded ones.

A marine propeller is constructed by sections of helicoidal surfaces acting together to rotate through the water with a screw effect.

1.9 WORKING

For vehicles running on land, the propelling system which drives them is different. In those systems, the engine powers the shaft which is attached to the vehicle tyre to move ahead of the body of the vehicle. However, for ships which are displaced in water, there are no such tyres or surfaces where they can ride.

The ship is displaced in the water and the propeller is used to drive the ship ahead or backwards, depending upon the direction of rotation or pitch of the propeller. The engine of the ship is connected to the propeller of the vessel via shaft arrangement.

As the engine rotates the propeller, the radiating blades which are set at a particular pitch form a helical spiral, similar to a screw. While doing this, it transforms the power of rotation into thrust which is linear in nature.

This linear thrust will act upon water such that as the propeller blades rotate it creates the pressure between the surface in front and back of it. Hence, a mass of fluid is accelerated in one direction creating a reactive force which helps the body attached to the propeller (which is the ship) moves ahead. For the ship to move in the reverse direction, the engine and hence the propeller is rotated in an anti-clockwise direction. This will reverse the thrust and the ship will move astern. However, the engine of the FP-propeller is always designed for clockwise rotation when sailing ahead, hence, pro-long operation in astern direction is not efficient.

For ships fitted with CP propeller, the engine direction is not affected hence astern efficiency of the ship is better than that of a fixed-pitch propeller.

1.10 PROPELLER WITH ANGLED BLADES

Propeller blades are fixed to their hub at an angle, just as the thread on a screw makes an angle to the shaft. This is called the pitch (or pitch angle) of a propeller and it determines how quickly it moves you forward when you turn it, and how much force you have to use in the process. Sometimes (and this can be confusing) the distance a propeller moves you forward as it turns through one complete revolution is also called its pitch, but it's easy to see that the angle of the blades and how far they move you forward in a single rotation are related.

Fig 1. 9 Angular bladed propeller

1.11 PROPELLER WITH TWISTED BLADES

Another complicating difference between screws and propellers is that propeller blades are twisted as well as angled. while a screw has a constant pitch, the pitch of a propeller tip blade *changes* along its length. It's steepest at the hub (in the center) and shallowest at the (outer edge). Here's why. Look side on at an airplane propeller and you'll see it resembles an airfoil (aerofoil), a wing that has a curved top and flat bottom.

An airfoil wing produces lift mainly by accelerating air downward and it works most efficiently when it's tilted slightly backward to make what's called an angle of attack with the horizontal. Now suppose you take two airfoil wings, mount them either side of a wheel and spin it around.

Turn fast enough, with the wings at just the right angle, and instead of generating lift you'll produce a screwing effect and a backward force that pushes you forward. This is effectively how a propeller works.

Different parts of a propeller move at different speeds: the tips of the blades move faster than the parts nearest the hub. To ensure a propeller produces a constant force (thrust) all along its length, the angle of attack needs to be different at different points along the blade—greater near the hub where the blade is moving slowest and shallower near the tips where the blade is moving fastest—and that's why propeller blades are twisted. Without the twist, the propeller would be making different amounts of thrust at the hub and the edges, which would put it under great stress.

Fig 1. 10 Propeller with twisted blades

1.12 PROPELLER HUB

The propeller hub is required irrespective of the manner in which the propeller shaft exits the hull of the ship. There The center portion of a propeller to which the blades are attached and by which the propeller is attached to the engine.
can be three main types of exits-

- Shaft bossing,
- P bracket holder, and
- A bracket holder.

Shaft bossing refers to the arrangement in which the propeller hub is placed right at the mouth of the stern tube, such that there is almost no portion of the marine shaft that is externally located.

On the other hand, the A and P bracket holders are built as overhang appendages that are located astern of the stern tube. They are more common on cruiser type sterns as compared to transom sterns. The marine shaft passes through the stern tube and then through the bracket supported by either a P or A type holder. The shaft terminates astern of the bracket at the propeller hub. Choosing between the different arrangements depends on the vessel type and restrictions on shaft exposure. However, depending on the arrangement, the hub must be properly constructed.
In shaft bossing, the hub is partially exposed to the external fluid. Thus, it must be internally waterproofed, and special gland systems are used to prevent the leakage of any fluids across the hub.

In addition, the hub must be well lubricated so as to reduce friction within the stern tube. For P and A bracket arrangements, the entire hub is exposed to water.

Due to the extended length of the propeller shafts, vibrational and catenary forces will act on the hub. Thus, it must be suitably built to withstand large vibrational shocks. Waterproofing is required, but only to prevent fluid entry into the internal mechanism.

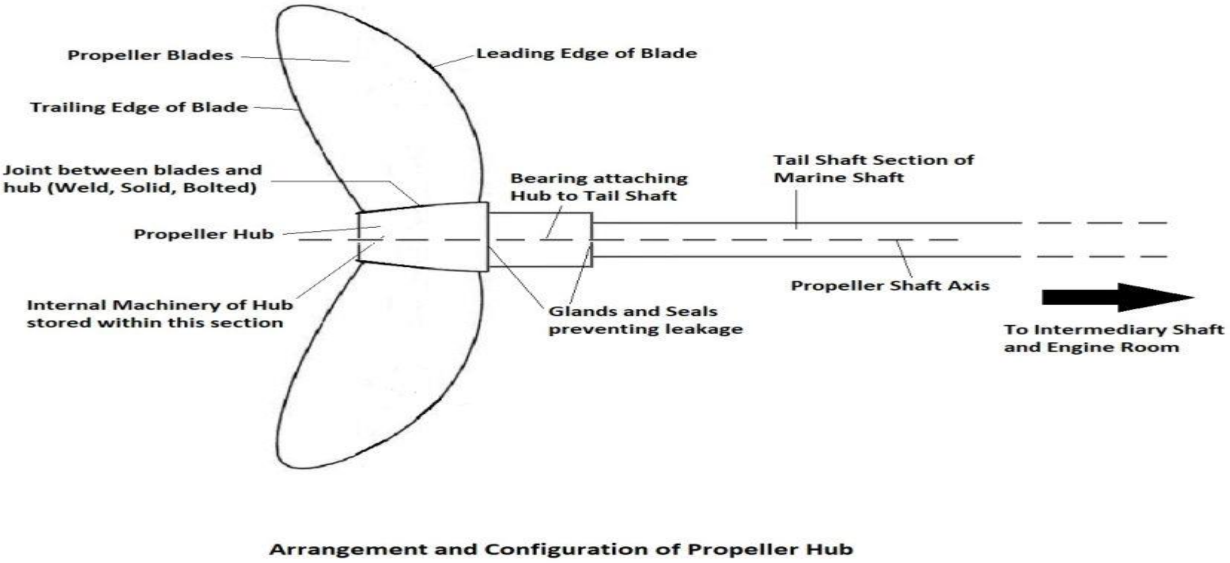


Fig 1. 11 Arrangement of propeller hub

1.13 PROPELLER SHAFT

The drive shaft (also called propeller shaft or prop shaft) is a component of the drive train in a vehicle, with the purpose of delivering torque from the transmission to the differential, which then transmits this torque to the wheels in order to move the vehicle.

1.13.1 TYPES OF PROPELLER SHAFT:

The ship engine is connected to the propeller via different shafts connected together, which can be named as:

1.Thrust Shaft

2.Intermediate Shaft

3.Tail Shaft

1.THRUST SHAFT:

The crankshaft of the engine is first connected to the thrust shaft which passes through the thrust bearing whose main function is to transfer the thrust to the ship’s structure. The casing of the thrust bearing is similar in construction to that of main engine bedplate and the bearing is lubricated by main engine lubrication system oil. The material of the thrust shaft is usually solid forged ingot steel.

2.INTERMEDIATE SHAFT:

The thrust shaft is then connected to a long intermediate shaft which comes in parts and joined together using solid forged couplings. The length and number of intermediate shaft joined together depends on the location of the main engine as a larger ship will have more distance between the main engine and the propeller. The material of the intermediate shaft is usually solid forged ingot steel.

3.TAIL SHAFT:

The Tail shaft, as the name suggests, is the end part of the shafting arrangement and carries the propeller. The tail shaft itself is carried on a lubricated stern tube bearing with seals as it connects and protrudes out of the ship’s engine room into the open sea, carrying the propeller.

The lubrication system can be of oil-based or water type. The tail shaft transmits the engine power and motion drive to the propeller. The material of the tail shaft is usually high strength duplex stainless steel alloy.

1.14 PROPELLER THEORY

Propeller theory is the physics governing the design of effective propellers. A propeller is the most popular propulsor on ships and small aircraft.

1.14.1 THEORY OF OPERATION

A propeller gives momentum to a fluid, which creates a force to act on the ship. The theoretical efficiency of any propulsor is that of an actuator disc in a perfect fluid. This is termed the Froude efficiency and is a natural limit that any device cannot exceed, no matter how great it is. Any propulsor with virtually zero slip in the water, whether this is a vast propeller or a large drag device, approximates 100% Froude efficiency.

The actuator-disc theory's essence is that if the slip is defined as the ratio of fluid velocity raise through the disc to vehicle velocity, the Froude efficiency is equal to 1/(slip + 1). Therefore, a mildly loaded propeller with a large swept area can have a high Froude efficiency.

A real propeller has blades made up of parts of helicoidal surfaces, which can be thought to 'screw' through the fluid. Truly the blades are twisted airfoils or hydrofoils, and each part contributes to the total thrust. Two to six blades are most prevalent, although designs that are designed to operate at diminished noise will have further blades, and one-bladed ones with a counterweight have also been employed.

Slightly loaded propellers for light aircraft and human-powered boats regularly have two blades. Motorboats regularly have three blades. The blades are connected to a *boss* (hub), which should be as tiny as the requirements of strength allow, with fixed-pitch propellers, the blades and boss are normally a single casting.

1.14.2 CAVITATION

Cavitation creates vapor bubbles in the water near a moving propeller blade in zones of low pressure due to Bernoulli's principle. It can happen if an effort is made to carry too much power through the screw or if the propeller is working at a very high speed. Cavitation can lose power, create vibration and wear, and create damage to the propeller. It can happen in many ways on a propeller. The two most prevalent types of propeller cavitation are suction side surface cavitation and tip vortex cavitation.

Suction side surface cavitation happens when the propeller runs at high rotational speeds or under heavy load. The pressure on the blade upstream surface can fall below the vapor pressure of the water, following in the formation of a vapor pocket. Under such circumstances, the variation in pressure between the blade's downstream surface (the "pressure side") and the suction side is restricted and ultimately diminished as the extent of cavitation is developed.

When most of the blade surface is coated by cavitation, the pressure difference between the pressure side and suction side of the blade loses considerably, as does the propeller's thrust, which is called "thrust breakdown". Operating the propeller under these conditions ruins energy and creates considerable noise. As the vapor bubbles collapse immediately erode the screw's surface due to localized shock waves against the blade surface. Tip vortex cavitation is created by the shallow pressures developed at the core of the tip vortex. The tip vortex is created by fluid wrapping around the propeller's tip, from the pressure side to the suction side. This video shows tip vortex cavitation. Tip vortex cavitation typically happens before suction side surface cavitation. It is less damaging to the blade because this type of cavitation doesn't fall on the blade but some way downstream.

Fig 1. 12 Cavitation on propeller blade

1.14.3 PROPELLER WALK

Propeller walk (also known as propeller effect, wheeling effect, paddle wheel effect, asymmetric thrust, asymmetric blade effect, transverse thrust, prop walk) is the term for a propeller's tendency to rotate about a vertical axis (also known as yaw motion). The rotation is in addition to the forward or backward acceleration.

