

Arab Academy for Science, Technology and Maritime Transport

College of Engineering and

Technology Department of

Mechanical Engineering

Final Year Project

AIR BUBBLE DRAG REDUCTION

Presented By:

Amr sameh Mohamed abdelal
17101086

Yousef Mohamed morsy
17101748

Amr Adel Ali
17102585

Mohamed Ali Mostafa
17101541

Supervised By:

Prof. Hassan El gamal

prof. Khaled El-Sherbeiny

Prof. Rola afifi

DECLARATION

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Student Name: Amr sameh
Registration Number:17101086
Signed: _____

Student Name: Youssef morsy
Registration Number:17101748
Signed: _____

Student Name: Mohamed ali
Registration Number:17101541
Signed: _____

Student Name: Amr adel
Registration Number:17102585
Signed: _____

ABSTRACT

This project has been prepared by Four Mechanical students of the Arab academy for science and technology and maritime transport as a part of their Graduation Project requirements.

This project aims to reduce the drag force of a designed KCS ship with holes in the bottom of it. This design matched with appropriate research and accurate analysis, an advanced design assembly of the ship with the objective of getting improved performance within the time bound and available resources to meet with the broad aspect of the project objective.

Graph and charts were chosen as suitable way to analyze data output according to different parameter inputs.

We used references in our project varies between several books, scientific papers and sites.

ACKNOWLEDGEMENTS

First and foremost, we would like to thank God for giving us the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily. Without his blessings, this achievement would not have been possible.

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Chapter 1

Introduction

Chapter 1
Introduction

Over the years there has been extensive and sustained research aimed both at determining techniques for reducing skin friction drag and at explaining how successful techniques work. The reduction of CO2 emissions has been a key target in the marine industry since the IMO's MEPC published its findings in 2009. Air lubrication method by air micro bubbles is one of the mature technologies for commercialization to reduce the frictional resistance and enhance fuel efficiency of ships. Air layer is formed by the coalescence of the injected air bubbles beyond a certain air flow rate. By selecting optimal air injector configuration and distribution ratio between two injectors, the total resistance was able to be reduced down, thus being the most effective way to reduce operating costs and fulfil the international criteria for reduction in CO2 emissions. Frictional drag is always proportional to the wetted surface of the vessel and typically accounts for more than 60% of the required propulsive power to overcome; hence the desire to reduce the wetted surface area is an active research interest. So, the reason for pursuing this research is because of our need to drive systems faster and farther for the same power.

1.1 DRAG REDUCTION

1.1.1 WHAT IS DRAG REDUCTION

Friction drag, resulted from the surface fluidic shear stress, occurs in all the cases where a relative motion exists between solid surface and fluid. Drag reduction techniques have received more and more attention in recent years due to their promising applications with great benefits in many areas. In the airplane design, only a few percent of friction drag reduction may improve its performance to a high level. Several techniques have been proposed so far to reduce the friction drag: water-repellent wall, microbubbles, surface microstructure, turbulent flow, and surfactant additives and so on.

The reduction of drag, which is a complex phenomenon, can be utilized in several engineering and industrial applications such as hydraulic machines, oil well operations, pumping systems, slurry pipeline systems, oil pipeline transport, automobiles, aircraft, submarines, ships, etc.

Pursuing a better understanding of the drag reduction phenomenon could also allow the design of more efficient systems and faster transportation vehicles; it means that savings in fuel by doing the same work with less energy and a decrease of contaminant emissions due to less burning fossil fuels would be viable.

If aerodynamic drag were reduced by 50 %, yearly costs savings in the 30 billion dollars range could be obtained. These facts make drag reduction an attractive issue for research. Furthermore, there is not yet a unique theory that can describe this complicated phenomenon, despite the significant theoretical and practical studies of the last three decades.

1.1.2 DRAG REDUCTION BACKGROUND

A drag force is produced in the direction of the flow when a fluid moves over a solid body, and it is the resultant of two forces. One is due to skin friction drag or friction drag, which is directly related to the wall shear stress; the other is the result of pressure drag, which is associated with the normal stresses. Skin friction, a consequence of the no-slip boundary on the surface, can be either laminar at low Reynolds numbers or turbulent at high Reynolds numbers (Bushnell & Moore 1991). Most of the practical situations where drag reduction could produce significant savings of energy and money take place in turbulent flow conditions.

