DESIGN AND FABRICATION OF UNMANNED PATROL VESSEL

A Project Report submitted in partial fulfillment of the requirements

for the award of the Degree of

BACHELOR OF TECHNOLOGY

in

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ABSTRACT

In this project an attempt was made to design and analyse an unmanned patrolling surface vessel for surveillance. For this purpose, a prototype vessel was built by following the standards dimensions i.e. length, breath, draft of the ship was taken from the parent ship. The prototype was built with fiber glass and resistance test was conducted for the bare hull at different speeds in towing tank. The experimental results obtained are compared with the results of ANSYS ICEM-CFD. Finally, it was observed that there is a good agreement between the experimental and simulation results with an error of 3%, which can be neglected.

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CHAPTER-I

INTRODUCTION

Ships are large, complex vehicles which must be self-sustaining in their environment for long periods with a high degree of reliability. A ship is the product of two main areas of skill, those of the naval architect and the marine engineer. The naval architect is concerned with the hull, its construction, form, habitability and ability to endure its environment. The marine engineer is responsible for the various systems which propel and operate the ship. More specifically, this means the machinery required for propulsion, steering, anchoring and ship securing, cargo handling, air conditioning, power generation and its distribution. Some overlap in responsibilities occurs between naval architects and marine engineers in areas such as propeller design, the reduction of noise and vibration in the ship's structure, and engineering services provided to considerable areas of the ship.

1.1 Classification of ships

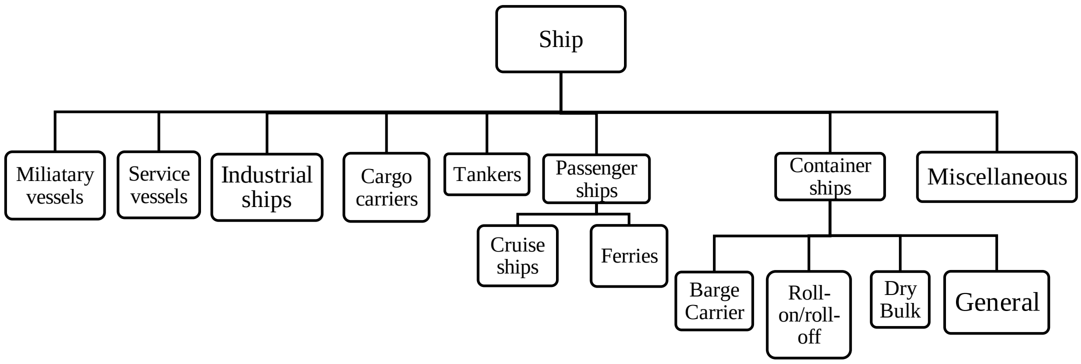


Fig.1.1 Classification of ships

A ship might reasonably be divided into three distinct areas: the cargo-carrying holds or tanks, the accommodation and the machinery space. Depending upon the type each ship will assume varying proportions and functions.

An oil tanker, for instance, will have the cargo-carrying region divided into tanks by two longitudinal bulkheads and several transverse bulkheads. There will be considerable quantities of cargo piping both above and below decks. The general cargo ship will have various cargo holds which are usually the full width of the vessel and formed by transverse bulkheads along the ship's length. Cargo handling equipment will be arranged on deck and there will be large hatch openings closed with steel hatch covers. The accommodation areas in each of these ship types will be sufficient to meet the requirements for the ship's crew, provide a navigating bridge area and a communications centre. The machinery space size will be decided by the particular machinery installed and the auxiliary equipment necessary.

A passenger ship, however, would have a large accommodation area, since this might be considered the 'cargo space'. Machinery space requirements will probably be larger because of air conditioning equipment, stabilizers and other passenger related equipment.

1.2 Naval Vessels

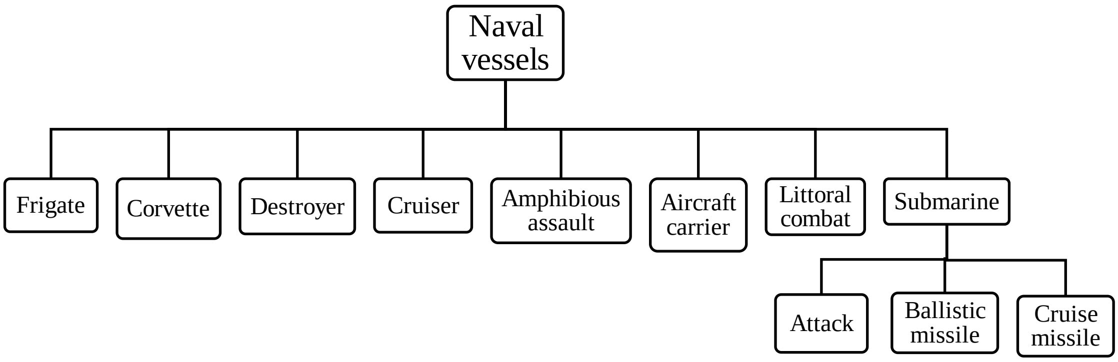


Fig.1.2 Classification of Naval vessels

1.2.1 Frigates

Frigates are usually regarded as ships weighing more than 3000 tons. Its role is to protect other ships of its strike group, the main part of this responsibility is to protect them from hostile submarines.

1.2.2 Corvettes

It features a stealth hull which decreases its radar cross section by 99%. A Corvette is a small warship with light arms. Due to this and their high manoeuvrability they are great in smaller seas, along the comparably low cost – many of the world’s navies operate them, due to Russia being connected to many smaller seas they have invested a lot in Corvettes and are by that the world’s biggest operator of corvettes.

1.2.3 Destroyers

Destroyers are among the widely used ships in the world. Their combination of high firepower and high endurance make them ideal for both wars, escort and (other) peace-keeping operations. The name Destroyer comes from the Russo-Japanese war in the early 20th century where they were named “Torpedo boat destroyer”. Today they are the heaviest surface combatants after the cruiser.

1.2.4 Cruisers

The cruiser is the strongest of them all. It is built to have great firepower and to be able to take out everything that its strike group can face. Due to its high cost and narrow mission capability, only the US, Russia and Peru (old ships) operate them. The line between cruisers and destroyers is not obvious due to some of the new destroyers (DDG-1000 for instance) having greater firepower than some cruisers.

1.2.5 Amphibious Assault Ships

These ships are warfare ships used to support ground troops in forms of ammunition, transport, refuelling of vehicles and to protect them from incoming enemy aero planes and surface vessels. Most of them have both a helicopter deck and a good deck where small amphibious vessels can be maintained and repaired. Some of them are regarded as aircraft carriers, for instance, the Japanese aircraft carriers Izumo has been renamed to helicopter destroyer even though it looks like an aircraft carrier.

1.2.6 Aircraft Carriers

The definition of an aircraft carrier is “A large naval vessel designed as a mobile airbase, having a long flat deck on which aircraft can take off and land at sea”. Just as the definition says it is used as a naval base and aircraft operation centre. The aircraft carriers are the biggest military ships in the world with some weighing over 1,00,000 tons and the capability to house almost 6,000 men. An alternate name of carriers is Supercarriers which is the name of aircraft carriers weighing more than 66,000 tons. The only country that operates more than 2 aircraft carriers is currently the United States (10 active).

1.2.7 Littoral Combat Ships

USS Freedom (back) and USS Independence (front) are both littoral combat ships of the US Navy.

Littoral combat ship – A small class of ships specialized to operate in zones with very shallow waters where other, bigger ships cannot be used. Under this name, there are only a few operational and they all belong to the US Navy. According to the United States Navy’s webpage, the LCSs are “envisioned to be a networked, agile, stealthy surface combatant capable of defeating anti-access and asymmetric threats in the littorals”.

1.2.8 Submarine

1.2.8.1 Attack

Attack submarine is the submarine type designed to take out other submarines and surface ships. They all use torpedoes to hunt their prey and some use cruise missiles in VLS to have an even greater range of targets. Due to their low visibility, they are great to protect friendly ships and to gather information about the enemy.

1.2.8.2 Ballistic Missile

This type of submarine is specialized to go out on the sea, hide and then launch ballistic missile with nuclear (or conventional) warheads to take out strategically important enemy targets. The new nuclear submarines can stay out at sea for months, at any instance being able to launch a missile of mass destruction from thousands of kilometres away. Due to this, all the modern ballistic missile submarines have nuclear reactors as the energy source which gives them a nearly unlimited range.

1.2.8.3 Cruise Missile

A cruise missile submarine is a submarine that can launch cruise missiles. They have extreme firepower, for instance, the cruise missile submarine class Ohio can launch 154 cruise missiles without refuelling nor re-arming. The earlier types of cruise missile submarines had to surface before launching their missiles, but that problem has been fixed and they can now launch their missiles without being seen with the naked eye.

1.3 Class of ship under study

Patrol boat/vessel:

A patrol boat (also referred to as a patrol craft, patrol ship or patrol vessel) is a relatively small naval vessel generally designed for coastal defence duties. There have been many designs for patrol boats. They may be operated by a nation's navy, coastguard, police force or customs and may be intended for marine (blue water) or river ("brown water") environments.

They are commonly found engaged in various border protection roles, including anti-smuggling, anti-piracy, fisheries patrols, and immigration Law enforcement. They are also often called upon to participate in rescue operations.

1.4 Classification of Patrol vessels:

Patrol vessels are broadly classified as:

- Inshore patrol vessels (IPV)
- Offshore patrol vessels (OPV)

They are warships typically smaller in size than a corvette sand can include fast attack craft, torpedo boats and missile boats, although some are as large as a frigate. The offshore patrol vessels are usually the smallest ship in a navy's fleet that is large and seaworthy enough to patrol off-shore in the open ocean. In larger militaries, such as in the United States military, offshore patrol vessels usually serve in the coast guard, but many smaller nations navies operate these types of ships.

The main difference between the IPV and OPV is their capacity to carry crew and ammunition. The IPVs are generally used by the coast guards for the surveillance near the coast lines whereas the off-shores are larger in volumes and are design to be operated far from the coast line. The IPV is employed for tracking the off shore fishing trawlers and also used in rescue operations.

1.5 Unmanned Surface Vessel (USV):

With future conflicts taking place primarily in the littoral regions around the globe against adversaries who possess increasingly more effective weapon systems, placing people in harm’s way may no longer be a viable option. USVs will provide the Fleet with additional military capabilities especially where loss of life is unacceptable. USVs can be deployed in waters where it’s unacceptable to send a manned vessel, including high threaten environments or areas contaminated by nuclear, biological, or chemical agents. They are reliable, fast, highly manoeuvrable, allowing them to conduct a wide range of missions, including patrols of the coast, without endangering navy personnel.

The unmanned combat system can address the Navy’s need for affordable, efficient and technically sound multi-mission systems capable of worldwide deployment for littoral combat. Successful missions of USVs in the second Gulf war have increased interest within the US Navy in USVs and several modern navies followed suit. USV have the potential, and in some cases the demonstrated ability, to reduce risk to manned forces, to perform tasks which manned vehicles cannot, to provide the force multiplication necessary to meet this threat and continue to accomplish our missions, and to do so in a way that is cost-effective. Potential USV missions could range from small torpedo-size data gatherers to large unmanned ships.

1.6 Description of USV

USV is based on innovations in high-payload, high-speed small craft design and unmanned systems technology to provide a highly capable unmanned surface vehicle meeting the strenuous demands of multiple missions. According to the United States magazine “Navy insider”, U.S. Navy published an “unmanned surface vessel Master Plan” (hereinafter referred to note as “Master Plan” lately) in 2007. The “Master Plan” reviewed various available USV types and characteristics, analysed the attributes associated with USV missions and compared vehicle attributes to mission needs. It defines four classes of unmanned vessel: X-class, Harbour-class, Snorkeler-class and Fleet-class. The “Master Plan” led to the conclusion that smaller USVs, seven to 11 meters in length, should be the backbone of the USV fleet.

Certain hull forms have specific characteristics that make them more suitable to certain operations. The requirements for a manned vehicle centre around human limitations, such as motion, temperature, habitation space, etc. However, the requirements for an unmanned system are based solely on what the machinery can handle. Due to this shift in requirements, new and innovative hull forms, which may be unsuitable for manned operations, become prime candidates
for USVs.

1.6.1 Anti-Terror

Operating by itself or integrated into a wider security network, the USV provides port, harbour and riverine security capability against covert or unconventional threats. The USV is unique in its ability to remotely conduct day and night port, harbour or riverine surveillance over extended hours, to interrogate potential threat platforms and to allow commanders to eliminate those threats if necessary. The USV is a force multiplier through its ability to conduct anti-terror protection without placing highly trained personnel at risk. With integrated navigational sensors e.g. GPS, navigation radar and video cameras, the USV can conduct harbour surveillance even in busy waterways. The USV has the ability to provide remote detection, interrogation and engagement of potential threats to merchant vessels or naval ships.

1.6.2 Surveillance and Reconnaissance

The USV can successfully monitor waterways with general guidance from a commander and operator at sea or from shore - no matter how hazardous the condition is. The USV usually has an on-mount camera allowing for day and night operation and has a forward-looking infrared laser rangefinder with capability to detect and track targets in the near vicinity. The communications unit of the USV maintains a constant link between the USV and the control station. The navigation, surveillance and reconnaissance capabilities allow sailors to identify suspicious behaviour, eliminate risks and safeguard high value maritime facilities and ships, especially in congested maritime traffic. Additionally, because the command control centre crew can operate from a distance, the missions completed by the USV provide increased capability and flexibility to operational maritime forces.

1.7 Challenges of unmanned shipping

1.7.1 Communication, sensor and control technology

Ships are already equipped with several systems to support remote or even autonomous operations: Shipping was among the first sectors to be allocated radio communication frequencies around 1910. Electronic navigation systems emerged in the 1930s and ships were among the first civilian adopters of satellite navigation. Anti-collision radar was made mandatory on ships from 1974 and automatic identification transponders from 2002. More advanced sensor systems such as low light and infrared television and small object radar systems are also available in the commercial market. Thus, one can argue that the technology needed to supporting autonomy is not the biggest challenge.

However, during the work on the MUNIN (Maritime Unmanned Navigation through Intelligence in Networks) project the following main areas where more research is needed have been identified:

- Merging of detected targets from different sensor systems to classify into objects that either can be ignored, or that can be automatically avoided or that require the attention of a shore operator.
- Automatic avoidance of detected and recognized targets in accordance with good seamanship and established rules

- Reception of new sailing plans from shore or weather routing services and automatic and safe integration into current sailing plans. This may include remote control from pilot, Vessel Traffic Service (VTS) or shore side operations centre.
- Fail to safe functions in case of missing communication during critical operations or other unexpected situations, including assisted or automatic recovery from fail to safe modes.