Knowing of and understanding propeller walk is important when maneuvering in small spaces. It can be used to one's advantage while mooring off, or it can complicate a maneuver if the effect works against the pilot.

Propeller walk is caused by the water, moved by the propeller in an axial direction and in a rotation. The water, coming from the propeller, gets a cone shape, widening when it leaves the propeller. If the rotating water cone contacts the ship's hull, a sideways force is generated. Propeller walk is hardly noticeable when sailing forward, since the propeller water will not hit a large surface of the ship's hull and corrections to the ship's course can easily be made with the rudder. When in reverse gear, the water will hit the hull directly, resulting in propeller walk.

1.15 BASICS OF PROPELLER DESIGN

1. Optimize the Number of Blades

A lesser amount of blades tends to equal a higher theoretical efficiency while a larger number increases the propulsion. As blades are added to the design, they increase the amount of drag but improve the ability to move water, resulting in a smoother (and less vibrational) motion. Choosing an optimal number of blades is especially important in performance craft as their hull design is more greatly impacted by it. Determining the number of blades based on the type of vessel, size, and intended performance characteristics is one of the important initial aspects of efficient propeller design.

2. Select a low RPM of Compatible Frequency

A low RPM design can increase the efficiency of a propeller by up to 10 to 15 percent. A challenge in choosing an appropriate RPM is to ensure that the rotational speed is different than the resonant frequency of other vessel components such as the shaft and hull.

The selection of RPM goes hand-in-hand with diameter as an important input to optimize fuel efficiency, as well. There are various sets of simulations and calculations that can be used to identify an optimal RPM range for a particular target marine design.

3. Select Propeller Diameter Based on Vessel Specs

The diameter of the propeller, defined as the diameter of the circle traced around the tips of the blades, has a direct impact on power. As with most factors in prop design, there is a balance to be struck, and the diameter should be optimized based on the expected power delivered to the shaft from the engine and the RPM.

Generally, power increases and RPM decreases as the diameter of the propeller is increased. Because of this, larger vessels and those carrying heavier loads could benefit from larger diameters, while performance vessels built for speed may benefit from smaller diameters. The larger diameters become necessary as horsepower increases.

4. Skew Blade Shape for Reduced Noise

There are two sides to each blade on a prop, the leading edge that cuts through the water as it turns, and the trailing edge which follows. One design concept popularized by the Navy is to curve the leading edges of the blades on the prop, instead of leaving them symmetrical.

This has the effect of extending the arc of the blade during rotation, which minimizes the effect of cavitation, thereby reducing drag which can have a positive benefit to the efficiency.

5. Find an Optimal Pitch

The pitch is defined as the forward movement of a propeller as if it was moving through a solid object (picture it as a screw). It is measured as a length and referred to as “true” pitch if the pitch length between the leading and trailing edges of the blade are the same and “progressive” if there is a low pitch for the leading edge and longer pitch for the trailing. Since pitch has a direct impact on RPM for any given vessel, it can be used to optimize the performance. There are benefits and drawbacks to true and progressive pitch designs and they should be considered in the context of all the other parameters being balanced. Modern marine propeller design is very much an art and requires an intense focus on theoretical design considerations and real-world applications given particular vessel and engine designs. Even though the basic components of marine props are essentially the same and have been optimized in terms of their basic design, their parameters can be altered to have a dramatic effect on overall performance. The best designs take into consideration all of these factors. Engineers and designers who can work with a number of different vessel applications often lead to greater innovations.

Fig 1. 13 propeller shaft intersection

1.16 REASON FOR HEAVY RUNNING OF A PROPELLER

A propeller is supplied with engine power to rotate and propel the ship in the desired direction. If the amount of power provided to the propeller is not generating the same rate of revolution, the propeller is considered to be in a heavy running state which may be due to the following reason:

- Damage to propeller blades
- Increase in hull resistance due to hull fouling resulting in a change in wake field
- During rough / heavy seas
- Ship sailing against the current
- Ship sailing in light ballast condition
- Ship Sailing In Shallow Water
- Ship with a flat stern

CHAPTER – 2

LITERATURE REVIEW

[1]**DR.Y.Seetharama Rao *et al,*** this work proposes a methodology to design a propeller with a metal and composite material to analyze its strength and deformation using Ansys software. In order to evaluate the effectiveness of composite over metals, stress analysis is performed on both composite and metal propeller using Ansys. Proposed methodology showed substantial improvements in metal propellers. The mean deflection, normal stress and shear stress were found for both metallic and composite propeller by using Ansys. From the results, stress analysis composite propeller is safe resonance phenomenon. In this work effort is made to reduce stress levels so that advantage of weight reduction along with stresses can be obtained. The comparison analysis of metallic and composite propeller was made for the maximum deformation and normal stresses.

[2] **Palle Prasad and Lanka Bosu Babu,** The work carries out the structural analysis of a CFRP (carbon fiber reinforced plastic) propeller blade which proposed to replace the Aluminum 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 modeled and designed such that it can with stand the static load distribution and finding the stresses and deflections for both aluminum 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 static structural analysis were carried out for two different materials.

[3] **M.Suneetha *et al*,** the paper aims at achieving high propulsive efficiency at low levels of vibration and noise, usually with minimum cavitation. Achieving this aim is difficult with conventional propellers, as ships have become larger and faster propeller diameters have remained limited by draught and other factors. Surface piercing propeller offers an attractive alternative to high-speed crafts, which operate under limited draught. The performance of the vehicle depends upon the efficiency of the propeller. The geometric shape and its surface finish will decide the efficiency of the propeller. The material used is carbon UD and aluminum. The research basically deals with the modeling and Analysis of the propeller using composite material of a marine vehicle having low draft. A propeller is complex 3D model geometry. CATIA modeling software is used for generating the blade model and tool path on the computer. Sectional data, pitch angle of the propeller are the inputs for the development of propeller model. Finite element analysis was carried out using ABAQUS. The propeller model developed in CATIA is converted in to IGES file and then imported to HYPERMESH for developing fine mesh of the model. As a part of the analysis static structural testing was conducted by varying material properties in pre-processing stage.

[4] **D.Gopaiah and N.Amara Nageshwara Rao,** The thesis deals with modeling and analyzing the propeller blade of underwater vehicle for its strength. A propeller is a complex geometry which requires high end modeling software. The solid model of propeller is developed using CATIA V5 R17. Tetrahedral mesh is generated for the model using HYPER MESH. Static, Eigen and frequency responses analysis of both aluminum and composite propeller are carried out in ANSYS. Inter laminar shear stresses are calculated for composite propeller by varying the number of layers. The stresses obtained are well within the limit of elastic property of the materials. The dynamic analysis of aluminum, composite propeller which is a combination of GFRP (Glass Fibre Reinforced Plastics) and CFRP (Carbon Fibre Reinforced Plastics) materials.

[5] **GuanmoXie,** In this study A multi-objective optimization approach is proposed for propeller preliminary design. A Non-dominated Sorting Genetic Algorithm II (NSGA II) is employed to approximate the set of Pareto solution through an evolutionary optimization process. Then a decision making approach is adopted to select “best” solution. A B-propeller design example is conducted to illustrate the analysis process.

[6] **Kai Yu*et al*,** In this study, a series of numerical calculations are carried out in ANSYS Workbench based on the unidirectional fluid–solid coupling theory. Using the DTMB 4119 propeller as the research object, a numerical simulation is set up to analyze the open water performance of the propeller, and the equivalent stress distribution of the propeller acting in the flow field and the axial strain of the blade are analyzed. The results show that FLUENT calculations can provide accurate and reliable calculations of the hydrodynamic load for the propeller structure. The maximum equivalent stress was observed in the blade near the hub, and the tip position of the blade had the largest stress. With the increase in speed, the stress and deformation showed a decreasing trend.

[7] **Ante Sikirica *et al*,** In this paper, propeller configurations in cavitating flow are investigated, with emphasis on real-world performance differences caused by cavitation. Recommended CFD approach is presented with respect to configuration specifics. Available experimental data is used as a baseline for a single propeller, which is then analysed in ducted and tandem configurations with resulting cavitation extents and shape evaluated in the context of current designs.

[8] **Keun Woo Shin and Poul Andersen,** In this study The variation of propeller performance with respect to cavity extent over the blade surface is investigated by DES with a cavitation model. INSEAN E779A propeller is considered as a test case, because the cavitation tunnel test results of thrust and torque breakdowns with respect to cavitation number and cavity extent are available for several loading conditions (Pereira et al 2004a). Cavitation simulation results are validated against the experimental result at two cavitation numbers in the highest loading condition among those considered in the experiment.In the validation, the effects of the transition model and the seed density on cavity extent and propeller performance are examined and the propeller inflow is adjusted to reach the measured thrust instead of modeling the blockage effect of the cavitation tunnel. Cavitation

simulations are made with varying cavitation number. The comparison of the CFD and experimental results shows a reasonable agreement in the variations of cavity extent, thrust and torque in moderate cavitation. Thrust and torque breakdowns are simulated at higher cavitation numbers and larger cavity extents in CFD, as cavity area is overestimated especially in extensive cavitation.

[9] **B.Sridhar Reddy** ***et al,***this work proposes a modal analysis to design a propeller with a metal and composite material to analyse its natural frequencies and mode shapes using ANSYS software. In order to evaluate the effectiveness of composite over metals, modal analysis is performed on both composite and metal propellers using ANSYS. Proposed method shows substantial improvements in composite propeller over the metal propeller.From the results of modal analysis composite propeller is safe against resonance phenomenon. In this paper effort is made to reduce frequency of the composite propeller so that advantage of weight reduction can be obtained. The comparison analysis of metallic and composite propeller has been made for the natural frequencies.

[10] **KiamBengYeo** ***et al***, In this study The Finite Element Analysis (FEA) of marine propeller blade stress distribution due to hydrodynamic loading is presented and discussed. The analysis provided a better insight to complex marine propeller shape and interaction with hydrodynamic loadings. Stainless steel Wageningen B Series 3 blade propeller with 250 mm diameter, EAR of 0.5 and P/D ratio of 1.2 was adopted in the analysis. The propeller was subjected to the rotational speed of 0-6000 rpm. The pressure distribution demonstrated a positive pressure region on the face section and a negative region on the back section that produces the thrust generation. At 6000 rpm, a maximum positive pressure was achieved at 3225 kPa with a negative pressure of 7229 kPa. The hydrodynamic loading from the pressure distribution computation was applied to the stress distribution computation. From the analysis, the propeller blade stress distribution predicted a highly concentrated region near to the hub and decreasing with the growing value of the propeller radius. The highest stress value of 739 MPa at 6000 rpm was obtained at higher than the stainless steel yield stress (170 MPa) and the blade tip deflected towards the ship hull by 2.73 mm.

[11] **Aulia Windyandari *et al,*** The aim of the research is to identify the propeller that would be applied to the fishing boats typically found in the North Coastal Region of Central Java using B-Series marine propeller. Computational Fluid Dynamics (CFD) analysis for assessing the performance of thrust and torque of the developed propeller was performed.

[12] **M.M. Bernitsas *et al,*** In this report The B-series propellers were designed and tested at the Netherlands Ship Model Basin in Wageningen. The open-water characteristics of 120 polynomial regression analysis. The derived polynomials express the thrust and torque coefficients in terms of the number of blades, the blade area ratio, the pitch-diameter ratio and the advance coefficient. The Reynolds number effect and the effect of variation of blade thickness on the B-series propeller characteristics have also been evaluated at N.S.M.B. In this report the polynomials derived are used to plot the open water propeller characteristics for Reynolds number 2.0105 and for the ranges of number of blades.