The total shear stress in a turbulent flow is higher than laminar and is defined as:

$$\tau_{tot} = \tau + \tau_{turb} = \mu \frac{dU}{dy} - \rho \overline{uv}$$

Where y is the distance from the wall; U is the local mean velocity; μ is the absolute viscosity or dynamic viscosity; uv is the Reynolds stress, and ρ is the density of the fluid.

1.1.3 DRAG REDUCTION BY INJECTION OF MICROBUBBLES

Microbubbles is a drag reduction device that reduces skin friction of a solid body moving in water by injecting small bubbles into the turbulent boundary layer developing on the solid body.

Attempting to reduce drag of water vehicles by air injection is not new. Several patents were granted by the end of the 19th century and beginning of the 20th century; most of them consisted in placing an air film between the hull and the boundary layer (Latorre 1997). However, the first study on drag reduction in the United States of America (USA) by injection of bubbles was reported by McCormick & Bhattacharya (1973). This experiment was carried out in a fully submersed axisymmetric body of revolution (SABR) with a length of 91.44 cm and a maximum diameter of 12.7 cm. The total drag force was measured by a dynamometer that was mounted to the SABR. Hydrogen bubbles were produced by driving an electrical current through a wrapped wire (0.6 cm in diameter) to the SABR, the mass rate of hydrogen produced by electrolysis was evaluated as:

$$\dot{m}_H = 7.11 \times 10^{-10} \left(\frac{IW}{Z} \right)$$

Where I is the applied electrical current in amperes, W and Z are the atomic weight and valence number of the gas, respectively. For Hydrogen W = 1.008 and z = +1. The bubbles were injected beneath the boundary layer, and a maximum total drag reduction of approximately 30

% was measured. The total drag reduction was lower at higher Reynolds number. The drag reduction could be imputed to the decrease of the viscosity near the wall, which could also stop the transmission of the small viscous shear stresses from the turbulent region of the boundary layer to the wall.

1.2 AIR MICRO BUBBLES

1.2.1 WHAT IS AIR MICROBUBBLE

A microbubble is a gas cavity in liquid. The gas can be air, nitrogen, or a high molecular weight gas such as SF 6 or C 3F 8. The liquid is typically water. Microbubbles have a mean size of 3 μm, and in general 95% of the bubbles are smaller than 10 μm.

The microbubbles are stabilized by means of encapsulation by a shell that consists of biocompatible material such as protein, lipid, or polymer. In medical ultrasound, microbubbles are used as contrast agents.

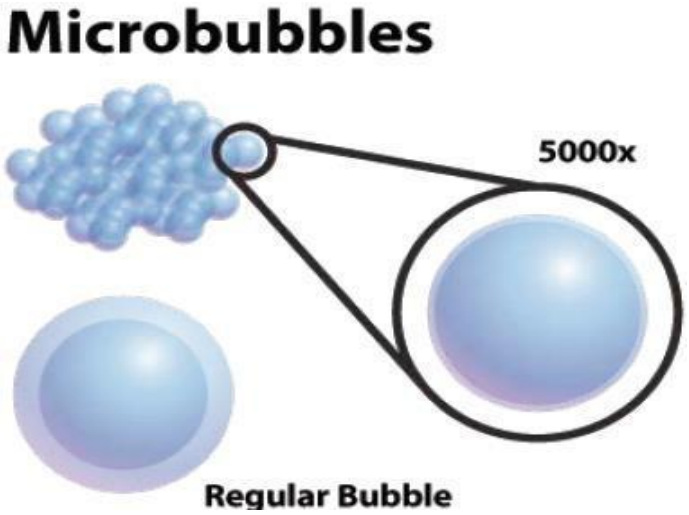


Figure 1.1 Microbubble size compared to regular bubble

1.2.2 THE BENEFIT OF MICROBUBBLE

In many instances, miniaturization is sought for the purposes of convenience. Why would microbubbles be a benefit? It might be the texture of the product is perceived better. Separations processes such as for minerals or biotech materials might be enhanced, or for the flotation or air-lift of wastes or oil recovery.

A common thread among the benefits of microbubbles is in their transport behavior mass, momentum, and heat transport at the interface of microbubbles is influenced by the interfacial surface area.