1.7.2 Improved system robustness

Ship systems are today designed and built to utilize a combination of maintenance strategies to provide enough safety and reliability level for the complete system. This includes the

- Use of technical and operational redundancy, periodic maintenance intervals and the possibility to repair or replace components by the crew. In the case of an unmanned ship, the latter strategy is obviously not available. Operational redundancy where alternate work procedures are used to achieve a certain task may also be problematic when this involves use of crew intervention. Thus, a major challenge for unmanned ships is to improve the system robustness to a degree where the operator can have a very high confidence that critical subsystems will not fail during the trip. Some important research issues here include:
- Looking at critical system design and improving where necessary to avoid single points of failures with sufficiently high confidence.
- Current preventive maintenance procedures need to be updated to ensure operability during intervals at sea also for components that currently have been designed to be replaceable during voyage.
- Determining the need for new sensors as well as new procedures and analysis methodology to detect early signs of degradation and failure.
- Developing fail-to-safe procedures in case of major system failure. This needs to be complemented with appropriate recovery strategies.

1.7.3 Integration with existing transport system

- Another challenge is the design of a ship concept that can be used in a world where most vessels are still controlled by humans. This puts particularly pressure on an autonomous navigation system, as it also has to interact with manned vessels according to existing rules of road and practices for good seamanship. It also needs to include new concepts for rescue operations at sea. Some issues that MUNIN will investigate are:

- Remote pilotage including integration with ship and the shore side operations centre.
- More advanced VTS with some direct control over ship and routes, again in cooperation with a shore side operations centre.
- Participation of an autonomously operated ship in a search and rescue operation.
- This includes detection of emergency situations, e.g., identifying life boats or rafts and reporting this to the appropriate SAR authority.
- Better navigation support and obstacle detection can reduce accidents by providing decision support for the officer of the watch.
- Small object detection can provide valuable assistance in search and rescue operations.
- Better maintenance strategies can reduce technical incidents and off-hire costs.
- Improved ship-shore communication and coordination can be used to simplify pilotage, VTS operations and management of the ship.

OBJECTIVES

The main objectives of the present analysis are to design and fabricate an unmanned surface vessel for security and surveillance because of the following reasons:

- India is having a coast line of 7516 km and the surveillance is undertaken by the Indian Navy and Indian Coast Guards with the help of around 25 patrolling vessels.
- For running these vessels, skilled manpower is required and in emergency cases their lives are at high risk.
- Due to the advancements in the science and technology, developed countries have updated their defence systems with automation.
- In this project, an attempt was made in designing and fabricating an unmanned surface vessel.
- The unique advantages are it can be guided with the help of remote control for certain distances and it can also capture the surrounding images.
- All the aforesaid applications can be performed without manpower.
- These vessels can be guided from the control room which would be present on the shore.

CHAPTER-II

LITERATURE SURVEY

An Unmanned Surface Vehicle (USV) is a kind of autonomous marine vehicle which travels on the surface of water and perform missions without human intervention. Thus, the importance of USVs lies in the fact that they are able to carry out tasks in variety of environments without jeopardizing human life. Currently, USVs are used in variety of missions including pollutant tracking, surveillance operation, mapping of underwater terrain and studying on oceanography [***Naeem W, Sutton R et. al 2006***].

As a country with long coastline and large sea areas, there is a need for efficient patrol and surveillance of the vast India Exclusive Economic Zone. Patrolling using traditional resources such as patrol boats and ships puts a strain on operational costs and personnel. A remotely operated unmanned vehicles are expected to carry out the tasks in a more economic and efficient manner. For the past few years, USVs have been developed to perform several missions. At the Massachusetts Institute of Technology (MIT), under MIT Sea Grant College Program in 1993-2000, a number of USVs have been designed. The goal was to develop a light Autonomous Surface Vessel (ASV) to be used as a tool for precision survey platform and communication and navigation link to an Autonomous Unmanned Vessel (AUV) [***Caccia, Bruzzone et. al 2008***].

In addition, an USV known as Surface Craft for Oceanographic and Undersea Testing (SCOUT) was also developed for investigations of acoustic navigation algorithm [***Curcio, Leonard et. al 2005***]. As catamaran shape is able to provide enhanced roll stability, greater payload and redundancy in hull floatation, a catamaran shape vehicle called Autonomous Coastal Exploration System (ACES) was developed in 1997[***Manley1997***]. The vessel constituted by two commercial hulls linked by main mechanical steel structure, 3.3 HP gasoline engine for propulsion, power battery for computer, navigation and control and generator for battery recharging. Engine throttle and rudder were actuated by stepper motors. Upon completion, ACES was equipped with sensors suitable for hydrographic survey.

A modified version of catamaran was fabricated by a modular fiberglass plastic composite structure and hull-housed battery and was tested in 1999 [***Manley, Marsh et. al 2000***]. In 1997 - 2000, the European Union funded the project named as Advanced System Integration for Managing the coordinated operation of robotic Ocean Vehicle

(ASIMOV). The mission was to support a fast-direct acoustic communication link with an AUV and thus in between AUV and a support vessel [***Pascoal A, Silvestre C et. al 2006***]**.**

The catamaran type was selected for hull shape design. In the project, a 3.5 m long catamaran characterized by wing-shaped central structure was developed. The USV was able to carry acoustic transducers and propelled by two bladed propellers driven by electric motor. Navigation, guidance and control and mission control were managed by an onboard resident system which is Doppler Velocimeter and DGPS. It is capable to collect bathymetric maps and marine data for research purpose.

Furthermore, Instituto Superior Técnico (IST) in Lisbon was developing Caravela [***Pascoal A, Oliveira P et. al 2000***] which is a long-range autonomous research vessel for testing advanced concepts in vessel/mission control and radar-based obstacle avoidance. It was powered by two diesel generators charging of electrical batteries. Meanwhile the propulsion was guaranteed by two electrical thrusters at the stern of vehicle. In China, a water-jet propelled USV was also developed [***Wu G, Sun H et. al 2009***]. The USV was equipped with water-jet propulsion, engine, nozzle pump and astern deflector and the control system is guaranteed by rudder sensor, astern deflector sensor, compass, radar, GPS, wireless communication equipment and embedded computer systems. Investigation on different sailing states showed the feasibility of the motion control strategy of the USV.

[Yusuke Tahara et. al] concerns development and demonstration of a computational fluid dynamics (CFD)-based multi-objective optimization method for ship design. Three main components of the method, i.e., computer-aided design (CAD), CFD, and optimizer modules are functionally independent and replaceable. The CFD method is a Reynolds-averaged Navier–Stokes (RaNS) solver developed. The CFD method is implemented into a self-propulsion simulator, where the RANS solver is coupled with a propeller-performance program. In addition, a manoeuvring simulation model is developed and applied to predict ship manoeuvrability performance.

Currently, computational fluid dynamics (CFD) is used as an analysis tool to study alternative ship hull-form designs. The background for developing CFD-based optimization methods wherein automatic determination of optimum shape is part of the simulation. Such approaches with complex CFD analysis have been developed by the present authors and colleagues [***Tahara Y, Sugimoto S et. al 2003***], where the main emphasis is placed on utilization of advanced geometry modelling and high-fidelity Reynolds-averaged Navier–Stokes (RaNS) equation solver [***Tahara Y, Himeno Y et. al 1998***], including consideration of complexity of a real-life design problem, conditions, constraints and comprehensive evaluation of the results through model test verification [***Campana EF, Peri D et. al 2004***]. Besides works cited above, other recent applications of CFD-based optimization [***Hino T, Kodama Y et. al 1998***] witness that optimal shape design is receiving growing consideration in the naval hydrodynamics community, filling the gap with other fields (automotive, aeronautical, etc.) at a fast pace.

On the other hand, the optimal design of the hull shape is basically a multi-criterion (or multi objective) problem. For instance, goals of the design process can be resistance reduction, low noise, minimal wave height, reduced amplitude and acceleration of particular motions, etc. In addition, ship designers may also be interested to enhance certain quantities related to the engine power or to the maintenance costs. In addition, ship designers may also be interested to enhance certain quantities related to the engine power or to the maintenance costs

The CFD has a RaNS solver developed by the authors [***Tahara Y, Hayashi G et. al 2003***]. The CFD method is implemented into a self-propulsion simulator [***Tahara Y, Wilson R et. al 2003***], where the RaNS solver is coupled with a propeller-performance program based on infinitely bladed propeller theory [***Nakatake K 1981***] in an interactive and iterative manner. In addition, a manoeuvring simulation model is developed and applied to predict ship manoeuvrability performance, where the results are verified through comparison with experimental data [***Kijima K, Nakiri Y 1999***].

The RaNS which has been developed by the author's for CFD education, research, and design applications for ship hydrodynamics, aerodynamic and fluid engineering [***Tahara Y, Katsui T et. al 2004***].

[Thomas Porathe et. al] presents work in progress within the MUNIN unmanned ship project. It will briefly discuss some points in a basic framework of design criteria for the Human-Machine Interface (HMI) of the Shore Control Centre where operators monitor, and have the ability to remotely control the unmanned vessels. The starting point will be the notion that unmanned ships might reduce human error. *Autonomy and manual control.* At one end of the spectrum we have the wave-goodbye-and-forgetcall-if-you-have-any-problems type of unmanned system. This kind of system will need a very reliable technology that can cope with all eventualities and call for help if needed. In such a system the ship would be assigned a destination port and a set arrival time and would then be left to solve the task by its own. Should there be any problems, the vessel would call and report its whereabouts and the nature of the problem (and what kind of help it required).

At the other end of the spectrum we would have a ship system where each ship had a land-based bridge team remotely controlling of the ship, just as had the bridge be lifted off the hull and placed on land and all the wiring prolonged by satellite links. The simplest (but also technically most difficult) would be to just copy the bridge ashore, and then stream all on-board information in real-time to that bridge: the vision through the wheelhouse windows via video cameras, the motions by a hydraulic system, etc. Done in this way the difference of control between unmanned and manned shipping would be small. There would still be an officer of the watch and a lookout/helmsman at the bridge of each ship. The technical challenge would be safe and secure transfer of very large data quantities, to cope with latency and to pay the satellite communication bill. (We have to some extent kept this idea is in the concept of the emergency "situation room.)

The concept investigated in the MUNIN project is one of autonomy and different levels of remote control if the autonomous system calls for help. We will rely on what we believe will be a robust autonomous system, once mature; meaning that we would expect human intervention to be an exceptional case in the trans-oceanic phase of the voyage. The hypothesis being that one operator can safely monitor several ships, given the right kind of integrated human-machine interface.

[Captain Per Erik Bergh] defines in his research paper that a fisheries patrol vessel is a vessel used to ensure compliance to fisheries laws and regulations both of a national and international nature.

A patrol vessel starts to become a Coastguard vessel when additional tasks are added to its mission, such as immigration, pollution control, search and rescue, and police activities. These may also require a vessel with different technical abilities, beyond those of a purely fisheries patrol vessel.

A Coastguard vessel can soon turn into a Navy vessel if additional tasks of national security and defence purposes are placed upon it.

This paper addresses only the fisheries patrol vessel.

The following list is not exhaustive, but it indicates reasons why countries may consider using a patrol vessel as part of their MCS system:

- To prevent fishing in areas closed for management reasons.
- To prevent fishing out of season, i.e., in closed seasons.
- To prevent the use of illegal gear among licensed vessels.
- To prevent unlicensed vessels fishing in any area.
- To prevent illegal catches, including undersized fish, illegal by-catch, etc.
- To prevent dumping.
- To ensure correct reporting of catches.
- To ensure correct reporting of fishing activity.
- To deploy observers or scientific personnel onto fishing vessels.
- To provide support to other platforms, such as patrol planes and VMS.
- To provide a service function to the fishing fleet, such as diving facility, medical
- assistance, technical assistance, etc.

If you are considering using a fisheries patrol vessel for any of the above or other reasons, your first step must be to clearly define both your needs and the relevant stakeholders within the fishing sector. This is a simple but important starting point, but must be systematically followed to cover all possible considerations.

This process will clearly define the type of vessel needed and the equipment required onboard. It is the background for the feasibility of using a patrol vessel for your identified needs. It is important to analyse the information to obtain a clear picture of your environment and to assess

[Zygfryd Domachowski's] paper presents some aspects of ship water jet propulsion. Advantages and limitations of its applicability are discussed. Also, possible use of water jet propeller to move a small-draught inland waterways ship, is considered

Water jet propulsion of ship is based on application of 3rd principle of Newton's dynamics: "If two bodies mutually interact, their interaction forces are equal to each other and pointing in opposite directions". In the water jet propulsion, a crucial role is played by a pump, located nearby ship's stern, it takes in water through a recess in ship's bottom. From outlet of the pump the water is directed under high pressure to a nozzle placed in the ship's stern. The force pushing out the water from the stern is equal – as to its value – to the force moving the ship in the opposite direction. As to rotate the nozzle is possible practically by an arbitrary angle the same ship propulsion force can be obtained at any arbitrary position of the nozzle. The ship propulsion force depends on water flow rate at the nozzle outlet.

Safety: In contrast to the screw propeller drive the water jet propulsion is not endangered by floating solid fragments, ropes or fishing nets. In particular, the water jet propulsion correctly fulfils its role in shallow waters (like in the considered case of its application to an inland waterway ship). Also, persons remaining in water: swimmers, water skiers, divers etc are not exposed to hazards from the side of such device. Any overload of main engine is excluded as its power demand maintains constant regardless of developed ship speed.

*Manoeuvrability***:** Even at a low speed of motion the water jet- propelled ships maintain excellent manoeuvrability due to possible setting an arbitrary spatial position of the outlet nozzle. Thrust force of an arbitrary value and arbitrary direction can be applied to ship. It is especially useful on narrow waterways (like in the considered case). In no circumstances any help from the side of any other floating unit is necessary. Even in rough weather conditions (strong wind, high waves) ship motion control is possible.

Energy efficiency: The water jet propulsion correctly adjusted to the driving engine and ship hull, makes engine work at optimum settings possible, i.e. when the specific fuel oil consumption is the lowest. It concerns all its operational phases: moving, starting, stopping and standing-by. Moreover, maintenance cost of such installation is low; it means that operational costs of such propulsion system are low.

Travelling comfort of passengers: As compared with the screw propeller drive the water jet propulsion ensures lower noise and vibration level on board of ship. In particular, no cavitation’s noise from the side of screw propeller is emitted. Screw propellers being of a lower rotational speed than that of rotating elements of water jet propulsion system are more bothersome. Pumps are placed in properly insulated casings.

Impact on the environment: The water jet propelled ships generate much lower waterborne disturbances (noise) as compared with the screw-propelled ones. It is especially important for the water natural environment because of much lower hazard to flora and fauna.

CHAPTER-III

DESIGN AND FABRICATION

3.1 Development of 3D model of the ship:

Initially the 2D AutoCAD model of the parent ship was developed into a surface model, later into a solid model using Max-surf and Solidworks respectively.