[13]**N.W.H. Bulten *et al,*** In this paper the aim is to get a full understanding of the occurring flow phenomena on the actual ship. With this knowledge the optimum propeller design can be made. During the validation process a critical review of the model scale measurements methods has been made. The validity of some of the commonly used procedures has been evaluated. The use of full scale CFD simulations provide direct full scale data on the hull wake field and the propeller performance. It has been shown that the commonly used extrapolation methods predict different answers. Decomposition of the forces acting on the hull, the propeller and the rudder is being used to get a proper insight in the flow field at full scale. In the end the design features which contribute to efficiency increase, and thus fuel consumption reduction, can be isolated, based on the results from detailed flow simulations.

[14] **Mohamed A.kotb *et al,*** This work emphasizes the importance of parameters necessary required to assess the performance of thrusters in the stationary or low speed mode using available systematic thruster tests. They also provide design diagrams which will assist in selecting the most appropriate dimensions of actual propellers to a particular ship applications.

[15]**Ahmad Fitriadhy*et al,*** This paper presents a Computational Fluid Dynamics (CFD) simulation approach to predict the thrust (KT), torque (KQ) and efficiency (η) coefficients in open-water condition. The scale model of propeller with various blade numbers (Z) have been appropriately taken into account within the range of advance number $0.1 \leq J \leq 1.05$. Here, B-series model propeller has been employed in computational simulation. the results revealed that the subsequent increase of blade numbers has been proportional with the magnitude of KT and KQ of the propeller. However, it was inversely proportional to the propeller efficiency coefficient (η); where the highest efficiency value was 89% occurred at Z=3. This CFD simulation provides a preliminary prediction of the propeller characteristics.

[16] **Edi Jadmiko *et al,*** In this study the modification of the skew angle is analyzed using the CFD (Computational Fluid Dynamics) method of how the relationship between performance and cavitation results from the various variations that have been made. So that later it can be known that skew angles produce maximum performance and low cavitation. From the simulation results it is concluded that the greater the skew angle, the value of the thrust and torque are decreased, but this is inversely proportional to the value of efficiency that has an upward trend line with the greater angle of skew. Increasing the skew angle can reduce the potential of cavitation at certain skew angles. The skew angle which has a thrust value, torque, and efficiency that is quite high and has a fairly low cavitation potential is at skew angle 0^0.

[17] **Jennie Andersson *et al***, In this study, they have used computational fluid dynamics (CFD) to study a 120m cargo vessel with an integrate rudder bulb-propeller hubcap system and a 4-bladed propeller series. The results indicate that a 3-4 % smaller diameter is optimal in behind conditions in relation to open water conditions at the same scale factor. The reason is that smaller, higher loaded propellers perform better together with a rudder system.

[18] **Jaya Kishore.S** ***et al,*** The idea of thesis deals with modeling and FEM analysis of the propeller blade of underwater vehicles for its strength. The propeller is a complex developed using solid works. The materials used are aluminum, composite propeller which is consisting of GFRP (Glass Fiber Reinforced Plastic) and CFRP (Carbon Fiber Reinforced Plastic) materials. FEM analysis of both aluminum and composite propeller are carried out in ANSYS WORK BENCH. Inter laminar stresses are calculated for aluminum and composite propeller. Based upon the results we are suggested which materials will gives best and accurate results to improve the strength of propeller.

[19]**S.SUBHAS** ***et al,*** In this work, Fluent 6.3 software is also used to solve advanced phenomena like cavitation of propeller. The simulation results of cavitation and open water characteristics of propeller are compared with experimental predictions, as obtained from literature.

[20**]Shreyash C. Godge** ***et al****,* This analysis of a propeller is based off the coordinates of model KCD 32 (Emerson and Sinclair, 1967). Using SOLIDWORKS to recreate the geometry of a three dimensional geometry, analysis was conducted. The study is completed using a computational program, Ansys FLUENT, and velocity, pressure distribution, torque is compared to experimental results. Reasonable results are produced such that the torque and efficiency trends will be in acceptable limits with respect to experimental data. The acquired results are used as input data to carry out stress analysis on propellers made of three composite materials namely carbon composite, alumina composite and polymer composite.

[20]**Bogdan Darie**, In this paper, the open water performances of the SMP11's propeller (cf. figure below) will be numerically simulated using a commercial CFD code based on RANS solver with a hybrid mesh. In the following the propeller geometry is known, the methods used are described, as well as the results and conclusions of the analysis and of the experimental tests, from the SMP'11 Workshop on Propeller Performance: Potsdam Propeller Test Case.

[21]**Wen Yee Hau*et al,*** This study presents the investigation of marine propeller hydrodynamic performance and parameters through Computational Fluid Dynamic analysis. Propellers with different Pitch to Diameter (P/D) ratio, propeller blade number, skew angle, rake angle and Expanded Area Ratio (EAR) were subjected to computational flow analysis based on the Reynolds Averages Navier-Strokes Equation-(RANSE) solver. Results found that all thrust coefficient ($K_{t,}$) and torque coefficient(K_q) decreases with the increasing advance coefficient (J). The efficiency of propeller performance had also consistently showed characteristic trend of non linear increases to a peak an optimum value before decreasing drastically with increasing J value. The analysis found that no single marine propeller achieve optimum performance in thrust, torque, efficiency and velocity with less loading on the mechanical properties.

[22**] B.A.Biskup *et al,*** The book is an attempt to systematize problems related to substantiation and development of practical methods for general strength calculation of ship propellers. Two approaches are presented for determining the strength characteristics of screw propellers: the first is based on taking into consideration static loads on the propeller blade only, while the second takes into account variable (cyclic) forces acting on the screw propeller, The discussion of the calculation method based on static loads includes: determining the constant component of hydrodynamic loads and centrifugal forces, design calculations of the geometrical characteristics of the blade and of its separate elements, determining the maximum stresses in the propeller blade, and evaluating the strength characteristics of the blade.

CHAPTER - 3

FORMULAE

STRESS

$$\sigma = \frac{\text{Force on propeller blade}}{\text{Disk Area of propeller blade}} = \frac{\text{F}}{\text{A 0}}$$

DISC AREA (A_0)

Blade area (Disk area) $A_0 = \frac{\pi \times D^2}{4}$

Where, D = Diameter of the propeller.

PROPELLER DIAMETER (D)

$$D = \frac{\delta\,\text{opt} \times \text{VA}}{\text{n}}$$

Where, V_A=speed of advance of the propeller.

n = speed of rotation.

δ_{opt} = it is obtained from chart.

PROPELLER THRUST (T)

Propeller thrust can be calculated using equation:

$$T = \frac{Pd \times \eta 0}{Va}$$

Where, P_d = delivered power,

HUB DIAMETER (d)

$$d= {}^{P}\!/_{D}$$

Where, p = pitch, D = diameter.

LENGTH OF THE BLADE

$$\text{Length of blade} = \frac{Ad}{\text{Meanwidthratio} \times \text{D}}$$

EFFICIENCIES:

- **Shaft efficiency(η_S)**

$$\eta_S = \frac{\text{PD}}{\text{Pa}}$$

Where, P_D=power delivered to the propeller.

P_B=Brake power.

- **Hull efficiency (η_H)**

$$\eta_H = \frac{\text{Pe}}{\text{Pt}} = \frac{1-t}{1-w}$$

Where, w=fraction coefficient=1- $\frac{Va}{V}$

t=thrust deduction coefficient.

- **Propulsive efficiency (η_D)**

$$\eta_D = \frac{Pe}{Pd} = \eta_H \text{ x } \eta_O \text{ x } \eta_R$$

Where, P_D=power deliver to propeller.

P_E=effective power.

ADVANCE NUMBER OF THE PROPELLER:

$$J = \frac{V_A}{nd}$$

Where, V_A= advance speed of the propeller.

n=rpm, d=propeller diameter.

THRUST DEDUCTION COEFFICIENT:

$$t= \frac{F}{T} =1 - \frac{Rt}{T}$$

Where, T=thrust force,

R_t= resistance.

THRUST COEFFICIENT:

$$K_T = \frac{T}{Þxn2xd5}$$

Where, T=thrust force, Þ=mass density.

TORQUE COEFFICIENT:

$$K_Q = \frac{Q}{Þxn2xd5}$$

Where, Q=propeller torque=$\frac{Pd}{2\pi n}$

d=propeller diameter.

n=rpm.

CHAPTER - 4

DESIGN OF PROPELLER

4.1 DESIGN ANALYSIS

To aid in propeller design, open water experiments with small–scale propeller mode were made in towing tanks were also carried out using existing classification society rules. The experiments were used to verify the design calculations like the thrust, torque and revolution per minute (rpm).In vibration analysis, a specialized dynamometer is used to measure the blade frequency, force generated by the propeller.

The design procedure was restricted to the use of charts and series certified by the **Society of Naval Architecture and Marine Engineers [SNAME]**. These took into considerations certain propeller chart characteristics like propeller pitch, pitch velocity, pitch ratio, mean axial speed of advance, propeller diameter (D), blade area, number of blades, blade outline, thickness, section shapes which are governed by the need to avoid cavitation, Engine power and rated rpm, effective power (PE) and the ship speed (Vs) were fixed. This is also possible by the use of the charts to explore the best combination of diameter, revolution per minute (rpm) and pitch ratio gives the best efficiency.

Propeller design analysis aimed at obtaining minimum power requirements, cavitation, noise, vibration and maximum efficiency conditions at an adequate revolution. Two methods are usually used in propeller design:

a. Use of diagrams obtained from open water propeller experiments for systematic propeller series.

b. The use of mathematical methods (Lifting line, lifting surface, vertex lattice, boundary element method) based on circulation theory.

This work covers the first design method only.

4.2 DESIGN APPROACH FOR PROPELLER

In order to take up the design for the propeller there is requirement of the initial design variables of the propeller as:

1. Delivered power (kw)
2. Rate of rotation(rpm)
3. Speed of ship(m/s)
4. Number of blades(z)
5. Taylors wake fraction(w).

The speed of ship (Vs), the number of propeller revolution (n), the blade number (Z) and the blade area ratio (A_E/A_0) are known while pitch ratio (P/D), diameter (D) and the performance characteristics (J, KT, KQ, η_o) are investigated among probable solutions.

1) The speed of advance **v_A** is obtained by using the formula:

$$V_A = V_S\,(1-w)$$

Where *w* is the Wake fraction (*w* = 0.15).

2) In the preliminary design stage, only the brake power **P_B** and the speed of ship are fixed, and it is possible using charts to explore the best combination of D (ins), n (rpm) and (P/D) to give the best efficiency.

Brake power PB is the power delivered at engine coupling or flywheel while shaft power Ps is the power available at the output coupling of the gearbox.

The relationship between PB and Ps is stated below: $P_S = P_B\,\eta_S$.

Where η_S is the shaft efficiency and have value of 0.98 for ships with engine located aft and 0.97 for ships with engine located amidships. For the purpose of this work 0.98 was used.

For design and performance analysis of the propeller blade using Wageningen B series, the delivered power is: $P_D = Ps\ \eta s$

3) **B_P** can be calculated since P_D, V_A & n are known,

$$B_p = \frac{P_D^{0.5} n}{V_A^{2.5}}$$

4) The values of η_o, (P/D) and δ_{opt} can be traced using BP-DELTA charts corresponding to this values of B_p. The optimum diameter is given as

$$D = \frac{\delta_{opt} V_A}{n} \quad \mathrm{s}$$

4.3 DESIGN CALCULATION

The initial design variables of the propeller are given below:

Brake Power = 85bhp

Ship speed Vs = 30 Knots (1knot = 0.514 m/s)

1) The speed of advance VA of the propeller is calculated using equation:

V_A= V_S (1- w) = 30(1 − 0.15) = 25.5 knots, (w=0.15)

2) Brake power P_B is calculated as follow:

P_d=80, n=3000, v_a =25.5

$$B_p = \frac{P_D{}^{0.5} n}{V_A{}^{2.5}}$$

$$= \frac{80^{0.5} \times 3000}{25.5^{2.5}} = \frac{26832}{3283.601} = 8.172 = 8.0 = B_p$$

3) From the chart of type B series of 4-bladed shown in Appendix A, the value of B_p = 0.8 is read. The point of intersection between the B_P line and optimum line was traced to get

(P/D) =1.15, η_0=0.73, δ_{opt}=113

From above results optimum diameter of the propeller is given as

$$D = \frac{\delta_{opt} V_A}{n}$$

$$= \frac{113 \times 25.5}{3000} = \frac{3264}{3000} = 0.9605\text{ft} = 11.5\text{inch} = D$$

Hence, the optimum diameter for the propeller obtained is 11.5 inch.