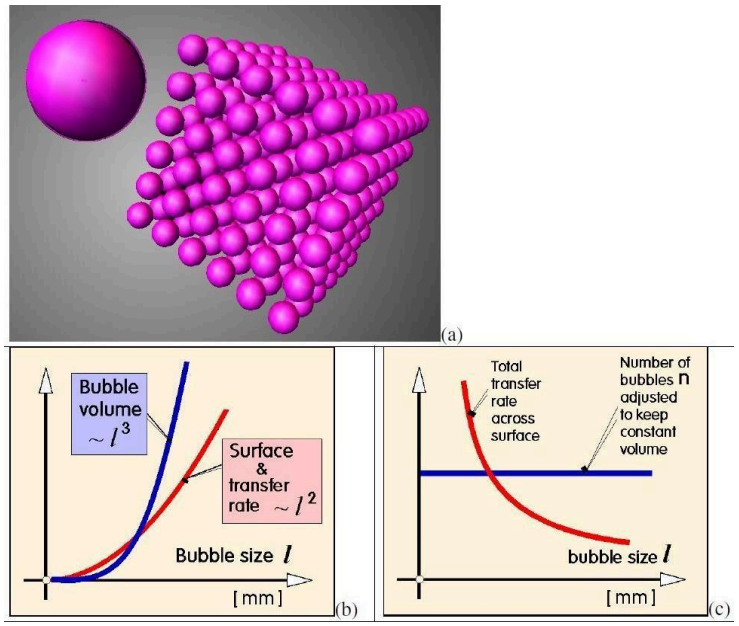


Figure 1.2 Depicts the key feature of high surface area to volume ratio

The transfer benefit of microbubble generation. (a) Division of volume into n smaller, equally sized objects, products additional surface area that scales with the cube root of the dividing number. (b) For single bubble, the surface area and transfer rate scale as the square of the bubble size 1, but bubble volume scales with its cube. (c) Therefore, the total transfer rate with the number of bubbles adjusted to keep the air phase volume constant, scales inversely with the bubble size 1. Smaller bubbles lead to greater transfer.

1.3 SHIP RESISTANCE

One of the most important considerations for a naval architect is the powering requirement for a ship. Once the hull form has been decided upon, it is necessary to determine the amount of engine power that will enable the ship to meet its operational requirements. Knowing the power required to propel a ship enables the naval architect to select a propulsion plant, determine the amount of fuel storage required, and refine the ship's center of gravity estimate.

Throughout history, naval architects have endeavored to increase the speed of ships. Increased speed enables a warship to close with its opponent, or conversely, to escape from an attack. Increased speed enables merchant vessels to reach port sooner and maximize profit for its owner.

Until the early 1800's, wind was the force used to propel ships through the water and ships could only go as fast as the wind would propel them. Additionally, because ships were constructed of wood, the structural limitations of wooden hull configurations drove hull designs to primarily meet the structural needs while hydrodynamics was only a secondary concern. With the advent of steam propulsion in the early 1800's, naval architects realized that ship speeds were no longer constrained by the wind and research began into the power required to propel a hull through the water using this new propulsion medium.

Testing of full-scale ships and models determined that the power required to propel a ship through the water was directly related to the amount of resistance a hull experiences when moving through the water.

The motion of a ship through water requires energy to overcome resistance, i.e. the force working against movement. As the resistance of a full-scale ship cannot be measured directly the knowledge about the resistance of ships comes from model tests. The total resistance on calm water can be divided into three main components: frictional resistance, residual resistance and air resistance.

During the operation of ship, the paint film on the hull breaks down. Erosion starts, and marine plants and barnacles, etc. grow on the surface of the hull. In addition, the propeller surface can become rough and folded. The total resistance caused by fouling may increase by 25-50% throughout the lifetime of a ship.

Resistance increases because of sea, wind and current. The resistance when navigating in

head-sea could perhaps increase by as much as 50-100% of the total ship resistance in calm weather.

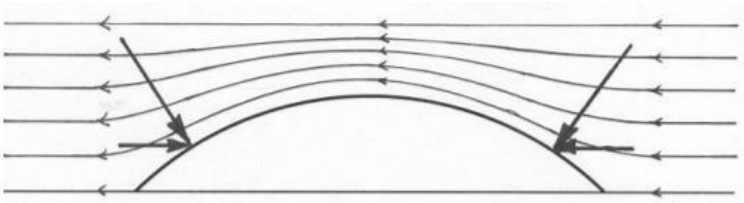


Figure 1.3 Ideal flow around a body.