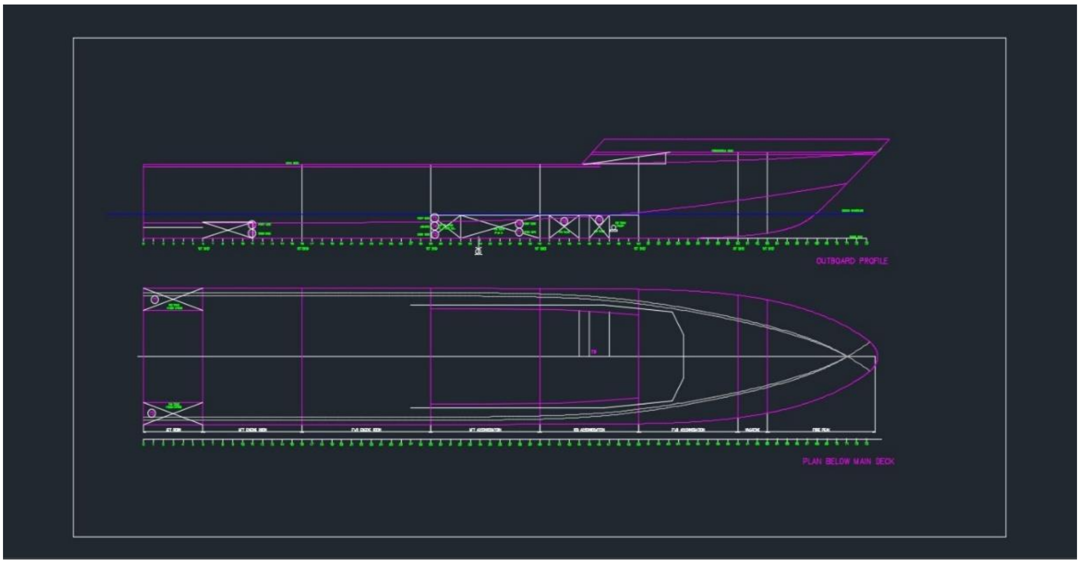


Fig.3.1 2D AutoCAD Model of parent ship

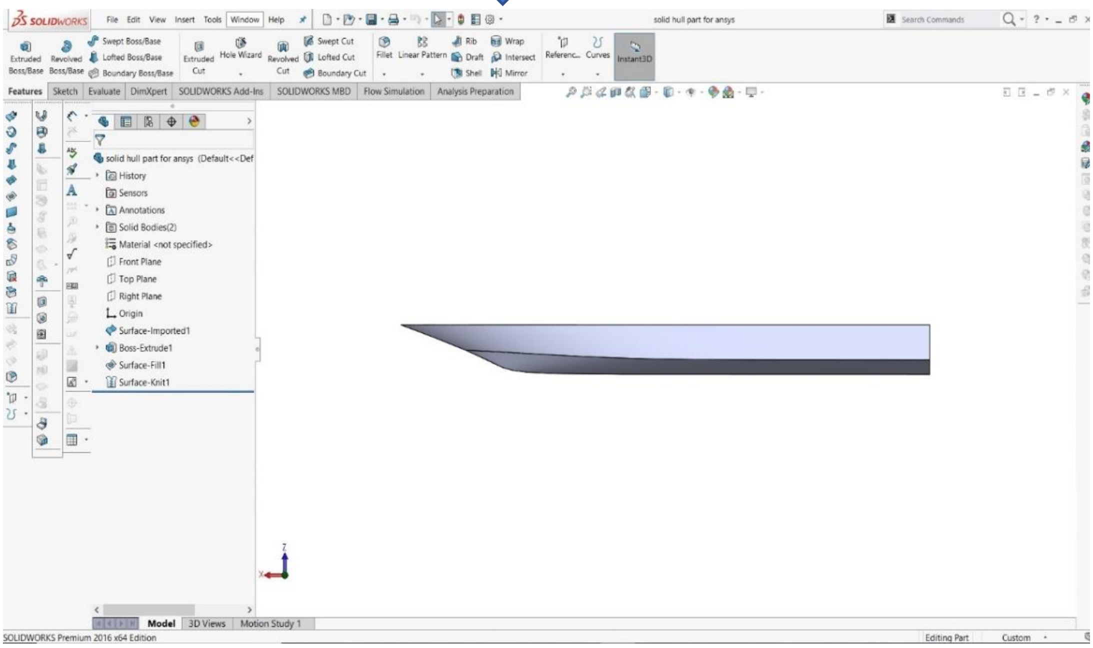
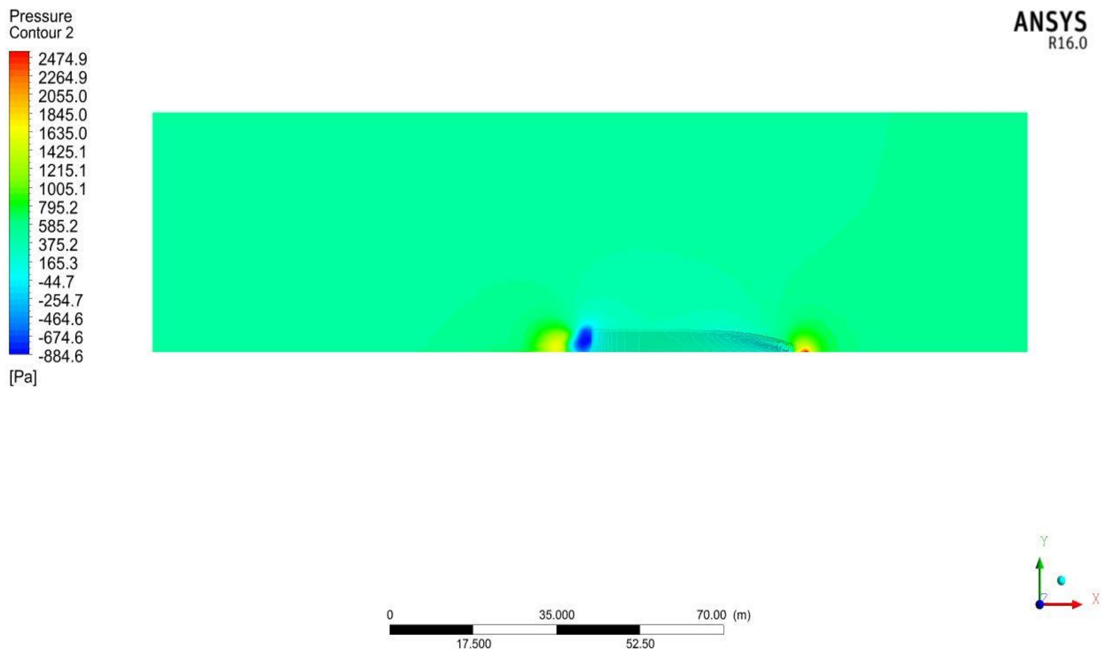


Fig.3.2 3D Software Model using Solidworks

3.2 Analysis of the 3D model:

The 3D model of the ship was imported into ANSYS software by saving the file into ".stp" (STEP) format, which enables the importing of all the necessary information of the model from one software to another. Later analysis was performed on the bare hull of the ship at various speeds. The image shown below is the resistance analysis done on the hull at the speed of 7 knots.



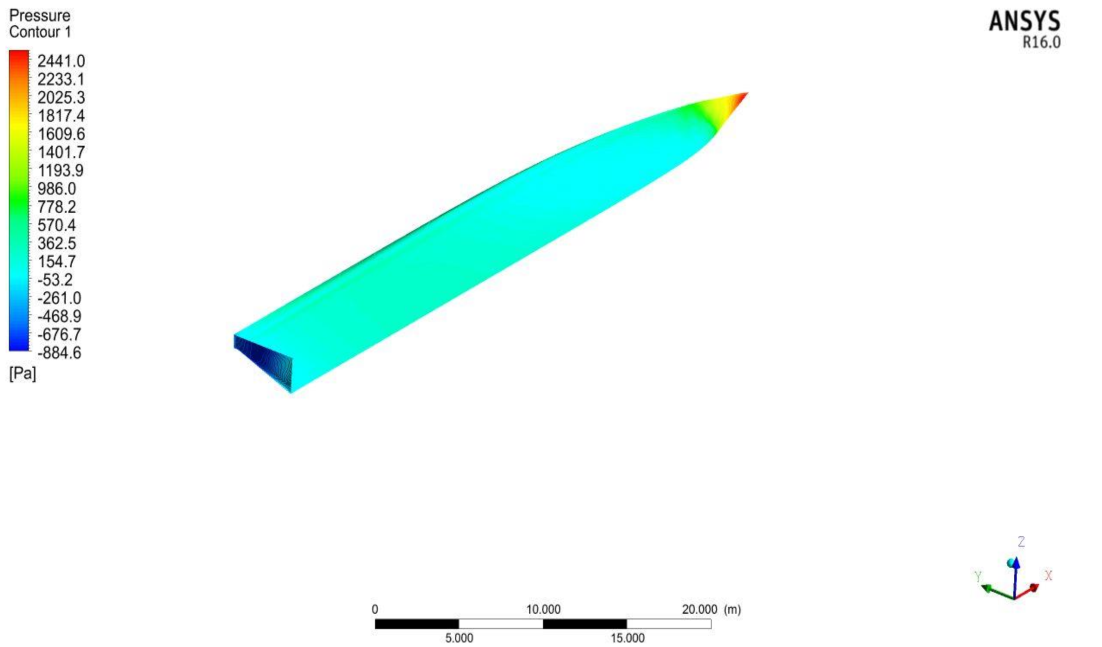


Fig.3.3 Analysis of the 3D Model

3.3 Pattern making of the ship:

The basic dimensions of the parent ship like length, breadth and draft was taken as reference and it was scaled down to 1:40 and the pattern was made with the help of foam sheet as shown below.

Fig.3.4 Pattern of the ship

3.4 Fiberglass material and resin preparation:

After making the pattern of required dimensions, it is then prepared for the application of fiberglass. Fiberglass material is used for making the main hull of the prototype. A fiberglass mat of standard thickness is chopped down into pieces and is applied with the help of resin. The process involved in the preparation of resin is mentioned as below.

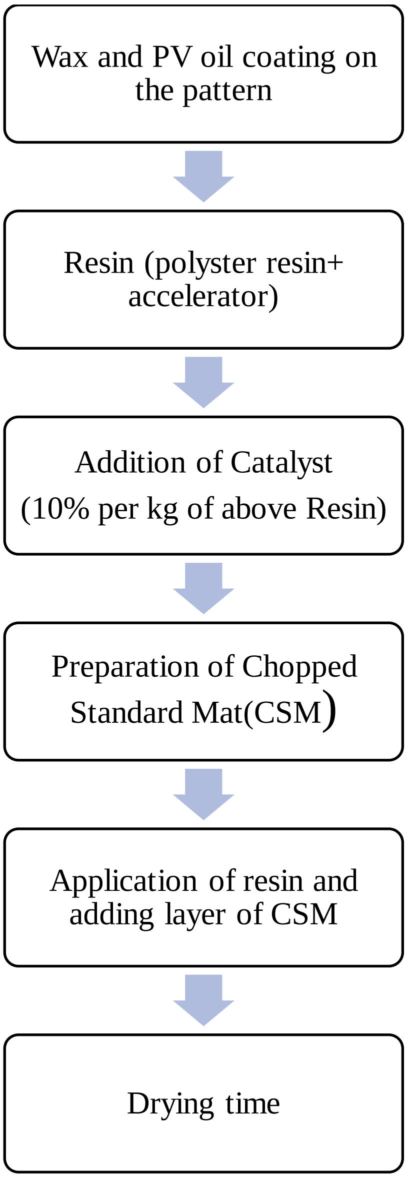


Fig.3.5 Flow process of preparation of fiberglass resin

- A coating of wax and PV oil is applied on the inner part of the pattern of the prototype.
- Now for the preparation of final resin 2% of accelerator is mixed per kilogram of polyester resin.
- Later add 10% of the catalyst per kilogram of the resin prepared in previous step.
- In order to get the required colour, a colour pigment is added to the above mixture. For our prototype we have added a grey colour pigment.
- Now this finally prepared resin is applied on the inner part of the pattern where wax and PV oil coating were applied at the initial stage.

- After the first coating of resin, the Chopped Standard Mat (CSM) is applied on the pattern. This prototype was prepared from CSM No: 450. Use the resin for proper application of CSM.
- Repeat the application of resin and CSM in order to get the required strength and thickness for the prototype. For this prototype, 3 layers were applied in order to get the overall thickness of 2.4 mm.
- Finally, this pattern is allowed to dry. The drying time for the final product varies from one to another based on the thickness of CSM applied.

3.5 Application of layers of fiberglass:

After the preparation of pattern, fiberglass sheets each of 0.8mm thickness were applied with the help of resin and after letting it dry for 1 day, the fiberglass layers get sufficient strength and the hull can be separated from the pattern.

Fig.3.6 Coating the ship with fiberglass

3.6 Bare hull of fiberglass is obtained:

After scraping out the foam sheet material, a bare hull of required dimensions is obtained as shown below. Now the outer surface of the hull is cleaned again in order to ensure a smooth surface finish.

Fig.3.7 Bare hull of fiberglass

Once the cleaning is done, the hull is checked for any holes that could be formed during the making process. And if any holes exist, then it is covered with putty.

3.7 Floating Test:

After making sure that the hull is free from holes and any kind of cracks, it is then made to undergo a floating test where the dead weight (weight of all the electrical components) is added and then the stability of the hull is checked.

Fig.3.8 Floating Test

3.8 Installation of Electrical Components:

3.8.1 Brushless Motor:

Fig.3.9 Brushless Motor

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) as shown in Fig.3.9, or synchronous DC motors, are synchronous motors powered by DC electricity via an inverter or switching power supply which produces an AC electric current to drive each phase of the motor via a closed loop controller. The controller provides pulses of current to the motor windings that control the speed and torque of the motor. In this project brushless motor was used for rotating the propeller and the technical specifications are shown in the table.3.1.