4) Since, diameter is known pitch can be calculated as we know

$$P/D = 1.15$$

$$P = 1.15\times D = 1.15\times 11.5 = 13.2 \text{ inch}$$

Having determined the pitch, diameter and delivered horse power of the propeller, the thickness Blade, the blade area from the ratios stated for these in the type B series chart for 4 blade design are as follows:

Number of blades (Z) = 4

Blade area ratio (A_E/A_0) = 0.55

Blade thickness ratio = 0.05

5) To determine the hub (Boss) diameter of the propeller, the relation Boss (hub) diameter ratio

$$\frac{d}{D} = 0.18$$

$$D = 0.18D = 0.18\times 11.5 = 2.1 \text{ inch}$$

Table 4. 1 Design data

S.NO	**PARAMETERS**	**METRIC UNITS**
1.	Engine brake power	85hp
2.	Ship speed	35knots
3.	Delivered power	80hp
4.	V_A	25.5knots
5.	Power coefficient (B_P)	8.0
6.	Efficiency	0.73
7.	Propeller diameter	11.5 inches
8.	No of blades	4
9.	Boss diameter	2.1 inches
10	pitch	13.2 inches

CHAPTER - 5

MODELING

Modeling of the propeller is done using CATIA V5. 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 as shown. As the above process is very complicated we model the propeller blade by using single section surface option.

5.1 INTRODUCTION ABOUT CATIA

CATIA is acronym of **C**omputer **A**ided **3D I**nteractive **A**pplication. It is one of the leading 3D software used by organizations in multiple industries ranging from aerospace, automobile to consumer products.

CATIA is a multi platform 3D software suite developed by Dassault Systems, encompassing CAD, CAM as well as CAE. Dassault is a French engineering giant active in the field of aviation, 3D design, 3D digital mock-ups, and product lifecycle management (PLM) software. CATIA is a solid modelling tool that unites the 3D parametric features with 2D tools and also addresses every design-to-manufacturing process. In addition to creating solid models and assemblies, CATIA also provides generating orthographic, section, auxiliary, isometric or detailed 2D drawing views. It is also possible to generate model dimensions and create reference dimensions in the drawing views. The bi-directionally associative property of CATIA ensures that the modifications made in the model are reflected in the drawing views and vice-versa.

CATIA provides the capability to visualize designs in 3D. When it was introduced, this concept was innovative. Since Dassault Systems did not have an expertise in marketing, they had revenue sharing tie-up with IBM which proved extremely fruitful to both the companies to market CATIA.

In the early stages, CATIA was extensively used in the design of the Mirage aircrafts; however the potential of the software soon made it a popular choice in the automotive sector as well. As CATIA was accepted by more and more manufacturing companies, Dassault changed the product classification from CAD / CAM software to Project Lifecycle Management. The company also expanded the scope of the software.

CATIA can be used at different stages of the design - ideate, draw, test and iterate. The software comes with different workbenches ("modules") that allow CATIA to be used across varied industries – from parts design, surface design and assembly to sheet metal design. CATIA can also be used for CNC.

CATIA offers many workbenches that can be loosely termed as modules. A few of the important workbenches and their brief functionality description is given below:

Part Design: The most essential workbench needed for solid modeling. This CATIA module makes it possible to design precise 3D mechanical parts with an intuitive and flexible user interface, from sketching in an assembly context to iterative detailed design.

Generative Shape Design: allows you to quickly model both simple and complex shapes using wireframe and surface features. It provides a large set of tools for creating and editing shape designs.
Though not essential, knowledge of Part Design will be very handy in better utilization of this module.

Assembly: The basics of product structure, constraints, and moving assemblies and parts can be learned quickly. This is the workbench that allows connecting all the parts to form a machine or a component.

Kinematic Simulation: Kinematics involves an assembly of parts that are connected together by a series of joints, referred to as a mechanism. These joints define how an assembly can perform motion. It addresses the design review environment of digital mock-ups. This workbench shows how a machine will move in the real world.

These are only four of the many workbenches that CATIA offers. A few of the other modules include Machining, Equipment & System, Infrastructure and Ergonomics Design & Analysis. And of course, there are many other CATIA workbenches, each important in its own way.

5.2 MODELLING PROCEDURE OF A 4 BLADE PROPELLER

1) SKETCHING:

Initially the profile of the hub is drawn with the help of the sketcher tool.

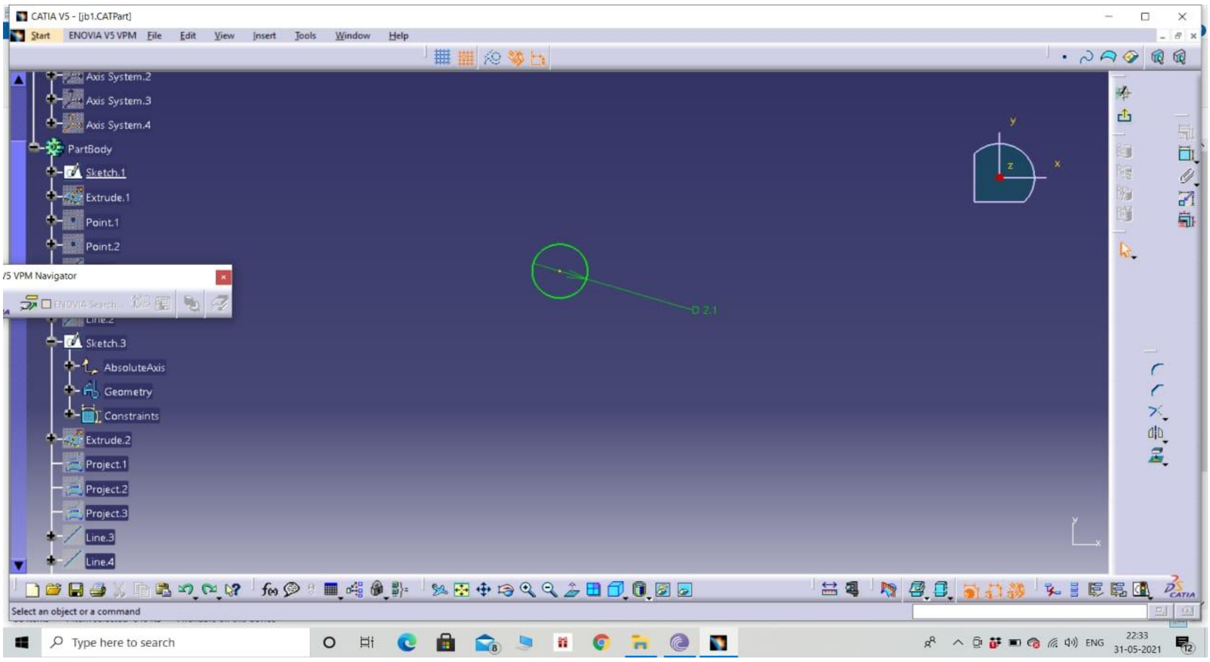


Fig 5. 1 sketch of hub

2) GENERATIVE SHAPE DESIGN:

The profile which is generated from the sketcher, is extruded along x-direction for forming a 3D surface for the hub.

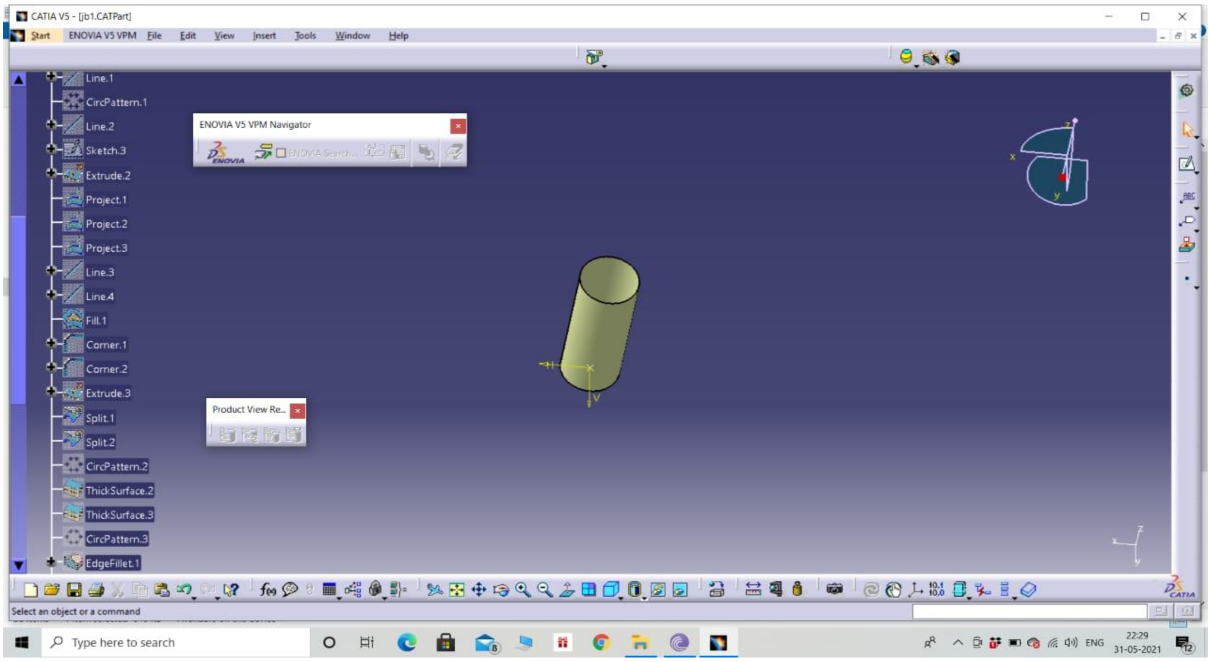


Fig 5. 2 Extrusion of hub

3) DESIGN OF A PROPELLER BLADE:

The profile of the propeller blade is generated from the design data. The surface of the blade is generated by using “FILL” command.