Figure 1.3 shows a body submerged in an ideal (inviscid) fluid. As the fluid flows around the body, there is a pressure distribution normal to the body. In the forward section of the hull there is a component of pressure resisting motion, and in the aft section of the body there is a component of pressure assisting motion. In an ideal fluid these pressure forces are equal and the body experiences no resistance.

Unfortunately, water is not an ideal fluid, and therefore the body will experience resistance.

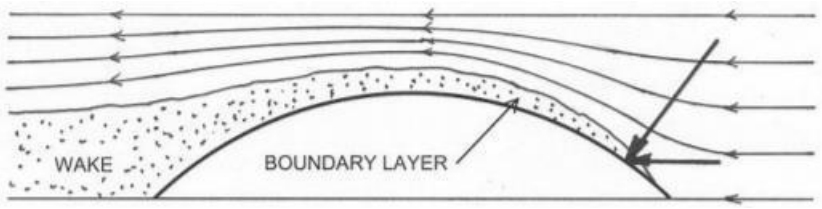


Figure 1.4 Flow around a body submerged in water

Figure 1.4 shows a hull submerged in a real fluid with viscosity. Fluid particles cling to the body, resulting in the formation of a "boundary layer," where the flow rapidly changes speed, from zero speed at the side of the body, to the free-stream speed. Two forms of resistance happen as a result of viscosity Friction Resistance and Viscous Pressure Resistance. Friction arises from the shear stresses in the fluid and acts tangential to the body. Viscous pressure resistance acts normal to the body.

1.3.1 Frictional Resistance

As a ship moves through the water, the friction of the water acting over the entire wetted surface of the hull causes a net force opposing the ship's motion. This frictional resistance is a function of the hull's wetted surface area, surface roughness, and water viscosity. Viscosity is a temperature dependent property of a fluid that describes its resistance to flow. Syrup is said to be a very viscous liquid; the fluid particles in syrup being very resistant to flow between adjacent particles and to other bodies. On the other hand, alcohol has a low viscosity with little interaction between particles.

Although water has low viscosity, water produces a significant friction force opposing ship motion. Experimental data have shown that water friction can account for up to 85% of a hull's total resistance at low speed ($Fn \leq 0.12$ or speed-to-length ratio less than 0.4 if ship speed is expressed in knots), and 40-50% of resistance for some ships at higher speeds.

1.3.2 Viscous Pressure Resistance

In the forward portion of the hull pressure forces act normal to the surface; however, in the aft portion of the hull the boundary layer reduces the forward acting component of pressure. This reduction in the forward acting component results in a net resistance force due to pressure acting on the hull. This increase in resistance due to pressure is called "viscous pressure drags" or "form drag", and is sometimes also referred to as the normal component of viscous resistance.

As you might expect, from looking at **Figure 1.4**, the shape of a ship's hull can influence the magnitude of viscous pressure drag. Ships that are short in length with wide beams will have greater form drag than those with a larger length to beam ratio.

1.3.3 Residual resistance

Residual resistance comprises wave resistance that refers to the energy loss caused by waves created by the vessel and viscous pressure resistance. This residual resistance normally represents 10-25% of the total resistance for low-speed ships and up to 40-60% for high-speed ships.

The residual resistance coefficient, is defined as the total model resistance coefficient minus the model friction resistance coefficient

The residual resistance includes wave resistance, the viscous pressure resistance, and the additional resistance due to the form or curvature of the hull.

1.3.4 Air Resistance

Air resistance is the resistance caused by the flow of air over the ship with no wind present. This component of resistance is affected by the shape of the ship above the waterline, the area of the ship exposed to the air, and the ship's speed through the water. Ships with low hulls and small "sail area" or projected area above the waterline will naturally have less air resistance than ships with high hulls and large amounts of sail area. Resistance due to air is typically 4- 8% of the total ship resistance, but may be as much as 10% in high sided ships such as aircraft carriers. Attempts have been made reduce air resistance by streamlining hulls and superstructures, however; the power benefits and fuel savings associated with constructing a streamlined ship tend to be overshadowed by construction costs.