Table.3.1 The specifications of the motor used:

Sr. No	Product	3650 slot motor
1	Watts	820
2	Max voltage	<18 V
3	Max amps	45A
4	Rotor poles	4
5	kV (rpm/volt)	3000
6	Max rpm	50000
7	Length	50 mm
8	Diameter of motor body	36 mm with fins
9	Shaft diameter	3.175 mm
10	Length of extended shaft	15 m

3.8.2 Electronic speed controller:

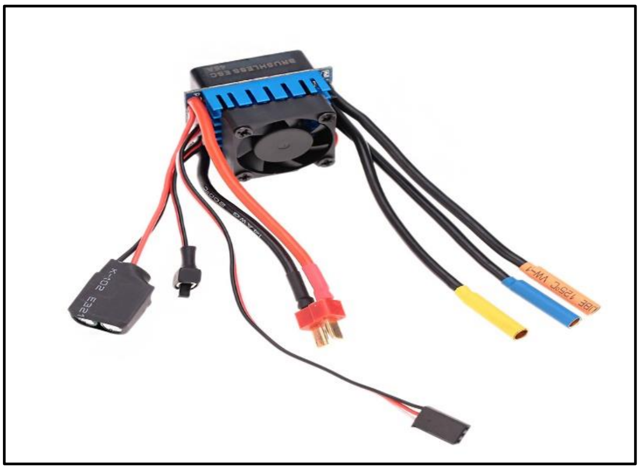


Fig.3.10 Electronic Speed Controller

An electronic speed control or ESC shown in Fig.3.10, is an electronic circuit that controls and regulates the speed of an electric motor. It may also provide reversing of the motor and dynamic braking. Miniature electronic speed controls are used in electrically powered radio-controlled models. The technical specifications of the ESC are presented in the table.3.2

Table.3.2 Specifications of brushless speed controller

Sr. No	Model	45 A
1	Cont. current/burst current	45A/180 A
2	Motor type	Sensor less brushless motor
3	Suitable car	1/10 CAR
4	Suitable brushless motor	>=9T
5	Resistance	0.0014 Ohm
6	Battery	2-3 cells Lipo ;4-9 cells NiMH
7	Bec output	5.8 V/3 A, (switch mode)
8	Dimension	32.5*34*24 mm

3.8.3 Y harness cable:

Fig.3.11 Y-harness cable

A Y-harness cable with dual female to mono female connection is used to interact with the two electronic speed controllers with the radio control transmitter and receiver system. The specifications of the harness cable used is mentioned in the table3.3

Table.3.3 Specifications of Harness cable:

Sr. No	Wire length	100mm (lead)
1	Material	metal
2	Design	2 pins

3.8.4 Radio control transmitter and receiver:

A 6-channel radio control transmitter and receiver were shown in the figure 3.12 were used to control the thrust and rudder mechanism of the prototype. By installing this, we can justify controlling the vessel from the shore itself. And the technical specifications of the radio control transmitter with receiver was shown in the table 3.4.

Fig.3.12 Radio control transmitter and receiver

Table.3.4 Specifications of Radio control transmitter and receiver

Sr. No.	Model type	Fixed-wing/glider/Heli
1	RF range	2.4055-2.475 GHz
2	2.4G system	AFHDS
3	Code type	GFSK
4	Sensitivity	1024
5	Low voltage warning	<9V
6	Dsc port	PS2
7	Charger port	Yes
8	ANT Length	26 mm
9	Weight	511 g
10	Power	12V 1.5AA*8
11	Display	LED indicator
12	Size	189*97*295 mm
13	Color	Black
14	Certificate	CE, FCC

3.8.5 Wireless Security Camera:

Fig.3.13 Wireless Security Camera

For surveillance purpose a camera needs to be installed, but in order to control the camera from the shore we need a wireless technology that could enable us to perform the task as desired. So, a WIFI supported camera as shown in Fig.3.13, has been employed on the main deck for this purpose, which can send the photographs or live tracking footages to the person controlling on the shore. This camera is powered by the help a battery and thus the problem with long power cords is eradicated. The specifications of the camera used is mentioned in the below table3.5.

Table.3.5 Specifications of Wireless Security Camera

Sr. No	Components	Specification
1	Lens	IR cut
2	Storage	64 GB
3	Connectivity	Wireless
4	Interaction	2-way intercom
5	Online storage	Cloud
6	Compatibility	Both Android and iOS

3.8.6 Lithium-Polymer (LiPo) batteries:

Fig.3.14 Lithium-Polymer battery

A lithium polymer battery, (abbreviated as LiPo, LIP, Li-poly, lithium-poly and others), is a rechargeable battery of lithium ion technology using a polymer electrolyte instead of a liquid electrolyte. High conductivity semisolid (gel) polymers form this electrolyte. These batteries provide higher specific energy than other lithium battery types and are used in applications where weight is a critical feature. The technical specifications are shown in the table 3.6 and the schematic figure was shown in the fig.3.14.

These batteries can also be charged with the help of a solar panel which are proposed to be fitted on the upper deck of the patrolling vessel.

Table.3.6 Specifications of Lithium Polymer battery

1	Voltage	11.1 V
2	Power	2200 mAh
3	Plug Style	T Connector
4	Watts	24.42 W

3.9 Installation of 3D printed water jet propulsion system:

Fig.3.15 3D Printed Water Jet Propulsion System

A water jet generates propulsive thrust from the reaction created when water is forced in a rearward direction. It works in relation to Newton's Third Law of Motion - "every action has an equal and opposite reaction".

A water jet propulsion system was made using 3D printer from PLA (polylactic acid) material, which is biodegradable in nature and its thermoplastic nature enables us to mould it to any desirable shape when heated.

3.10 Attachment of Deck:

The above-mentioned electrical components are fixed in the hull and are connected with the water jet propulsion system. After the installation of electrical components and propulsion system, the prototype is made to undergo a functionality check. Finally, the hull is covered with a deck made of foam sheet and then final paint work is done on the prototype.

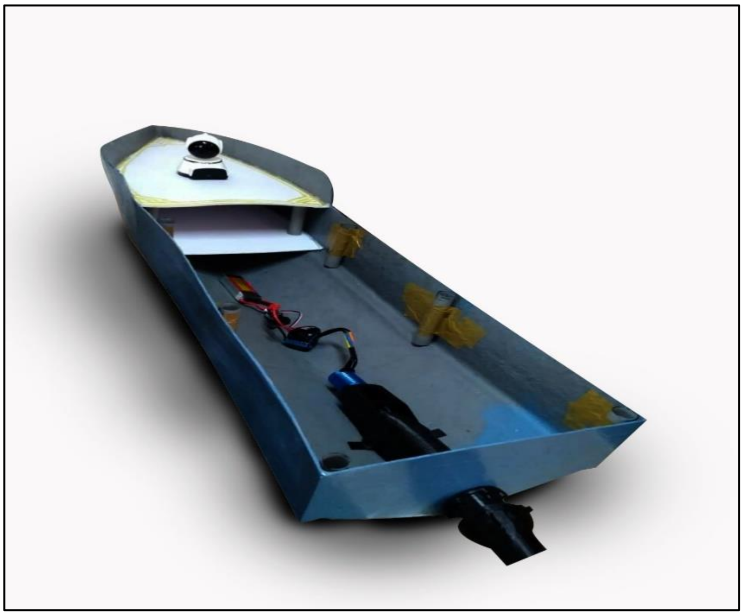


Fig.3.16 Hull with electrical components

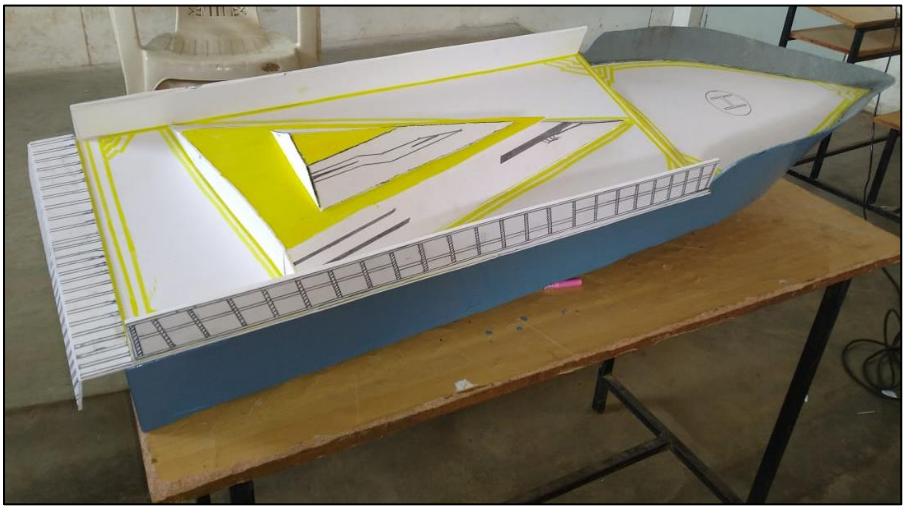


Fig.3.17 Hull after the attachment of deck

CHAPTER-IV

RESISTANCE

4.1 Resistance of a Ship:

A ship differs from any other large engineering structure in that in addition to all its other functions, it must be designed to move efficiently through the water with a minimum of external assistance.

When a ship moves through the water at any speed, a force or resistance is exerted by the water on the ship. Therefore, the ship must exert an equal thrust to overcome the resistance and travel at that speed. As a ship moves through water and air it experiences both air and water forces. The water and air particles may themselves be moving, the water due to currents and the air due to winds, and these will in turn be of varying magnitude and directions. As a result, the ship hull is tested in still water with no wind. Separate allowances are made for wind and the resulting distance travelled corrected for water movements. Unless the winds are strong the water resistance will be the dominant factor in determining the speed achieved.

Also, the problem of moving the ship involves the proportions and shape, or form of the hull, the size and type of propulsion plant to provide motive power, and the device or system to transform the power into effective thrust. The relationship between hull form and resistance to forward motion (or drag) and propulsion devices and their interaction with flow around the hull is an important criterion in designing a ship for a specific purpose.

4.2 Types of Resistance:

The resistance of a ship at a given speed is the force required to tow the ship at that speed in smooth water, assuming no interference from the towing ship. If the hull has no appendages, this is called the bare-hull resistance. The power necessary to overcome this resistance is called the towrope or effective power and is given by

$P_E = R_T V$

where P_E = Effective Power in kWatt (kW)

R_T = Total Resistance in kNewton (kN)

V= Speed in m/sec

This total resistance is made up of a number of different components, which are caused by a variety of factors and which interact one with the other in an extremely complicated way. In order to deal with the question more simply, it is usual to consider the total calm water resistance as being made up of four main components.

(a) The frictional resistance, due to the motion of the hull through a viscous fluid.

(b) The wave-making resistance, due to the energy that must be supplied continuously by the ship to the wave system created on the surface of the water.

(c) Eddy resistance, due to the energy carried away by eddies shed from the hull or appendages. Local eddying will occur behind appendages such as bossings, shafts and shaft struts, and from stern frame sand rudders if these items are not properly streamlined and aligned with the flow. Also, if the after end of the ship is too blunt, the water may be unable to follow the curvature and will break away from the hull, again giving rise to eddies and separation resistance.

(d) Air resistance experienced by the above-water part of the main hull and the superstructures due to the motion of the ship through the air.

The resistances under *(b)* and *(c)* are commonly taken together under the name residuary resistance.

4.2.1 Frictional Resistance:

One has only to look down from the deck of a ship at sea and observe the turbulent motion in the water near the hull, increasing in extent from bow to stern, to realize that energy is being absorbed in frictional resistance. Experiments have shown that even in smooth, new ships it accounts for 80 to 85 percent of the total resistance in slow-speed ships and as much as 50 percent in high-speed ships. Any roughness of the surface will increase the frictional resistance appreciably over that of a smooth surface, and with subsequent corrosion and fouling still greater increases will occur. Not only does the nature of the surface affect the drag, but the wake and propulsive performance are also changed. Frictional resistance is thus the largest single component of the total resistance of a ship, and this accounts for the theoretical and experimental research that has been devoted to it over the years.

$$C_F = \frac{R_F}{\frac{1}{2}\rho S V^2} = 0.072(VL/\nu)^{-1/5}$$

4.2.2 Wave-making Resistance:

The wave-making resistance of a ship is the net fore-and-aft force upon the ship due to the fluid pressures acting normally on all parts of the hull, just as the frictional resistance is the result of the tangential fluid forces. In the case of a deeply submerged body, travelling horizontally at a steady speed far below the surface, no waves are formed, but the normal pressures will vary along the length. In a non-viscous fluid, the net fore-and-aft force due to this variation would be zero, as previously noted. If the body is travelling on or near the surface, however, this variation in pressure causes waves which alter the distribution of pressure over the hull and the resultant net fore-and-aft force is the wave-making resistance.

Over some parts of the hull the changes in pressure will increase the net sternward force, in others decrease it, but the overall effect must be a resistance of such magnitude that the energy expended in moving the body against it is equal to the energy necessary to maintain the wave system. The wave-making resistance depends in large measure on the shapes adopted for the area curve, waterlines and transverse sections, and its determination and the methods by which it can be reduced are among the main goals of the study of ships' resistance. Two paths have been followed in this study-experiments with models in towing tanks and theoretical research into wave-making phenomena. Neither has yet led to a complete solution, but both have contributed greatly to a better understanding of what is a very complicated problem. At present, model tests remain the most important tool available for reducing the resistance of specific ship designs, but theory lends invaluable help
in interpreting model results and in guiding model research.

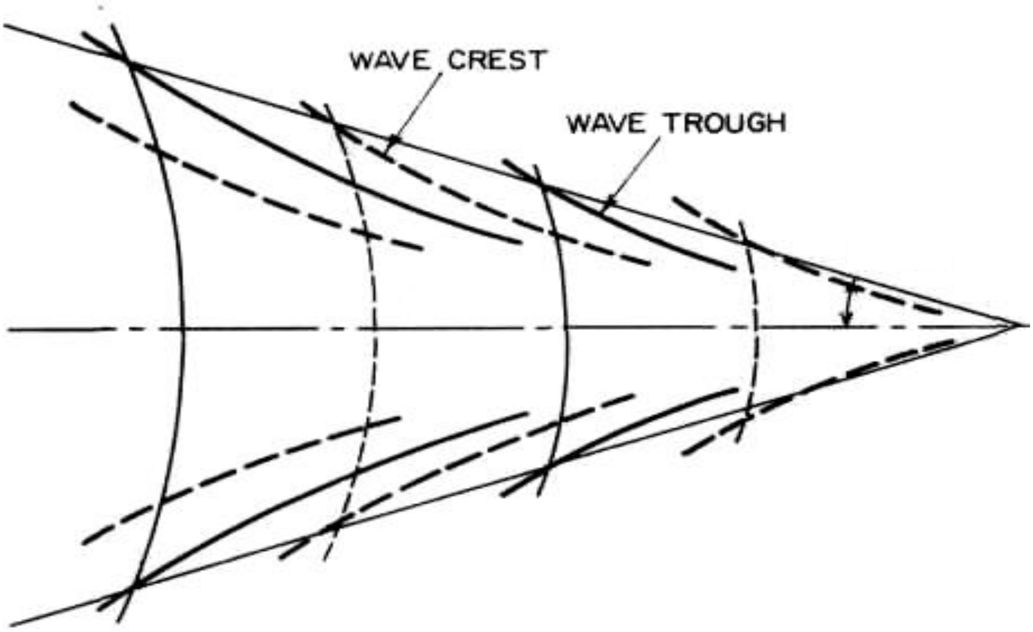


Fig.4.1 Kelvin wave pattern

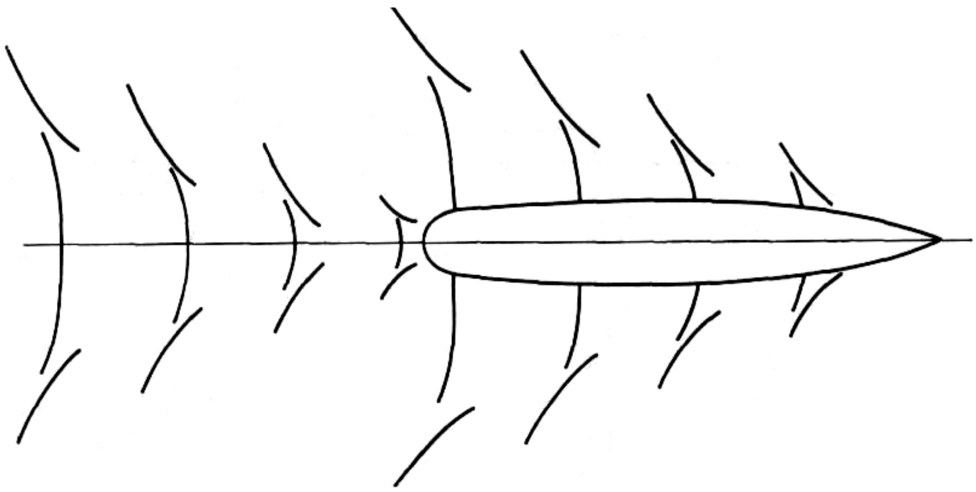


Fig.4.2 Schematic diagram of bow and stern wave systems

CHAPTER-V

SOFTWARES USED

5.1 AutoCAD:

It is a PC helped drafting programming track that empowers the user to make accurate 2-and 3-dimensional drawings utilized as a part of development and assembling. Auto CAD can make scaled drawings that are utilized to make equipment, arrange structure ventures, plan electrical hardware, and assemble homes and business structures.