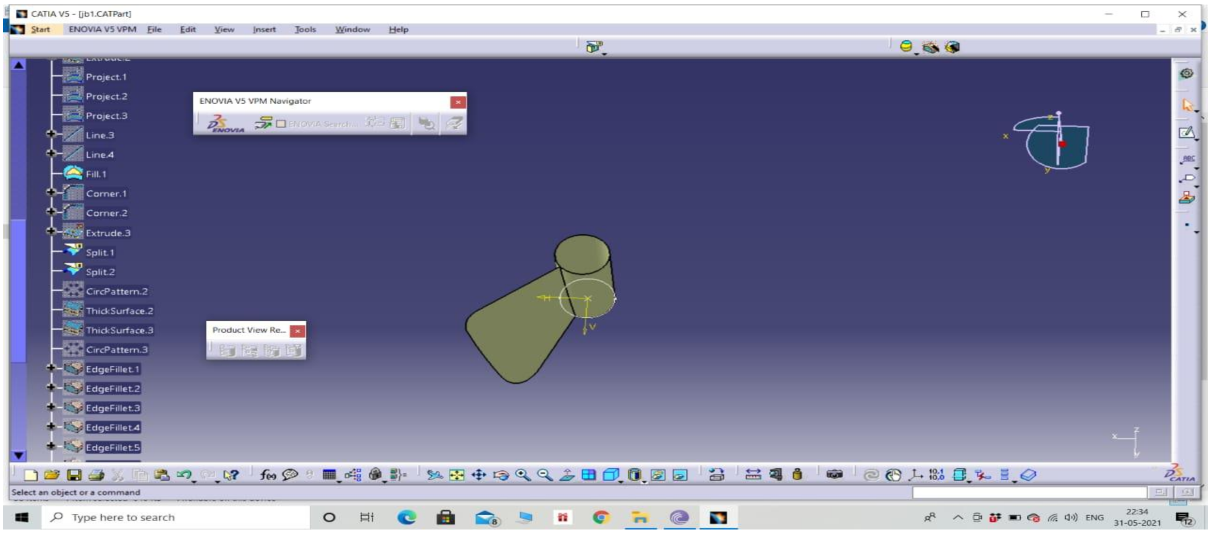


Fig 5. 3 Blade design

4) REPLICATION OF THE BLADES:

The blade which is generated is replicated along the hub of the propeller by using “CIRCULAR PATTERN” command in Replication toolbar.

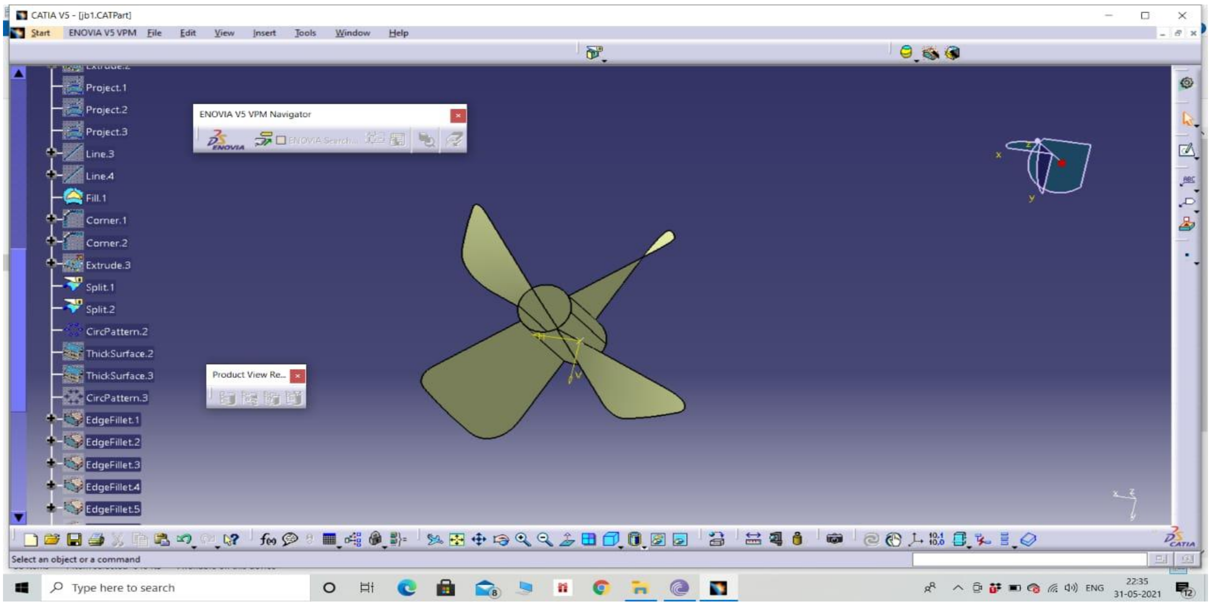


Fig 5. 4 Repetition of blades

5) DESIGN OF HUB CAP:

The geometry of the hub cap is hemi-spherical surface and it is generated by using “REVOLVE” command.

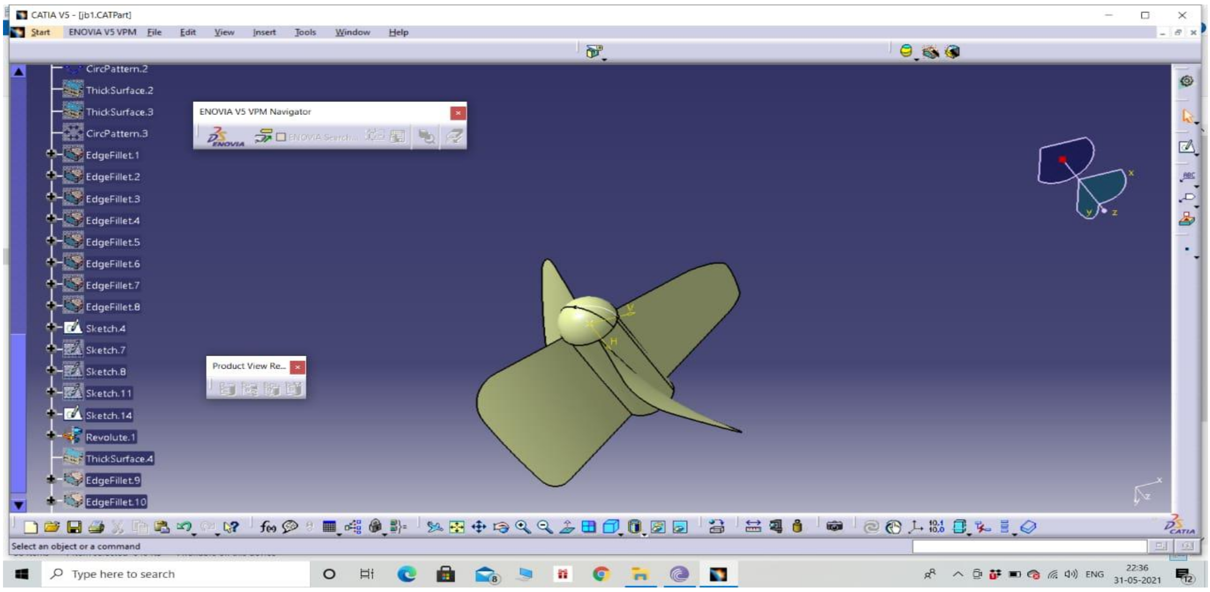
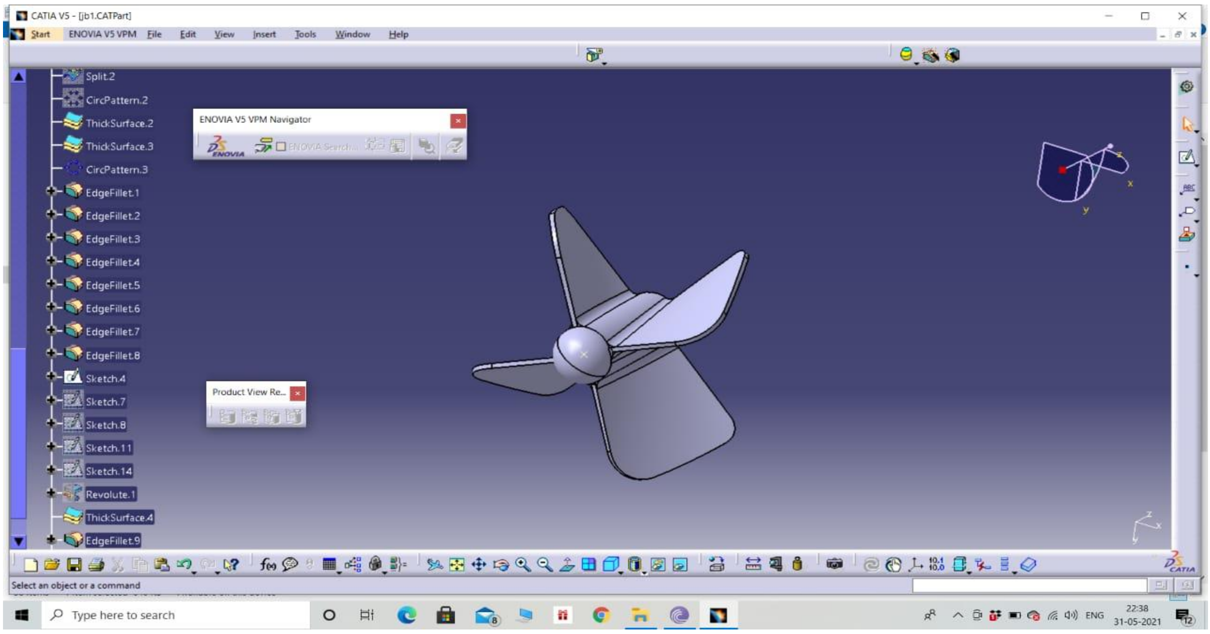


Fig 5. 5 Hub cap design

6) PART DESIGN:

After generating the shape of the propeller blade, the part is moved to part design module where the thick surface is added along the propeller blade profile. To add thick surface we use “THICK SURFACE” command in surface toolbar, which generates a thick surface along the shape of the propeller.



Select an object or a command

Fig 5. 6 Adding thickness to the surface

7) DRESS-UP FEATURES:

After generating solid surface, fillet is added at the root of the propeller blades and hub.

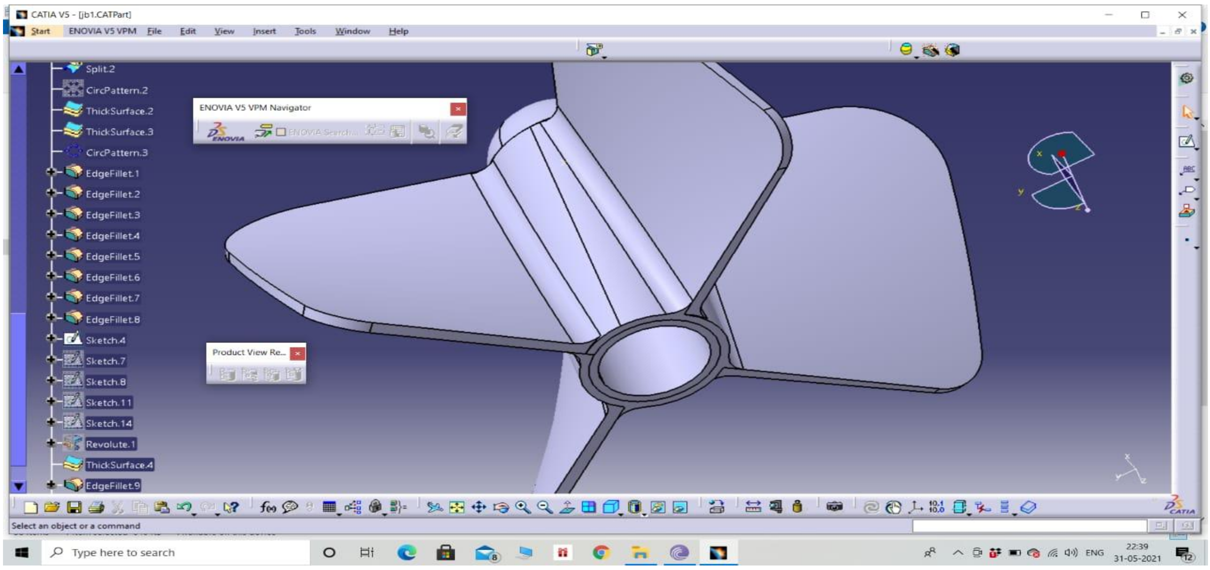


Fig 5. 7 Dress up features

CHAPTER - 6

SIMULATION

6.1 introduction

Simulation techniques consist in sampling the input and characterizing the uncertainty of the corresponding output. This is notably the case of the crude Monte Carlo method that is well suited to characterize events whose associated probabilities are not too low with respect to the simulation budget. However, for very seldom observed events, this approach does not lead to accurate results.