1.4 WAVE MAKING RESISTANCE

1.4.1 WHAT IS WAVE MAKING RESISTANECE

The second major component of hull resistance is the resistance due to wave making. The creation of waves requires energy. As ship speed increases, the height of the waves produced by the ship increases and therefore the energy required to produce these waves also increases. This lost energy is referred to as wave making resistance and often becomes a limiting factor in the speed of a ship.

An object moving through the water creates both divergent waves, which spread outward

from the ship, and transverse waves, illustrated in **Figure 1.5.**

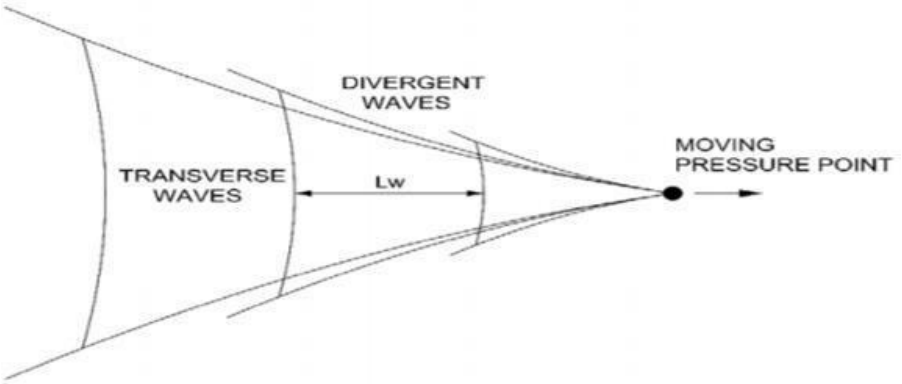


Figure 1.5 Wave pattern generated by a moving object in the water

Unlike the simple wave pattern developed by a moving pressure point (**Figure 1.5**), a real ship creates many wave systems, most prominently the bow and stern wave systems, shown in **Figure 1.6** These wave systems can interact with each other, either partially canceling the waves made by a ship (and reducing the wave making resistance) or by adding and increasing the wave making resistance. The effects waves have on each other waves as they collide and overlap is called constructive (adding) or destructive (reducing) interference.

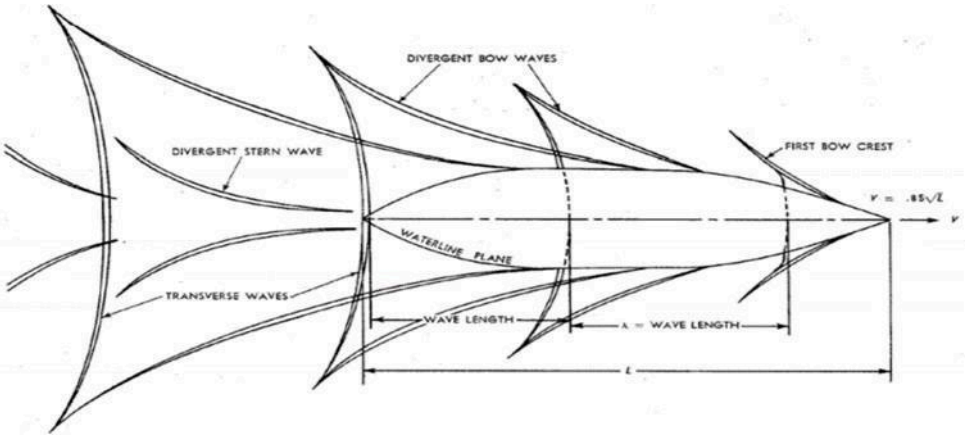


Figure 1.6 the bow and stern wave systems generated by a ship

1.4.2 THE WAVE PATTERN

The nature of the wave system created by a ship is similar to that which Kelvin demonstrated for a moving pressure point. Kelvin showed that the wave pattern had two main features: diverging waves on each side of the pressure point with their crests inclined at an angle to the direction of motion and transverse waves with curved crests intersecting the centerline at right angles.

A similar pattern is clear if one looks down on a ship travelling in a calm sea. The diverging waves are readily apparent to anybody on board. The waves move with the ship so the length of the transverse waves must correspond to this speed, that is their length is 2nV1/'g, the pressure field around the ship can be approximated by a moving pressure field close to the bow and a moving suction field near the stern.