5.1.1 AutoCAD Features:

- **Storage and accessibility: -** AutoCAD documents can be saved on a PC or chronicled in any capacity media. The software documents also can be saved on any cloud storage, from wherein they're easily handy at whenever, from anywhere provided there's an internet connection.
- **3D View: -** Even though it is feasible to sketch 3-D drawings manually, they're not as powerful and sensible as computer aided drawings. AutoCAD assist model 3D objects with colourings, substances and/or textures carried out to numerous surfaces making them vibrant and less complicated for the consumer to visualize the stop product.
- **Revisions and modifications: -** Any changes in manually drafted paper drawings would require the draftsman to draw the drawing again. on account that this involved a number of efforts, the draftsmen simply scratched out the older information and drew new details, ensuing lack of older info and additionally not-to-scale drawings. CAD has in-built gear that allow any range of revisions and changes effortlessly and fast. you could edit or delete details without problems the use of simple consumer-friendly commands. you may also shop the previous versions of the record if you wish to re-use them.
- **Speed: -** Developing a drawing in AutoCAD is much quicker than drawing manually. you can additionally save time and effort by using developing re-usable block library. smooth edits are viable with commands like copy, reflect, stretching, rotate and scale and plenty of greater such commands
- **Accuracy: -** AutoCAD permits you to attract with fractional dimensions and also outline precision to any variety of decimal places, which is not feasible

to attain in hand-drafted manual drawings, for this reason providing accuracy in all dimensions.

5.2 Solidworks

5.2.1 Introduction to Solidworks:

The Solidworks, cad software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

Solidworks is design automation software. In Solidworks, sketch ideas and experiment with different designs to create 3D models. Solidworks is used by students, designers, engineers, and other professionals to produce complex parts, assemblies and drawings.

- **Concurrent engineering (CE)**– Engineering and manufacturing process are enabled simultaneously from shared Solidworks data.
- **Higher quality** – Due to increased efficiency resulting from the ability to explore a greater number of design iterations during product development.
- **Lower unit costs** – Due to reduced development and prototype expenses.
- **Rapid prototyping (RP)** – Solidworks models can be used to produce prototypes from Stereolithography and other RP technologies.
- **Personnel development** – Solidworks technology provides a challenging environment for employees.
- **Personnel advancement** – A variety of positions regarding the management and supervision of Solidworks become available to advance employee careers.
- **Identify and eliminate inefficiencies** – Solidworks develops opportunities for the elimination of inherent inefficiencies in existing work flows and/or practices.
- **Increased workload capacity** – Efficient use of Solidworks allows the production of more work while maintaining current staff levels.
- **Greater feedback and control of production operations** – Solidworks enables NC tool paths to be generated, updated, and verified automatically with little human intervention.

- **Improved overall communications** – Solidworks enable a shift from the traditional paper-based design and manufacturing system to an electronic paperless one.
- **Increased accuracy of MRP data** – Solidworks data files can be easily linked and managed by MRP software.
- **Increased design flexibility** – Solidworks offers a more robust set of tools and methods to modify designs.
- **Increased design data integrity** – With a single Solidworks model supporting all downstream processes, changes are reflected quickly and accurately.

5.2.2 Solidworks Fundamentals:

Parts are the basic building blocks in the solid works software. Assemblies contain parts or other assemblies, called sub-assemblies. A Solidworks model consists of 3D geometry that defines its edges, faces and surfaces. The Solidworks software lets you design models quickly and precisely.

Solidworks models are defined by 3D design:

- *Based on components*: Solidworks uses 3D design approach as you define the part from the initial sketch to the final result, you create a 3D model. From this model, you can create a 2D drawing or mate components consists of parts and sub-assemblies to create a 3D assembly. You can also create 2D drawings of 3D assemblies. When designing a model using Solidworks can visualise it in 3 dimensions, the way the model exists once it is manufactured.
- *Component based:* One of the most powerful features in the Solid works application is that any change you make to a part is reflected in all associated drawings or assemblies.
- Origin: Appears as two blue arrows and represent the (0,0,0) coordinate of the model. When a sketch is active, a sketch origin appears in red and represents the (0,0,0) coordinate of the sketch.
- Plane: You can use planes for adding 2D sketch, section view of a model, or a neutral plane in a draft feature.
- Axis: Straight line used to create model geometry, features, or patterns. You can create an axis in different ways, including intersecting two planes. The

Solidworks application creates temporary axes implicitly for every conical or cylindrical face in a model.

- Face: Boundaries that help to define the shape of a model or a surface. A face is a selectable area (planar or non-planar) of a model or surface.
- Edge: Locate where two or more faces intersect and are joined together.
- Vertex: Point at which two or more lines or edges intersect. You can select vertices for sketching and dimensioning.

User interface: The Solidworks application includes user interface tools and capabilities to help you create and edit models efficiently.

Windows Function: The Solidworks application includes familiar windows functions, such as dragging and resizing windows. Many of the same icons, such as print, open, save, cut, and paste are also part of the Solidworks application.

Solidworks Documents Window: Solidworks document windows have two panels. The left panel, or Manager Panel, contains

Feature Manager Design tree: Displays the structure of the part, assembly, or drawing.

Property Manager: Provides settings for many functions such as sketches, fillet features, and assembly mates.

Configuration Manager: Create, select, view, multiple configurations of parts, and assemblies in a document.

5.3 ANSYS

The ANSYS Mechanical software to rapidly solve complex structural and thermal problems with ease.

Structural mechanics solutions from ANSYS provide the ability to simulate every structural aspect of a product, including nonlinear static analysis that provides stresses & deformations, modal analysis that determines vibration characteristics, through to advanced transient nonlinear phenomena involving dynamic effects & complex material behavior.

ANSYS is a software package that lets you digitally model real-world phenomena. It uses computer-based numerical techniques to solve physics problems. The range of problems ANSYS can solve is immense and could be anything from fluid flow, heat transfer, stress analysis and more.

The real power of an FEA or CFD package such as ANSYS is that it can solve problems that are not amenable to an analytical approach. That is, they don't have standard formulae. Now, with the arrival of cheap utility computing in the form of cloud, you can really push the limits of what can be modeled on the computer.

- ANSYS can import all kinds of CAD geometries (3D and 2D) from different CAD software's and perform simulations, and also it has the capability of creating one effortlessly. ANSYS has inbuilt CAD developing software's like Design Modeler and Space Claim which makes the work flow even smoother.
- ANSYS has the capability of performing advanced engineering simulations accurately and realistic in nature by its variety of contact algorithms, time dependent simulations and nonlinear material models.
- ANSYS has the capability of integrating various physics into one platform and perform the analysis. Just like integrating a thermal analysis with structural and integrating fluid flow analysis with thermal and structural, etc.,
- ANSYS now has featured its development into a product called ANSYS AIM, which is capable of performing multi physics simulation. It is a single platform which can integrate all kinds of physics and perform simulations.
- ANSYS has its own customization tool called ACT which uses python as a background scripting language and used in creating customized user required features in it.
- ANSYS has the capability to optimize various features like the geometrical design, boundary conditions and analyse the behaviour of the product under various criterions.

5.3.1 ANSYS Features:

- **Efficient and Flexible Workflow**: Fluent is fully integrated into the ANSYS Workbench environment, a platform designed for efficient and flexible workflows, CAD associativity and powerful capabilities in geometry modeling and meshing. The built-in parameter manager makes it easy to rapidly explore multiple design options.

- **Built for Multi physics**: Gain deeper insight into the complex, often counter intuitive interactions caused by multiple physics such as fluid–structure interaction (FSI). ANSYS Fluent is fully integrated with ANSYS Workbench to provide full two-way interactivity with ANSYS Mechanical, ANSYS Maxwell and other simulation technologies.
- **Solve Complex Models with Confidence**: ANSYS Fluent can solve your most sophisticated models for multiphase flows, chemical reaction and combustion. Even complicated viscous and turbulent, internal and external flows, flow-induced noise predictions, heat transfer with and without radiation can be modeled with ease.
- **Go Faster with High Performance Computing (HPC):** With HPC, ANSYS Fluent delivers CFD simulation solutions faster so that engineers and designers can make better decisions sooner in the design cycle. While ANSYS HPC provides linear scalability on systems with tens of thousands of processors, there is more to HPC than just the number of cores. ANSYS also optimizes processor architecture, algorithms for model partitioning, optimized communications and load balancing between processors to deliver results in breathtaking speed on a wide variety of simulation models.
- **Turbulence Modeling:** ANSYS Fluent software places special emphasis on providing a wide range of turbulence models to capture the effects of turbulence accurately and efficiently. Several innovative models such as the Menter–Langtry γ–θ laminar–turbulent transition model™ are available only in Fluent.
- **Heat Transfer & Radiation**: Fluent handles all types of radiative heat exchange in and between fluids and solids, from fully and semi-transparent to radiation, or opaque. You can choose from a variety of spectral models to account for wavelength dependencies in a simulation and to account for scattering effects.
- **Multiphase Flow:** A complete suite of models capture the interplay between multiple fluid phases like gasses and liquids, dispersed particles and droplets, and free surfaces.
- **Reacting Flow:** Whether simulating combustion design in gas turbines, automotive engines, or coal-fired furnaces, or assessing fire safety in and around buildings and other structures, ANSYS Fluent software provides a rich framework to model chemical reactions and combustion associated with fluid

flow. ANSYS Fluent handles non-premixed, partially-premixed, or premixed combustion models to accurately predict parameters like the flame speed, flame location, and the post-flame temperature.

- **Acoustics:** ANSYS Fluent computes the noise resulting from unsteady pressure fluctuations to solve acoustical simulations.
- **Fluid-Structure Interaction:** Fluent models the effects of solid motion on fluid flow by coupling with ANSYS structural mechanics solutions through the Workbench unified user environment. Fluent users enjoy robust and accurate two-way FSI without the need to purchase, administer or configure third-party coupling and pre- and post-processing software.
- **Optimize Your Design – Automatically:** Fluent's shape optimization tools can automatically adjust the geometric parameters until your optimization goals are met. For example, aerodynamics of a car or aircraft wing and the optimized flow rate in nozzles and ducts. Fluent's ground-breaking adjoint solver modifies the mesh from within to see the effect of a recommended change. The adjoint solver provides recommendations to improve geometries that are difficult and expensive to get any other way.

CHAPTER-VI

COMPUTATIONAL FLUID DYNAMICS

Computational Fluid Dynamics (CFD), is the analysis of systems involving fluid flows, heat transfer and associated phenomena such as chemical reactions by means of computer-based simulation. From the 1960s onwards, the aerospace industry has integrated CFD techniques into the design, R&D and manufacture of aircraft and jet engines.

The use of CFD to predict internal and external flows has risen dramatically in past decade. The widespread availability of engineering work stations together with efficient solution algorithms and sophisticated pre- and post-processing facilities enable the use of commercial CFD codes. The codes available may be extremely powerful, but their operation still requires a high level of skill and understanding from the operator to obtain meaningful results in complex situations.

The availability of affordable high-performance hard ware and the introduction of user-friendly interface have led to a recent upsurge of interest in CFD predictions. This greatly reduced cost and time required in testing of new designs. The opportunity to study very big systems that otherwise would be difficult to study and model indoors, or systems that could prove to be dangerous, became feasible with CFD.

Also, optimization of performance of products will be a lot cheaper because of no limitations in doing parametric studies. The way we solve problems when there is no analytical solution, is to make simplifications and assumptions that may pollute the result in some ways. We make simplified boundary conditions and simplified dynamic equations for the conservation of mass, momentum and energy. But with the increasing power of CFD, we are able to solve more complete forms of these equations and therefore get more accurate results.

There are also problems which are impossible to solve analytically in any way, and is in need of being solved numerically through CFD to get any reasonable results at all. Thus, with the help of CFD we can develop a deeper understanding of flow characteristics in certain processes and will therefore be able to further increase the knowledge used in the design process.

6.1 Governing Equations:

CFD, in one form or another form is based on the fundamental governing equations of fluid dynamics-the continuity, momentum, and energy equations. These are the mathematical statements of three fundamental physical principals upon which the fluid dynamics is based.

Fundamental principles are:

- Mass is conserved
- Newton's second law, F = ma
- Energy is conserved

6.2 Computational Solution for Turbulent Flows:

There are three main classes of techniques for dealing with turbulent flows:

1. Direct Numerical Simulation (DNS)
2. Large Eddy Simulation (LES)
3. Reynolds Averaged Navier-Stokes equations (RANS)

To resolve a turbulent flow by direct numerical simulation (DNS) requires that all relevant length scales be resolved from the smallest eddies to scales on order of the physical dimensions of problem domain. To get statistical quantities of interest, which cannot be measured, experimentally, can be evaluated from the simulations. DNS is used for developing an understanding of the physics of the flow and deployed in developing turbulence models for simple flows. However, from an engineering point of view, it provides far more information than an engineer needs, and it is simply too expensive to be employed on a regular basis.

Most engineering flows of interest are in the turbulent regime, which contains a wide range of length and time scales. In Large Eddy Simulation (LES), the large eddies are computed and the smallest eddies are modelled, as the large-scale motions are more energetic than the small-scale ones and are responsible for most of the transport. The small-scale turbulence serves mainly to drain energy from the large scales through the cascade process, and is more universal and nearly isotropic, which makes it more suitable to be modelled. The computational effort required for LES is less than that of DNS by approximately a factor of l0 using present day methods.[10]

The Reynolds-averaged Navier stokes equations are time averaged equations of motion for fluid flow. The idea behind the equation is Reynolds decomposition, whereby an instantaneous quantity is decomposed into its time averaged and fluctuating quantities. Time averaging the equations of motion gives rise to new terms, which can be interpreted as "apparent" stress gradients associated with the turbulent motion. These new quantities must be related to the mean flow variables through turbulence models.