Simulation is the process of creating a model of an existing or proposed system in order to identify and understand the factors that control the system, or to predict the future behavior of the system.

Simulation modeling solves real-world problems safely and efficiently. It provides an important method of analysis which is easily verified, communicated, and understood. Across industries and disciplines, simulation modeling provides valuable solutions by giving clear insights into complex systems

A simulation is a way of seeing a thing happens without it actually taking place in the same way. A simulation can be used to predict what might happen without doing it, in case it is dangerous or too expensive or difficult. It can also be used to show people what will happen next, or what happened in the past.

The initial step involves defining the goals of the study and determining what needs to be solved. The problem is further defined through objective observations of the process to be studied. Care should be taken to determine if simulation is the appropriate tool for the problem under investigation.

6.2 AUTODESK INVENTOR

Inventor is computer-aided design (CAD) software developed by Autodesk. It uses the concept of parametric design, used primarily to create technical drawings for mechanical purposes. It is found in many fields such as automotive, architecture, construction, etc.

Inventor allows 2D and 3D data integration in a single environment, creating a virtual representation of the final product that enables users to validate the form, fit, and function of the product before it is ever built. Autodesk Inventor includes parametric, direct edit and freeform modeling tools as well as multi-CAD translation capabilities and in their standard DWG drawings. Inventor uses Shape Manager, Autodesk's proprietary geometric modeling kernel. Autodesk Inventor competes directly with Solid Works, Solid Edge, and Creo.

Autodesk Inventor is a 3D mechanical solid modeling design software developed by Autodesk to create 3D digital prototypes. It is used for 3D mechanical design, design communication, tooling creation and product simulation.

6.2.1 AUTODESK FEATURES:

- Any CAD – Inventor can integrate with other CAD applications.
- Dynamic simulation – Models can be built rapidly and tested in real – life situations with inventor.
- Modeling flexibility – There are various modeling options available that can enable you to choose the way you design.
- Automation – You don’t have to write code to be able to set up your product configurator.
- Collaboration tools enable team members from different geographical locations to make input and comments to a design.
- Inventor can enable you to view designs online.

- Specialist tools like electrical harnessing helping in the automotive, construction, and engineering sectors.
- Used to make Demos, for instance, it can be used to simulate how a Robot would move in real life.
- Visualization – Designers can see how their products and model would appear in a real-life scenario with its advanced rendering and visualization tools.

6.2.2 APPLICATIONS OF AUTODESK INVENTOR:

Autodesk Inventor can be used for mechanical design, product simulation, and tooling creation. It can aid you greatly in simulation and visualization even before your products are built. Inventor is a dimension driven CAD application that is used in engineering designs, visualization simulation, and documentation. Autodesk Inventor can integrate with applications such as CADTALK.

Autodesk inventor is a leading 2D and 3D CAD application that can seamlessly bridge the gap between product designs, engineering, and manufacturing processes and it comes dozens upon dozens of great features. Inventor offers ease of uses and comes in different file types like IAM, DW, IPN, IPT, and it runs on Windows and Mac operating systems.

With Inventor the creation of intelligent parts such as steel frames, wire harnesses, rotating machinery is seamlessly automated. Inventor speeds up the design process significantly using advanced geometry mechanism. Manufacturers can use Inventor for simulation, which enables them to develop cost-effective products.

6.3 FINITE ELEMENT ANALYSIS (FEM)

Finite Element Analysis or FEA is the simulation of a physical phenomenon using a numerical mathematic technique referred to as the Finite Element Method, or FEM. This process is at the core of mechanical engineering, as well as a variety of other disciplines.

It also is one of the key principles used in the development of simulation software. Engineers can use these FEM to reduce the number of physical prototypes and run virtual experiments to optimize their designs.

Complex mathematics is required in order to understand the physical phenomena that occur all around us. These include things like fluid dynamics, wave propagation, and thermal analysis. Analysing most of these phenomena can be done using partial differential equations, but in complex situations where multiple highly variable equations are needed, Finite Element Analysis is the leading mathematical technique.

6.4 SIMULATION PROCEDURE

6.4.1 IMPORT GEOMETRY

The geometry which is modeled in CATIA is imported into stress analysis feature in AUTODESK INVENTOR application.

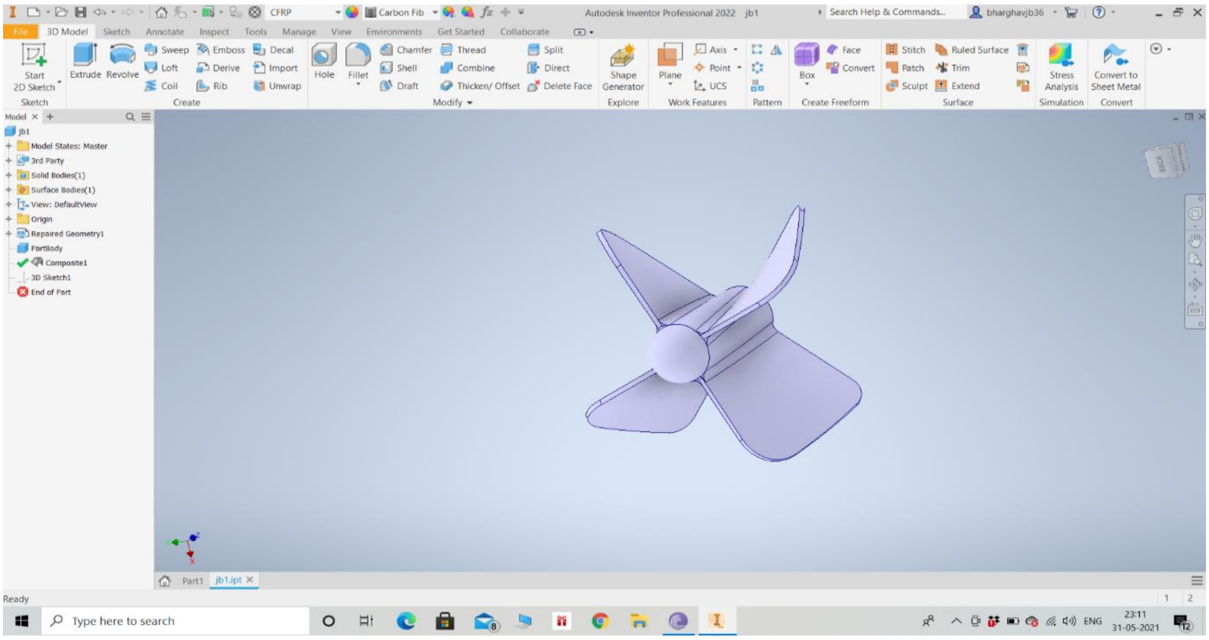


Fig 6. 1 Importing geometry

6.4.2 ASSIGNING OF MATERIALS

Materials are chosen from list of materials available in material tab

SELECTION OF MATERIAL

In our work we have chosen ALUMINUM and CARBON FIBER REINFORCED PLASTIC (CFRP) for analysis.

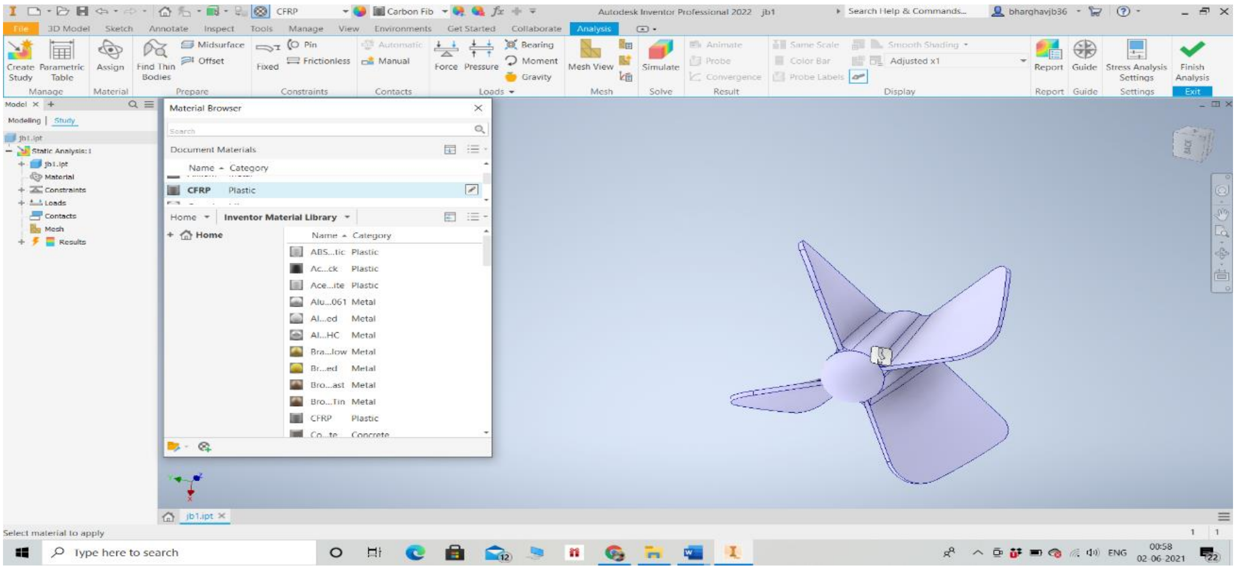


Fig 6. 2 Assigning of materials

Table 6. 1 Material properties

MATERIAL	Youngs modulus	Poisson’s ratio	Mass density	Damping coefficient
ALUMINIUM	70Gpa	0.29	2800kg/m^3	0.006
CFRP	118Gpa	0.28	1600kg/m^3	0.018

6.4.3 ADDING CONSTRAINTS

Here fixed constraint is applied on inner surface of the hub i.e. the intersection of propeller shaft and hub of propeller.