Both the forward and after pressure fields create their own wave system. The after field being a suction one creates a trough near the stern instead of a crest as is created at the bow. The angle of the divergent waves to the centerline will not be exactly that of the Kelvin wave field. The maximum crest heights of the divergent waves do lie on a line at an angle to the centerline and the local crests at the maxima are at about twice this angle to the centerline. The stern generated waves are less clear, because they are weaker, but mainly because of the interference they suffer from the bow system.

In addition to the waves created by the bow and stern others may be created by local discontinuities along the ship's length. However, the qualitative nature of the interference effects in wave-making resistance are illustrated by considering just the bow and stern systems. The transverse waves from the bow travel aft relative to the ship, reducing in height. When they reach the stern-generated waves they interact with them. If crests of the two systems coincide the resulting wave is of greater magnitude than either because their energies combine. If the crest of one coincides with a trough in the other the resultant energy will be less. Whilst it is convenient to picture two wave systems interacting, in fact the bow wave system modifies the pressure field around the stern so that the waves it generates are altered. Both wave systems are moving with the ship and will have the same lengths. As ship speed increases the wavelengths increase so there will be times when crests combine and others when crest and trough become coincident.

The ship will suffer more or less resistance depending upon whether the two waves augment each other or partially cancel each other out.

This leads to a series of humps and hollows in the resistance curve, relative to a smoothly increasing curve, as speed increases.

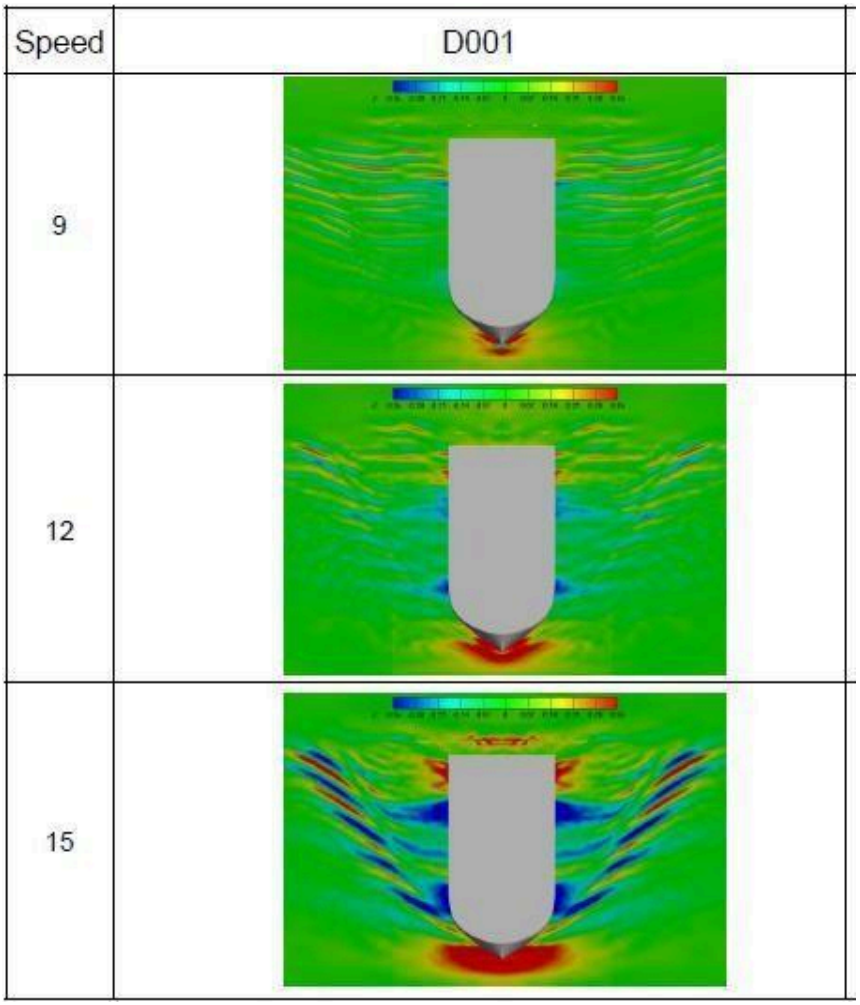


Figure 1.7 Relation between speed and wave pattern

1.5 KRISO SHIP MODEL

1.5.1 WHAT IS KRISO SHIP MODEL

The KCS was conceived to provide data for both explication of flow physics and CFD validation for a modern container ship with bulb bow and stern (i.e., ca. 1997). The conditions include bare hull and fixed model. No full-scale ship exists.