6.2.1 Reynolds Averaged Navier-Stokes Equations:

The mean value of a hydrodynamic quantity, for example, the Xi component of the velocity, U_i, *is* defined by

$$\bar{u}_i = \frac{1}{T}\int_{t_0}^{t_0+T} u_i dt$$

in which t_0 is any arbitrary time, and T is the time over which the mean is taken, should be large compared to the period of the random fluctuations associated with turbulence. This is called time averaging. The instantaneous value of the velocity u_{i_2} may be written as

$$u_i = \bar{u}_i + u_i'$$

In which u_i' is called the fluctuating part (or fluctuation) of u_i and $\overline{u_i}$ is its mean. This is called the Reynolds decomposition. The Reynolds decomposition can be applied to any hydrodynamic quantity. Continuity and momentum equations are only used in the present study as Governing equation. These equations are written in converged form for turbulent flow.

The $k-\varepsilon$ turbulence model:

The turbulence kinetic energy, ***k***, and its rate of dissipation, ε, are obtained from the following transport equations:

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k+G_b-\rho\varepsilon-Y_M+S_k$$

And

$$\frac{\partial}{\partial t}(\rho \varepsilon)+\frac{\partial}{\partial x_i}(\rho \varepsilon u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}+S_\varepsilon$$

In these equations, G_k represents the generation of turbulence kinetic energy due to the mean velocity gradients. G_b is the generation of turbulence kinetic energy due to buoyancy. Y_M represents the contribution of the fluctuating dilatation in compressible turbulence to the overall dissipation rate. $C_{1\varepsilon}, C_{2\varepsilon}$, and $C_{3\varepsilon}$ are constants. σ_k and σ_ε are the turbulent Prandtl numbers for k and ε, respectively. S_k and S_ε are user-defined source terms.

Modelling the Turbulent Viscosity:

The turbulent (or eddy) viscosity, μ_t, is computed by combining k and ε as follows:

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon}$$

Where, C_μ is constant.

6.3 Working of CFD Code:

CFD codes are structured around the numerical algorithms that can tackle fluid flow problems. In order to provide easy access to their solving power all commercial CFD packages included sophisticated user interfaces to input problem parameters and to examine the results. Hence all code contains three main elements

- A pre-processor
- A solver
- A post processor

6.3.1 Pre-processor:

Pre-Processing consists of the input of a flow problem to a CFD program by means of an operator friendly interface and the subsequent transformation of this input into a form suitable for use by the solver. The user activities at the pre-processing stage involve:

- Definition of the geometry of the region of interest: the computational domain.
- Grid generation- the sub-division of domain into a number of smaller, non-overlapping sub- domains: a grid (or mesh) of cells (or control volume or elements).
- Selection of the physical and chemical phenomena that need to be modelled.
- Definition of fluid properties.
- Specification of appropriate boundary conditions at cells which coincide with or touch the domain boundary.

6.3.2 Solver:

In outline the numerical algorithms consist of the following steps:

- Integration of the governing equations of fluid flow over all the control volumes of the domain.
- Discretization - conversion of the resulting integral equations into a system of algebraic equations.
- Solution of the algebraic equations by an iterative method.

6.3.3 Post- Processor:

As in Pre-Processing, a huge amount of development work has recently taken place in the post processing field. Due to the increased popularity of engineering workstations, many of which have outstanding graphics capabilities, the leading CFD packages are now equipped with versatile data visualization tools. These include:

- Domain geometry and grid display.
- Vector plots
- Line and shaded contour plots.
- 2D and 3D surface plots.
- Particle tracking

6.4 Methodology of Work:

6.4.1 Outline:

- Domain study.
- Model generation of the ship using Maxsurf software.
- Generation of mesh model for the bare hull by using ICEM-CFD.
- Solution of the flow problem using CFD code (CFX)
- Validation of results with the available experimental results.

6.4.2 Description:

The basic steps involved are:

- Problem specification and geometry preparation. It involves the specification of problem, including the geometry, flow conditions and the requirements of the simulation.
- Selection of governing equations and boundary conditions
  - Boundary conditions
  - Specified velocity on inlet
- Selection of gridding strategy and numerical method
  - A numerical method and a strategy for dividing the flow domain into cells, or elements must be selected.
- Assessment and interpretation of results
  - Post processing of data

6.5 Bare Hull and its Dimensions:

The main body of a ship to which are attached superstructures and appendages is called ship hull. The ship hull geometry consists of water lines and section. These are drawn with the help of data which is prescribed in offset table. While modelling the ship hull the non-dimensional geometrical data was converted into point co-ordinate data. This data was used to generate the expanded sections; these sections were stacked according to their axial distance perpendicular to axes line and generate the water lines were generated parallel to the axes. These sections were offset according to the offset distance. Finally, these were wrapped around to get the final sections and these sections were connected smoothly by lofted surfaces.

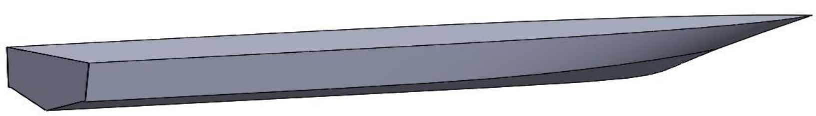


Fig.6.1 Ship hull geometry

Table No. 6.1. Principal particulars of the ship hull and domain

Sl. No	Hull Dimensions	Domain size
1	Length – 51.5m	Length - 200 m
2	Breadth – 9.2 m	Breadth - 20 m
3	Draft – 1.5 m	Height - 51 m
4	Scale factor	40

6.6 Domain for Bare Hull:

First, the surface model of the bare hull and was generated using the modelling software Maxsurf and then it was imported in '.stp' format to ICEM-CFD software for meshing purpose. The computational domain in this study extends for 1.5L in front of the ship hull, 2.5L behind the hull, 1.5L to the side and 0.75L under the keel of the model. The air layer extends 0.25L above the still water surface. The hull with domain is shown in the Fig 6.2.

Researchers have worked with different domains and mostly agreed for a domain size as shown in Fig.6.2, ITTC conference exhibited the same. The mesh is generated in such a way that cell sizes near the hull surface are small and increase towards outer boundary.

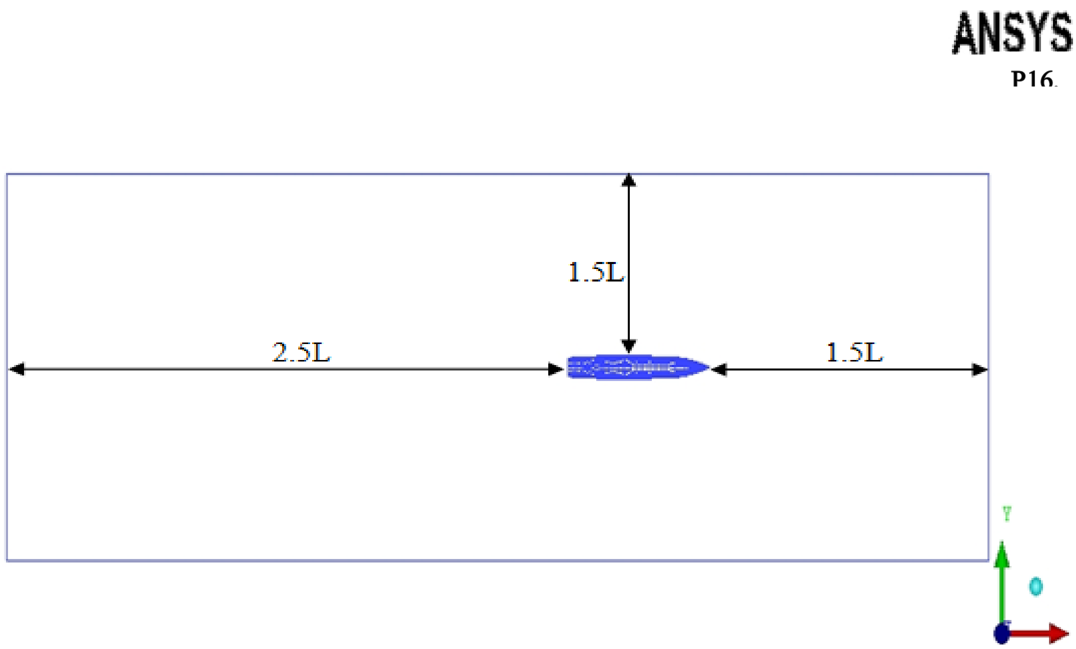


Fig. 6.2 (a) Ship hull domain in 2-D view

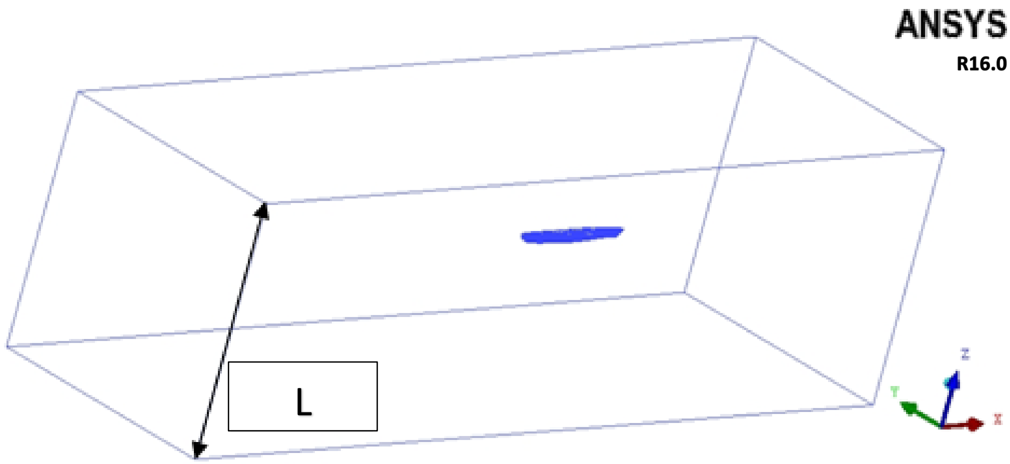


Fig. 6.2 (b) Ship hull domain in 3-D view

6.7 Mesh Generation

6.7.1 General:

The computational grid represents the geometry of the region of interest. It consists of grid cells that provide an adequate resolution of the geometrical features. In hydrodynamics, body-fitted grids are used almost universally. However, several kinds of mesh topology are available:

- **Structured grid:** The points of a block are addressed by a triple of indices (i, j, k). The connectivity is straight-forward because cells adjacent to a given face are identified by the indices. Cells have the shape of hexahedral, but a small number of prisms, pyramids and tetrahedral with degenerated faces and edges are sometimes accepted
- **Unstructured grid:** Meshes are allowed to be assembled cell by cell freely without considering continuity of mesh lines. The most typical cell shape is the tetrahedron, but any other form including hexahedral cells is possible.

6.7.2 Grid Generation:

The flow domain is required to be discretized to convert the partial differential equations into a series of algebraic equations. This process is called grid generation. For reducing the total number of nodes and increasing the number of nodes near the ship hull the total domain is divided into two parts and an interface is given between the two. To generate the structural grid with hexahedral cells, the grid generator of the RANSE code (ICEM CFD) has been used for building the required multi-block mesh for the code solver. The mesh was refined in the free surface region in order to get a fine mesh at the free surface. Furthermore, for predicting accurate values, the mesh elements were refined on and near the ship hull surface in order to calculate accurate pressure forces acting on the hull form at the four Froude numbers.

The steps involved in grid generation are listed below:

a) The blocking strategy
b) Starting the project
c) Blocking the geometry
d) Splitting and Collapsing blocks
e) Associating to geometry
f) Generating the mesh
g) Checking the mesh quality

6.7.2.1 The Blocking strategy:

In this, the hull is regarded as a solid region, while the region surrounding the hull is regarded as the fluid region. Using Block Splitting at "Prescribed point", generate a Hexahedral Mesh for both of the regions, so that the topology of the solid region is a degenerate 'Hexahedral' mesh.

6.7.2.2 Starting the project:

From UNIX or DOS window, start ANSYS ICEMCFD. Go to File>Geometry>Open geometry and choose the geometry file (.stp).

6.7.2.3 Blocking the geometry:

Select blocking > create block > Initialize block. Select the LIVE Part, make sure Type >3D Bounding Box is selected (default) and Apply.