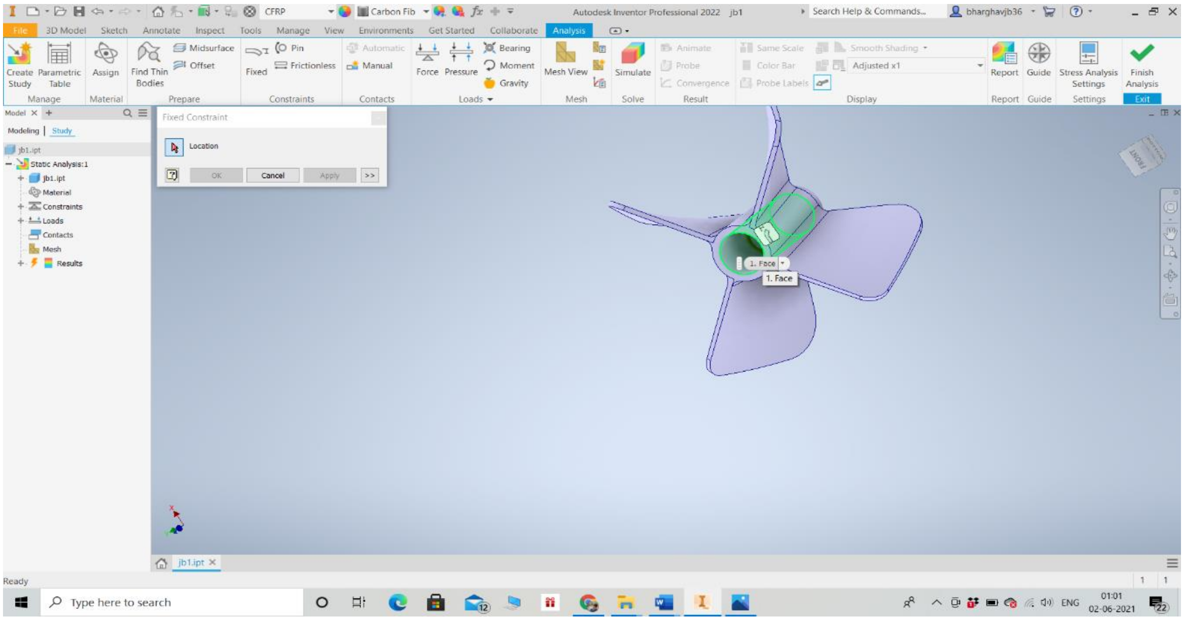
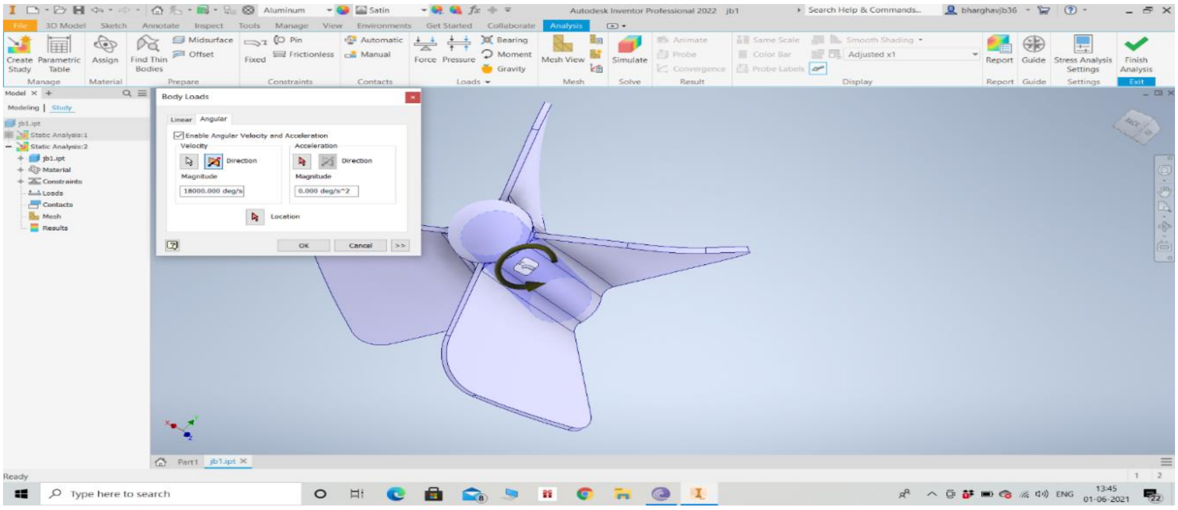


Fig 6. 3 Adding constraints

6.4.4 LOADING

After constraint is fixed loading is added



Body Loads

Linear | Angular

☑ Enable Angular Velocity and Acceleration

Velocity – Direction – Magnitude: 18000.000 deg/s

Acceleration – Direction – Magnitude: 0.000 deg/s^2

Location

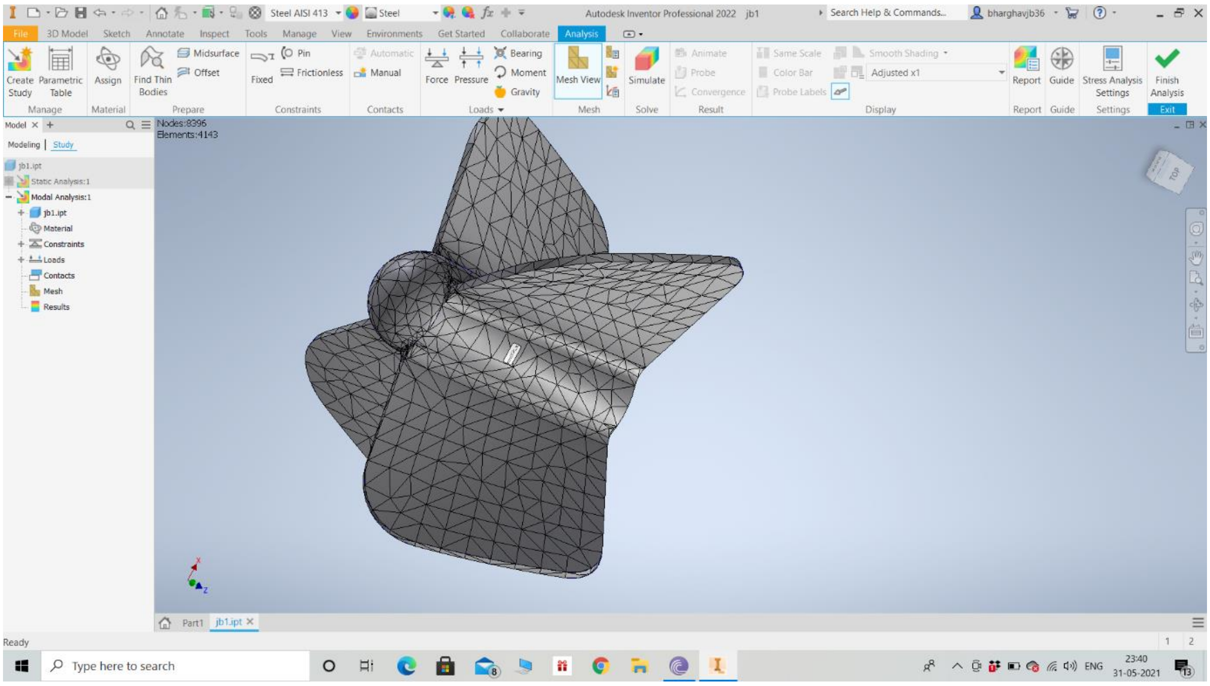
Fig 6.4 Assigning loads

6.4.5 MESHING

In Finite Element Analysis the goal is to simulate some physical phenomena using a numerical technique called the Finite Element Method, we create a mesh which splits the domain into a discrete number of elements for which the solution can be calculated.

The larger amount of mesh divisions you request, the harder the calculations become for the Autodesk inventor stress Analysis module, With a larger number of mesh divisions we get a more accurate approximation. FEA uses a geometrical mesh made up of nodes and elements to simulate a wide range of physical interactions.

The size of the mesh adopted was 2mm and the total number of elements are 3281 and nodes are 6674.

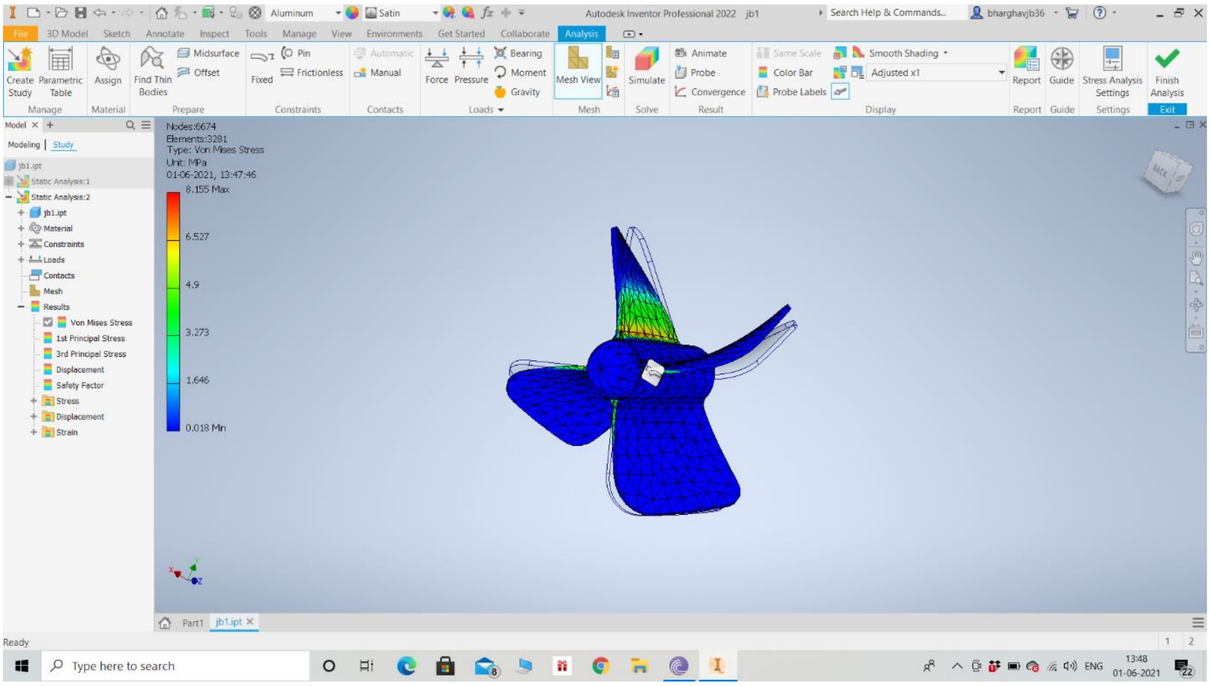


Nodes:8396
Elements:4143

Fig 6. 4 Meshed view of propeller

6.4.6 RUN SIMULATION

After mesh is generated the simulation is made to run and results are obtained.



Nodes:6674
Elements:3281
Type: Von Mises Stress
Unit: MPa
01-06-2021, 13:47:46

Fig 6. 5 Simulation of results

CHAPTER - 7

RESULTS AND DISCUSSIONS

Structural analysis of propeller is carried out for propeller in Autodesk Inventor software and analysis is conducted on propeller considering two materials Aluminum having mass density 2800 kg/m^3 and Carbon fiber reinforced plastic (CFRP) having mass density 1600 kg/m^3.The following parameters like stress, strain, principal stress, principal strain and displacement are obtained for both aluminum and CFRP and are discussed below.

7.1 RESULTS

7.1.1 VON MISES STRESS

ALUMINIUM

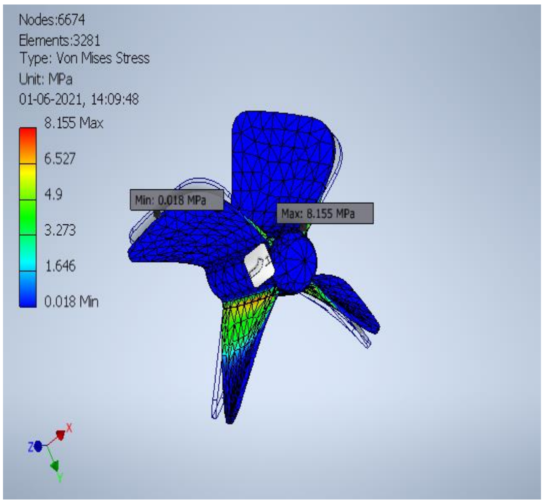


Fig 7. 1 Von mises stress Aluminum

CFRP

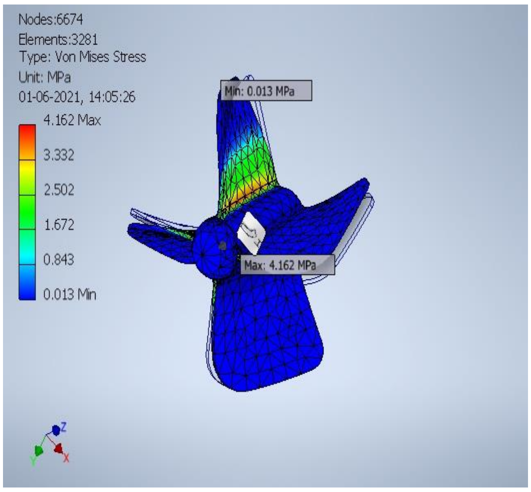


Fig 7. 2 Von mises stress CFRP

Table 7.1 Von mises stress Aluminum

Max	8.154
Min	0.018

Table 7. 1 von mises stress CFRP

Max	4.162
Min	0.013

7.1.2 1ST PRINCIPAL STRESS

ALUMINIUM

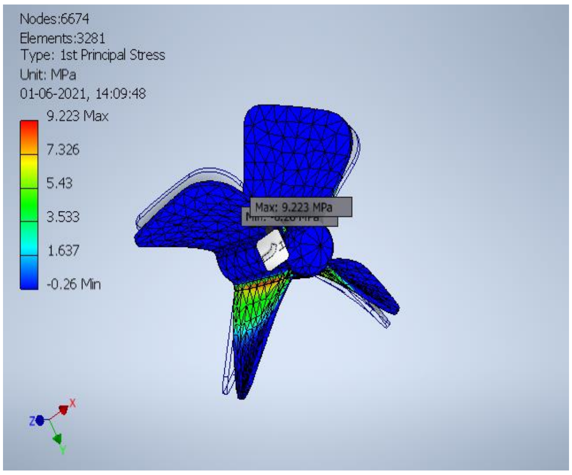


Fig 7. 3 1st principal stress Aluminum

Table 7.3 1st Principal stress Aluminum

Max	9.22mpa
Min	-0.259mpa

CFRP

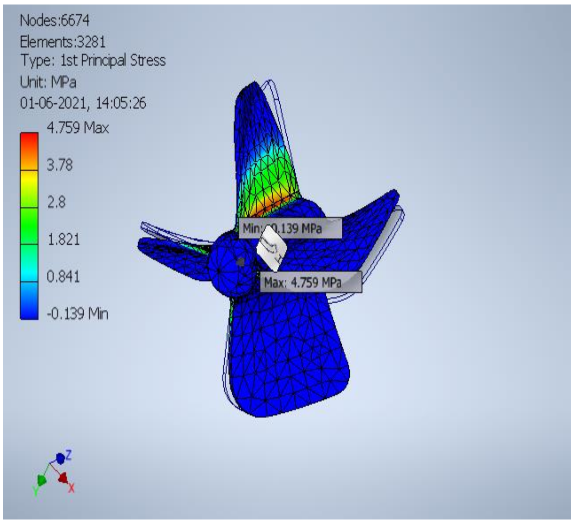


Fig 7. 4 1st principal stress CFRP

Table 7.4 1st Principal stress CFRP

Max	4.74mpa
Min	-0.137mpa

7.1.3 3RD PRINCIPAL STRESS

ALUMINIUM

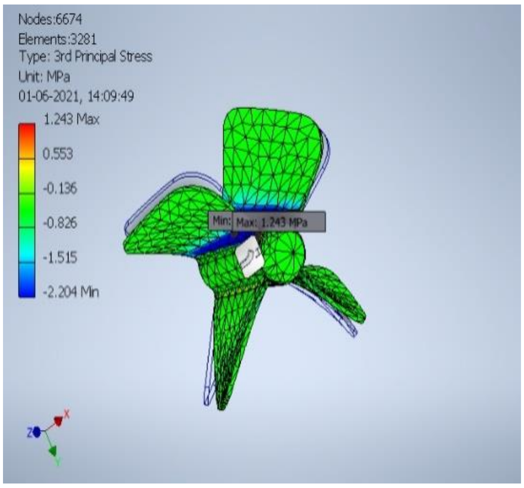


Fig 7. 5 3rd Principal stress Aluminum

Table-7.5 3rd principal stress Aluminum

Max	1.242mpa
Min	-2.20mpa

CFRP

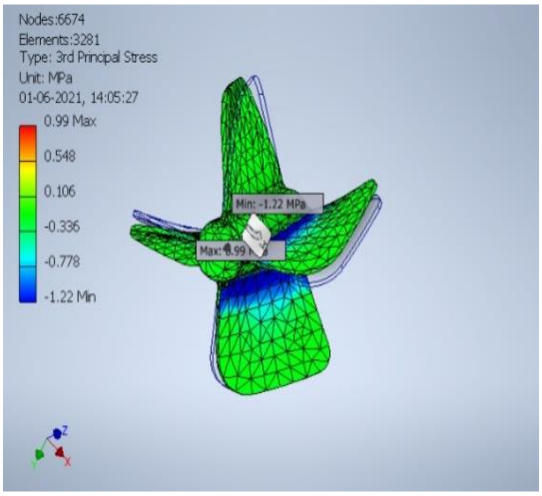


Fig 7. 6 3rd principal stress CFRP

Table-7.6 3rd Principal stress CFRP

Max	0.877mpa
Min	-1.22mpa

7.1.4 DISPLACEMENTS

ALUMINIUM

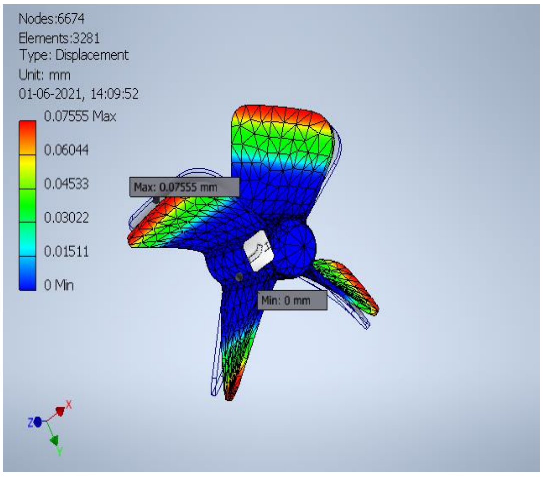


Fig 7. 7 Displacements in Aluminum

Table 7.7 Displacements in Aluminum

Max	0.075mm
Min	0mm

CFRP

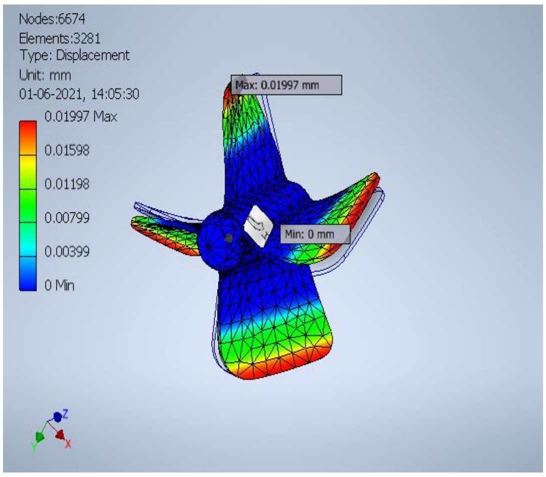


Fig 7. 8 Displacements in CFRP

Table 7.8 Displacements in CFRP

Max	0.019mm
Min	0mm

7.1.5 STRAINS

Table-7.9 results of strain

Name	ALUMINIUM	CFRP
Equivalent strain	$1.079e^{-04}$	$2.937e^{-05}$
1st Principal strain	$1.233e^{-04}$	$3.227e^{-05}$
2nd Principal strain	$-1.145e^{-09}$	$-1.176e^{-08}$

7.2 DISCUSSIONS

7.2.1 STRAINS

The Equivalent and principal strains which are mentioned above are lower for CFRP propeller are lower than the strains developed in Aluminum propeller.

7.2.2 STRESS ANALYSIS

It is observed from above results that stresses generated in CFRP propeller are lower than that of stresses generated in Aluminum propeller. The maximum stress in the propeller is generated at root of the blade and minimum stress in the propeller is generated at the tip of the propeller blade.

7.2.3DEFORMATION

The blade of the propeller behaves as the cantilever beam as the Maximum deformation of blades occurs at the tip of the propeller blade and minimum deformation occurs at the root of the propeller blade. The blades of the propeller deformed opposite to the direction of rotation and there is slight deformation of blades in the direction of hub of the ship.

CHAPTER - 8

CONCLUSION

As per the analysis conducted and results obtained so far, the values of stress, strain and deformation helps us to choose the correct propeller useful for the design application. The propeller we have chosen was 4-blade marine propeller and analysis was done in Autodesk Inventor software. The optimal diameter of the propeller was calculated using Bp delta charts from which the required design parameters were obtained by taking into consideration of optimum line for the chosen design variables. The materials that are considered are aluminum and CFRP, the results of stress analysis shows that the stresses generated in CFRP are 45-50% lower than the stresses generated in aluminum which reduces the chances of failure in CFRP propeller. The deformation observed in CFRP propeller is 25% lower than the aluminum propeller which makes the CFRP propeller comparatively more stiffer. The weight of Aluminum propeller is 54% higher than that of CFRP which makes CFRP as an ideal choice over aluminum.

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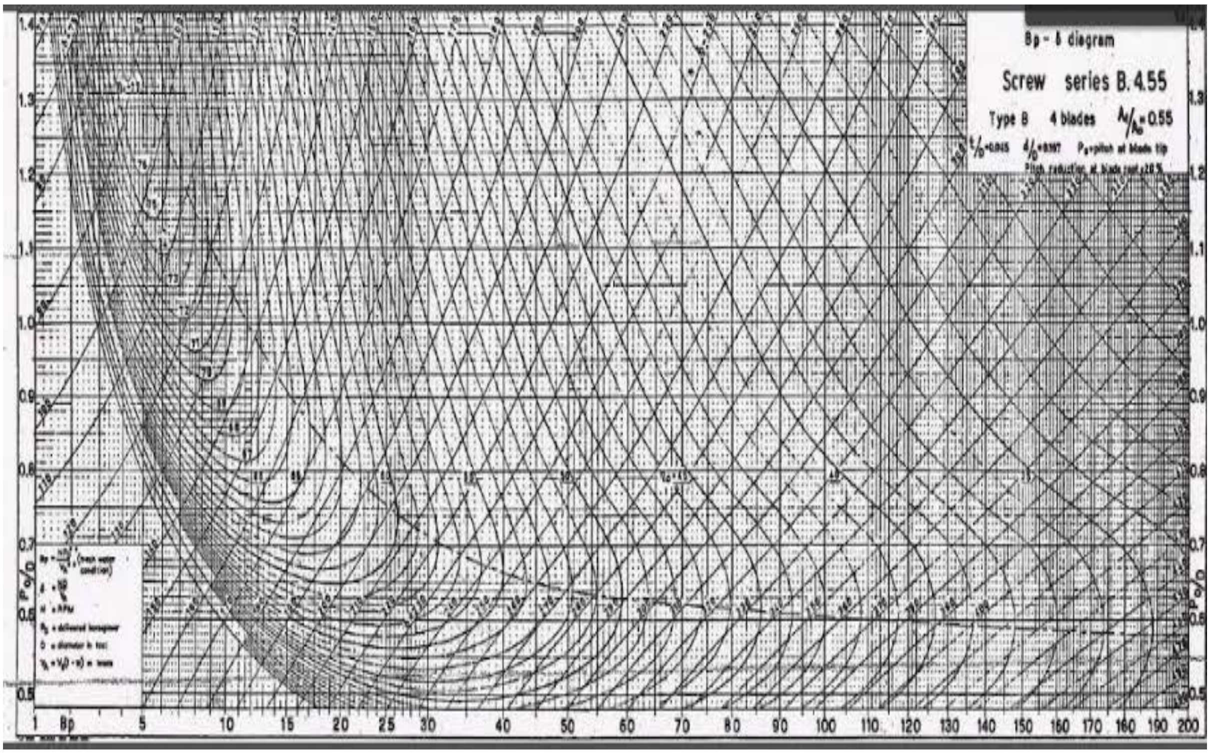
APPENDIX


Bp - δ diagram
Screw series B. 4.55
Type B 4 blades Ae/Ao = 0.55
Po = pitch at blade tip
Pitch reduction at blade root 20 %
Po/D
Bp
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
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