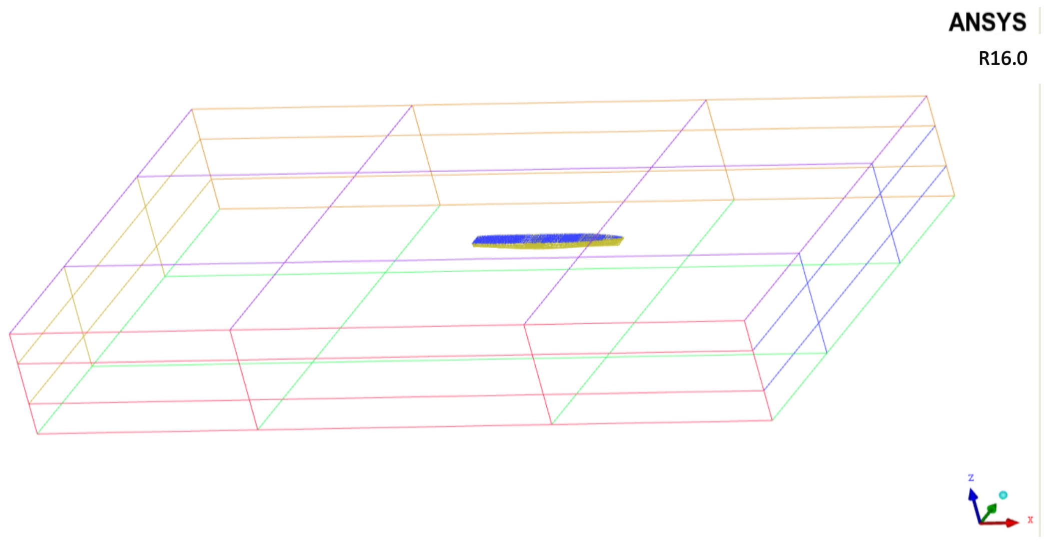


Fig.6.3 Blocking of inner zone geometry

6.7.2.4 Splitting and collapsing of the blocks:

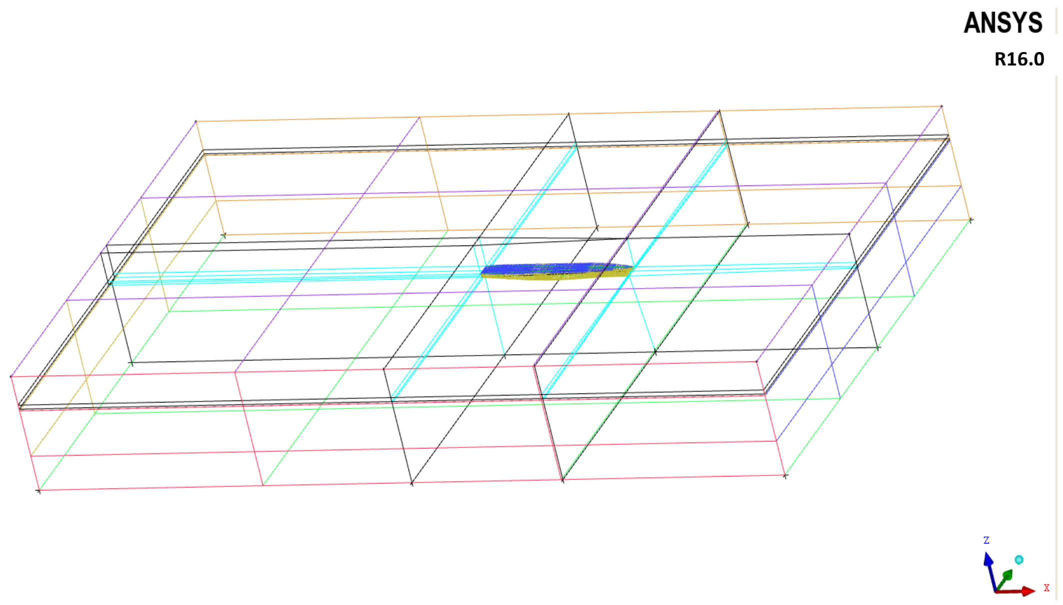


Fig.6.4 Splitting of the blocks

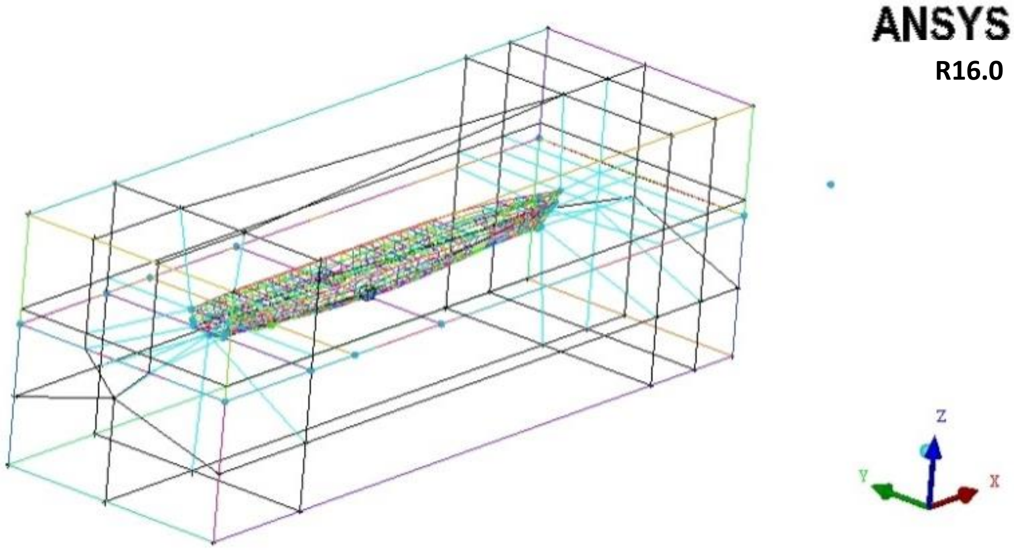


Fig.6.5 Collapsing of the blocks

Inner zone of the domain is split into blocks as shown. This is to bring the edges of the blocks to the shape of a ship. The respective edges are collapsed to get the desired result.

6.7.2.5 Associating to geometry:

Associate vertex:

To fit the initialized blocking more closely to the geometry, associate vertices to points.

Select blocking > Associate > Associate vertex and a window will open. Toggle ON Geometry > Points and right mouse click on vertices > Numbers under blocking from display tree. Then toggle ON Blocking > vertices> Select point under entity.

Press the vertex selection icon and select Vertex. Press the point selection icon and select point and press apply to associate them.

Associating edges to curves:
Select Associate Edge to curve.

The edges of the blocking will now be associated to the curves of the CAD geometry. First select the edges, then the curves to associate the edges. The block edges then transform from “white’ to ‘green’, confirming their association with the curve. If two or more curves are selected per operation, those curves will automatically be grouped (concatenated). The curves change to one colour, indicating that they have been grouped to one curve.

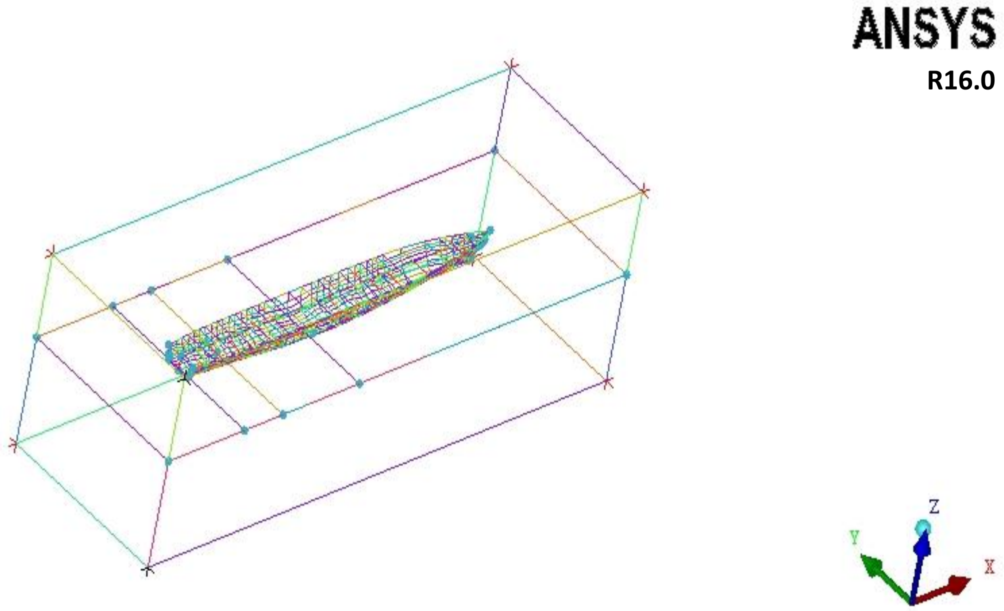


Fig.6.6 Association of hull and its domain

6.7.2.6 Mesh Generation:

Defining edge parameters to adjust the mesh
Select Blocking >Pre-mesh >set parameters >Update Sizes. Make sure update all edges, and press apply. This will compute the node distributions on the blocking edges parameters. Turn ‘ON’ Blocking > Pre-Mesh from the Display Tree. Press Yes, when it says, Mesh is currently out of date – recomputed? Right click on Blocking > Pre-Mesh>Solid & wire in the Display Tree to display the mesh in solid/wire for better visualization.

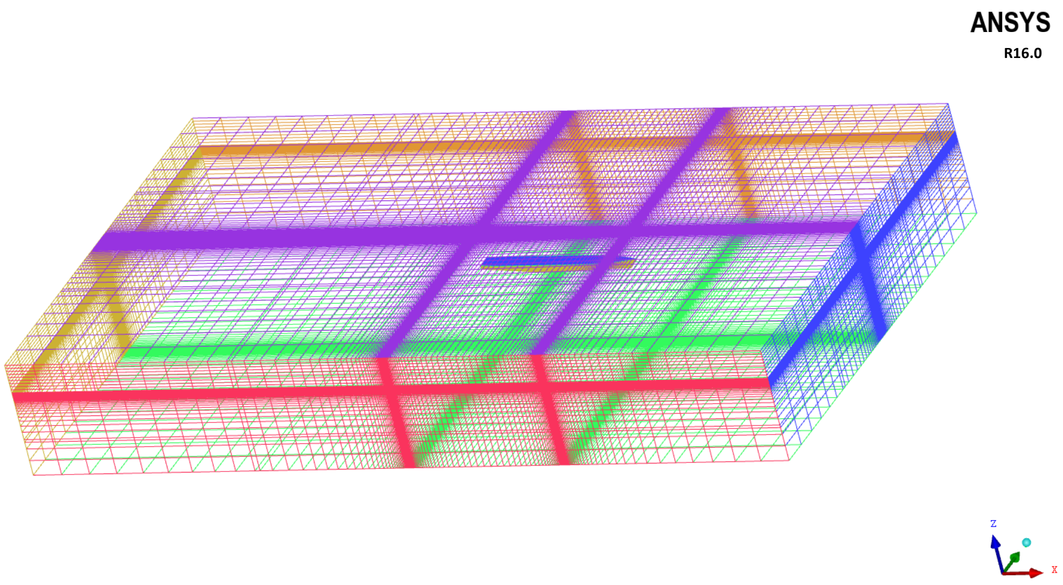


Fig.6.7 Hull & Domain mesh

6.7.2.7 Checking the mesh quality:

The determinant check computes the deformation of the cells in the mesh by first calculating the Jacobian of each hexahedron and then normalizing the determinant of the matrix. A value of 1 represents a perfect hexahedral cube, while a value of 0 is a totally inverted cube with a negative volume. The mesh quality, measured on the x-axis, of all cells will be in the range from 0 to1. If the determinant value of a cell is 0, the cube has one or more degenerated edges. In general, determinant values above 0.3 are acceptable for most solvers. The y-axis measures the number of cells that are represented in the histogram. This scale ranges from 0 to a value that is indicated by the height. The subdivision among the quality range is determined by the number of assigned bars.

CHAPTER-VII

RESULTS AND DISCUSSIONS

The wave cuts along the hull surface at four speeds 7, 14, 20 and 24 knots. The comparisons between the predicted results and the available experimental results show in general good agreement between the results at the three speeds.

The comparison between the predicted wave pattern around the hull by CFX using the turbulence model method at V= 7, 14, 20 and 24 knots, and the available experimental results obtained show the ability of CFX for predicting nearly the same wave contours. However, it may be difficult to calculate the wave contours at low Froude number due to the small value of the wave making resistance in this case. On the other hand, there is a good agreement between CFX results and the numerical results for the wave contours at higher Fn. The transverse and divergent waves have a pronounced effect on the wave pattern, which has been predicted well by CFX.

The detected distribution of the pressure coefficient on the hull at four different speeds is presented in the following figures. The higher value of the pressure coefficient can be found at the stagnation region on the hull near bow. The pressure increases again aft of the stern region due to the effect of hull geometry on the flow pattern around the hull at high speed. The pressure decreases and approximately extends over the entire region of the hull mid part due to nearly the constant cross-section of the hull in this region. Finally, the effect of the hull wave pattern on the hull pressure distribution was detected well by the code at the draft region.

The numerical results obtained for the pressure resistance by CFX at four speeds, are presented in the table.

Pressure Contour at various speeds:

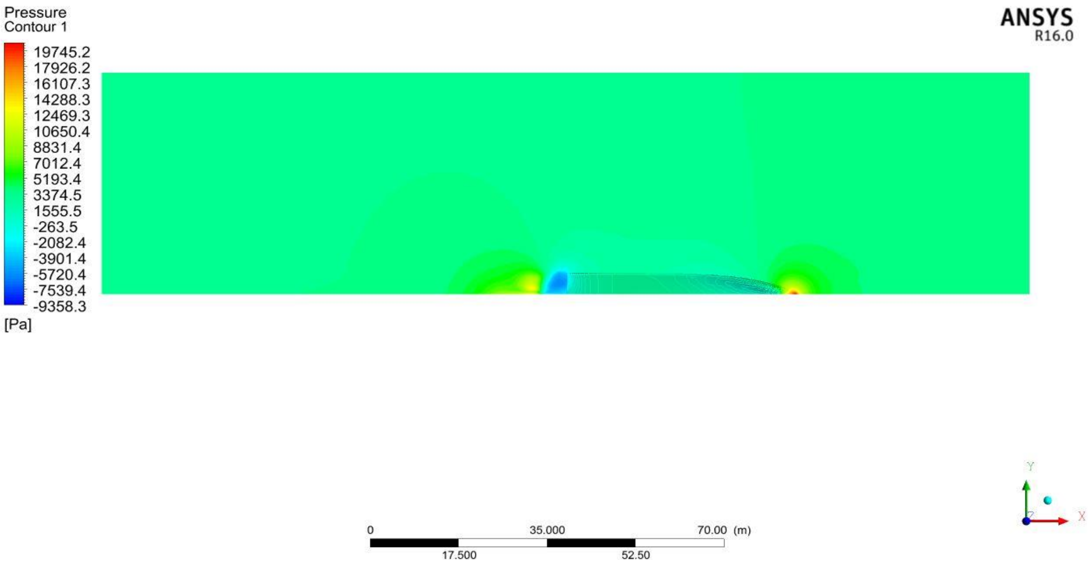


Fig.7.1 At velocity = 7 knots

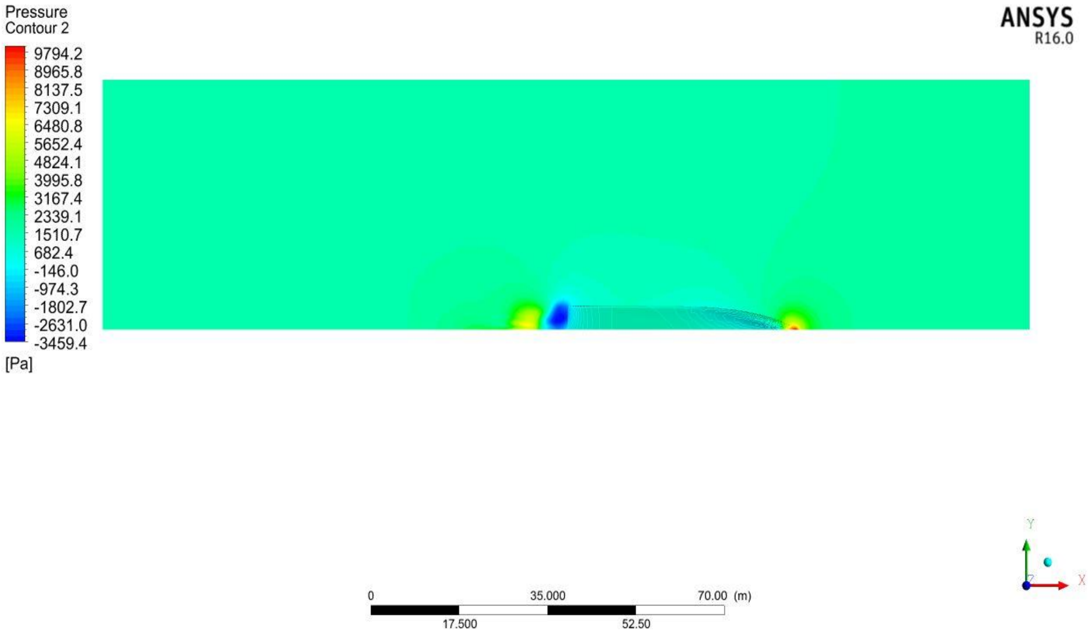


Fig.7.2 At velocity = 14 knots

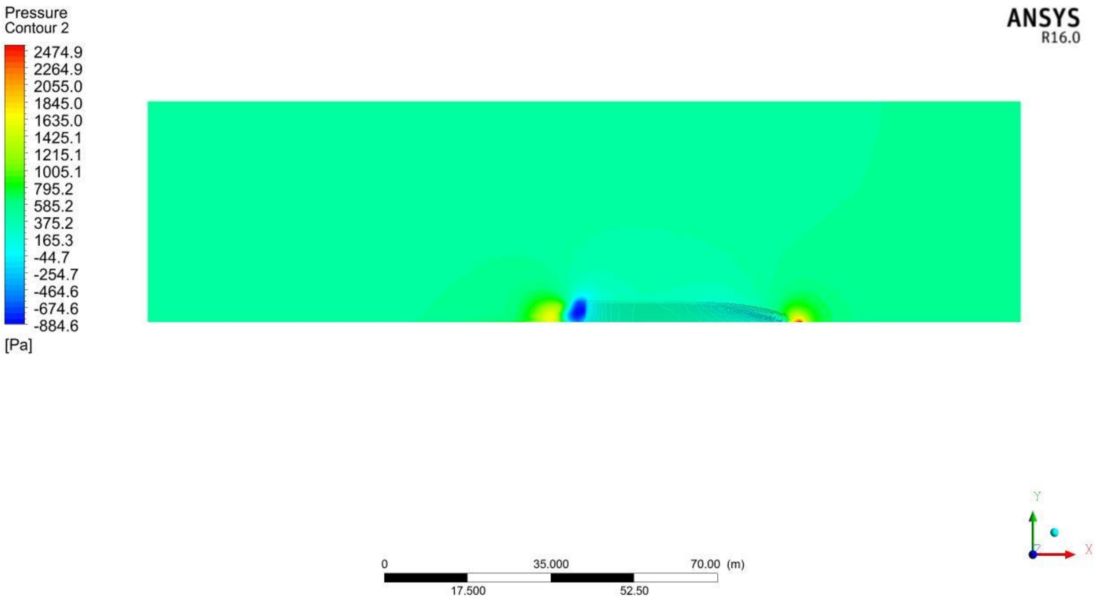


Fig.7.3 At velocity = 20 knots

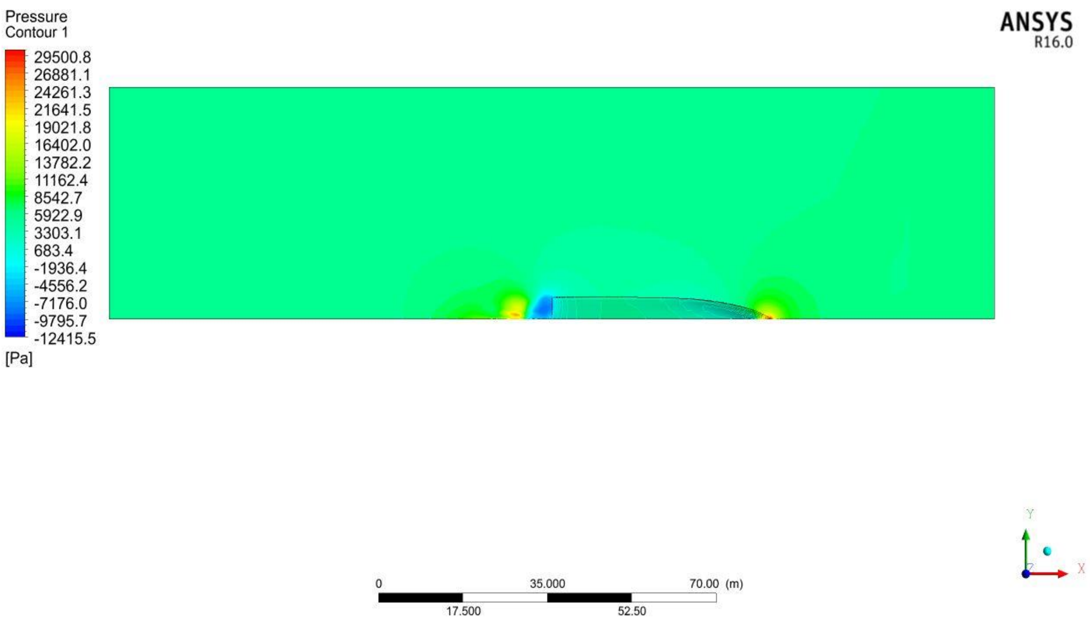


Fig.7.4 At velocity = 24 knots

Table.7.1 Experiment Data vs CFD Data

Sr. No	Experimental Data		CFD Data	
	V (knots)	R_T (kN)	V (knots)	R_T (kN)
1	7	15.2	7	17.4
2	14	76.1	14	68
3	20	168	20	158
4	24	195	24	191

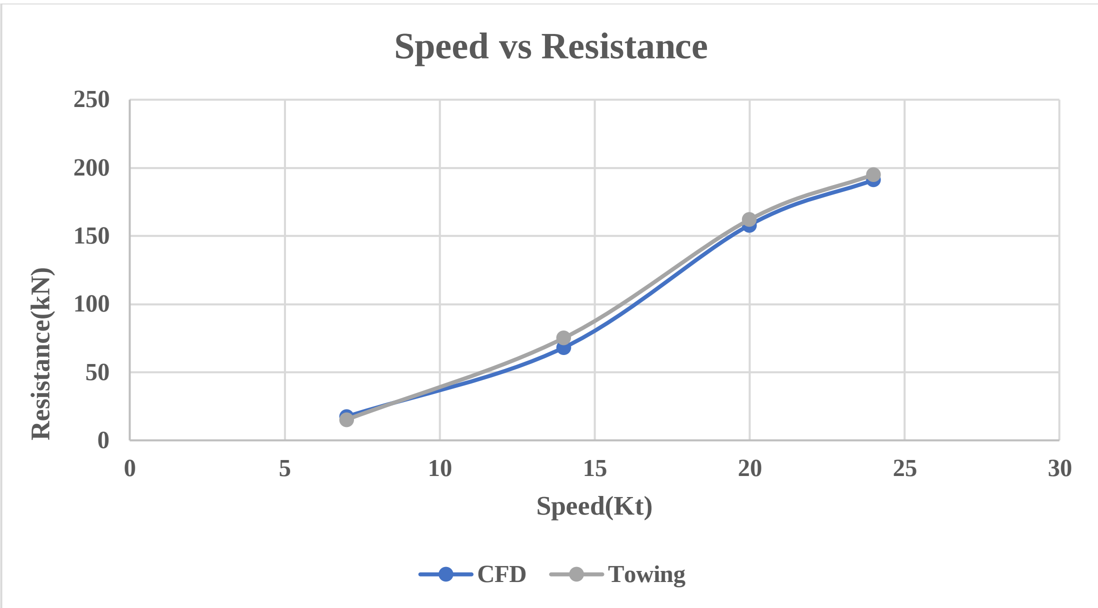


Fig.7.5 Graph of resistance vs speed for CFD and towing tank results

CHAPTER-VIII

CONCLUSION

In this project work, design and fabrication of an unmanned prototype patrolling vessel was constructed and it was tested at different conditions and parameters. Based on the experimental observations the following conclusions are drawn.

- The dimensions of the unmanned patrol vessel were taken from a parent ship which were obtained from Hindustan Shipyard Limited.
- Based on the parent ship data stations were developed by using AutoCAD design software.
- 3D surfaces of the vessel were generated using Maxsurf ship building software which was performed at Indian Maritime University, Visakhapatnam.
- In general parent ships lengths are varied from 40 to 200 meters which was very difficult for design and fabrication. In-order to overcome the hurdle, the parent ship was scaled down to 1:40 by following the international standards.
- Prototype was built with fiberglass which was easily available in the market.
- The prototype was tested in the towing tank for different speeds and their resistance.
- The obtained resistance values are compared in the ICEM-CFD simulation software both are in a good agreement with an error of 3% which can be neglected.
- The unmanned patrol vessel was fitted with different electronic equipment and thus the desired functionality is observed.

FUTURE SCOPE

The prototype that was designed by us, consists of electrical components which gives a greater advantage over the conventional patrolling vessel such as having more space and less weight. As such, this prototype when scaled to original dimensions, can further be upgraded with automatic armory system. This feature would allow the person on shore to encounter the enemies in open sea.

And with few other modifications like automatic safety tube ejector, this prototype can be upgraded as a rescue vessel which can help the person drowning in the sea, by the time a rescue team reaches that person.

REFERENCES

[1] Brizzolara S. Parametric optimization of SWAT-hull forms by a viscous-in viscid free surface method driven by a different evolution algorithm. 25th Symposium on Naval Hydrodynamics, vol. 5, St. John's, NL, Canada,2004.

[2] Caccia, M., Bruzzone, G. and Bono, R. 2008. A practical approach to modelling and identification of autonomous surface craft, IEEE Journal of Oceanic Engineering.

[3] Campana EF, Peri D, Tahara Y, Stern F. Comparison and validation of CFD based local optimization methods for surface combatant bow. 25th Symposium on Naval Hydrodynamics, vol. 5, St. John's, NL, Canada, 2004.

[4] Curcio, J., Leonard, J. and Patrikalakis, A. (2005). SCOUT - A low cost autonomous surface platform for research in cooperative autonomy. Proceedings of MTS/IEEE Conference on Oceans, Washington, USA, 19-23 September 2005.

[5] Duvigneau R, Visonneau M, Deng GB. On the role played by turbulence closures in hull shape optimization at model and full scale. Journal of Marine Science and Technology 2003.

[6] Hino T, Kodama Y, Hirata N. Hydrodynamic shape optimization of ship hull forms using CFD. 3rd Osaka Colloquium on Advanced CFD Applications to Ship Flow and Hull Form Design, Osaka Prefecture University, Japan, 1998.

[7] Hoekstra M, Raven HC. A practical approach to constrained hydrodynamic optimization of ships. NAV2003 Conference, Palermo, Italy, June 2003.

[8] Kijima K, Nakiri Y. Approximate Expression for Hydrodynamic Derivatives of Ship Manoeuvring Motion Taking into Account of the Effect of Stern Shape, vol. 98, J. the West Japan Society of Naval Architects, Japan, 1999.

[9] Manley, J. 1997. Development of the autonomous surface craft "ACES". Proceedings of MTS/IEEE Conference on Oceans, Halifax, Nova Scotia, 5-9 October 1997.

[10] Manley, J., Marsh, A., Cornforth, W. and Wiseman, C. 2000. Evolution of the autonomous surface craft AutoCat. Proceedings of MTS/IEEE Conference and Exhibition on Oceans, Rhode Island, 11-14 September 2000.

[11] Minami Y, Hinatsu M. Multi objective optimization of ship hull form design by response surface methodology. 24th Symposium on Naval Hydrodynamics, Fukuoka, Japan, 2002.

[12] Naeem, W., Sutton, R. and Chudley, J. 2006. Soft computing design of a linear quadratic Gaussian Controller for an Unmanned Surface Vehicle. Proceedings of 14th Mediterranean Conference on Control and Automation, Ancona, Italy, 28-30 June 2006.

[13] Nakatake K. A practical method to calculate propulsive performance of ships. Memoirs of the Faculty of Engineering 1981.

[14] Newman III JC, Pankajakshan R, Whitfield DL, Taylor LK. Computational design optimization using RANS. 24th Symposium on Naval Hydrodynamics, Fukuoka, Japan, 2002.

[15] Pascoal, A. Oliveira, P. and Silvestre, C. 2000. Robotic ocean vehicles for marine science applications: the European Asimov project. Proceedings of MTS/IEEE Conference and Exhibition on Oceans, Rhode Island, 11-14 September 2000.

[16] Pascoal, A., Silvestre, C. and Oliveira, P. 2006. Vehicle and mission control of single and multiple autonomous marine robots. Advances in Unmanned Marine Vehicles.

[17] Peri D, Campana EF, Di Mascio A. Development of CFD-based design optimization architecture. 1st MIT Conference on Fluid and Solid Mechanics. Cambridge, MA, U.S.A., 2001.

[18] Peri D, Campana EF. High fidelity models in the multi-disciplinary optimization of a frigate ship. 2nd MIT Conference on Fluid and Solid Mechanics. Cambridge, MA, U.S.A., 2003.

[19] Peri D, Campana EF. Multidisciplinary design optimization of a naval surface combatant. Journal of Ship Research 2003.

[20] Peri D, Campana EF. High fidelity models in simulation-based design. 8th International Conference on Numerical Ship Hydrodynamics, Busan, South Korea, 2003.

[21] Peri D, Campana EF. High-fidelity models and multi objective global optimization algorithms in simulation-based design. Journal of Ship Research 2005.

[22] Tahara Y, Himeno Y, Tsukahara T. An application of computational fluid dynamics to tanker hull form optimization problem. 3rd Osaka Colloquium on Advanced CFD Applications to Ship Flow and Hull Form Design, Osaka, Japan, 25–27 May 1998.

[23] Tahara Y, Paterson E, Stern F, Himeno Y. Flow- and wave-field optimization of surface combatants using CFD-based optimization methods. 23rd Symposium on Naval Hydrodynamics, Val de Ruil, France, 2000.

[24] Tahara Y, Ando J, Himeno Y. CFD-based optimization of tanker stern form-minimization of delivered horsepower using self-propulsion simulator, Practical Design of Ships and Other Floating Structures, Shanghai, China,2001

[25] Tahara Y, Sugimoto S, Murayama S, Katsui T, Himeno Y. Development of CAD/CFD/Optimizer-Integrated Hull-Form Design System, vol. 240, J. Kansai Society of Naval Architects, 2003; 29–36 (also a related Manuscript was presented at NAPA User Meeting 2003, Helsinki, Finland, 2003).

[26] Tahara Y, Hayashi G. Flow Analyses Around Downwind-sail System of an IACC Sailing Boat by a Multiblock NS/RaNS Method, vol. 194, J. Society of Naval Architects of Japan, 2003

[27] Tahara Y, Katsui T, Himeno Y. Development of simulation-based design for ship hydrodynamics and fluid engineering. 4th Conference for New Ship & Marine Technology, Shanghai, 2004

[28] Tahara Y, Stern F, Himeno Y. CFD-based optimization of a surface combatant. Journal of Ship Research 2004

[29] Tahara Y, Peri D, Campana EF, Stern F. CFD-based multi objective optimization of a surface combatant. 5th Osaka Colloquium on Advanced Research on Ship Viscous Flow and Hull Form Design by EFD and CFD Approaches, Osaka, Japan, 14–15 March 2005.

[30] Tahara Y, Wilson R, Carrica P. Comparison of free-surface capturing and tracking approaches in application to modern container ship and prognosis for extension to self-propulsion simulator. CFD Workshop, Tokyo, 2005, Tokyo, Japan, 9–11 March 2005.

[31] Wu G., Sun H., Zou J. and Wan L., 2009. The basic motion control strategy for the Water-Jet-Propelled USV. Proceeding of 2009 IEEE International conference on Mechatronics and Automation, Changchun, China, 9-12 August2009.