EFD data was collected at two sites.

Korea Research Institute for Ships and Ocean Engineering performed towing-tank experiments to obtain resistance and wave field.

Ship Research Institute of Japan performed towing-tank experiments to obtain hull surface pressure and velocity field downstream of propeller plane for both with and without propeller.

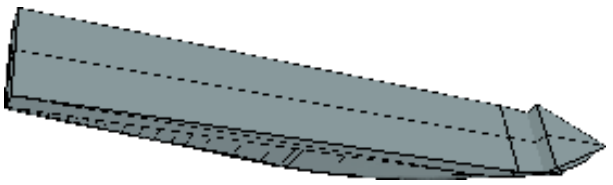


Figure 1.8 KRISO CONTAINER SHIP(KCS)

The present study considers, for the KRISO Container Ship (KCS hereafter), the model scale resistance computation, and two Computational Fluid Dynamics (CFD hereafter) solvers being used in this regard. Both wave and viscous components of the total model scale resistance are computed by the use of a potential flow solver, respectively by the use of a viscous flow solver. Of most importance in getting accurate results for the complex flow problems that are defining the free-surface viscous flow, the computational grid is properly generated. In order to validate the numerical techniques, the experimental results of the model scale resistance tests conducted in the towing tank of the Faculty of Naval Architecture from the “Dunarea de jos” University of Galati were considered.

Designed by the Maritime and Ocean Engineering Research Institute (MOERI hereafter) the KCS ship was used as a benchmark ship at several workshops on CFD in ship hydrodynamics: Gothenburg 2000 Workshop on CFD in ship hydrodynamics, CFD

Workshop Tokyo 2005 and Gothenburg 2010 Workshop on CFD in ship hydrodynamics a generous set of experimental data being provided in the literature. The KCS ship was also considered as a benchmark ship at the first workshop on verification and validation of ship maneuvering simulation methods held in Copenhagen, in 2008.

1.5.2 MODEL SCALE RESISTANCE COMPUTATION FOR THE KRISO CONTAINER SHIP (KCS)

In this study, the computational results for KRISO Container Ship (KCS) are presented. CFD analyses are performed to simulate free surface flow around KCS by using RANS approach with success. Also, the complicated turbulent flow zone behind the ship is well simulated. The RANS equations and the non-linear free surface boundary conditions are discretized by means of a finite volume scheme. The numerical methodology is found to be appropriate for simulating the turbulent flow around a ship in order to estimate ship total resistance and free surface. By the numerical results, total resistance is calculated for the ship model and the result is satisfactory with regard to the experimental one. As a result of well captured free surface, the wave elevation on/around the hull is compared with the experimental results.

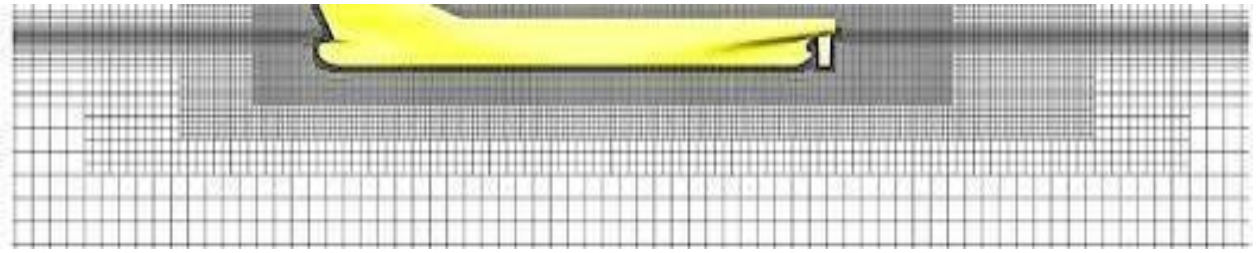


Figure 1.9 Verification and Validation for the Resistance of a KRISO Container Ship in Calm Water

1.5.3 A NUMERICAL APPLICATION TO PREDICT THE RESISTANCE AND WAVE PATTERN OF KRISO CONTAINER SHIP (KCS)

The KRISO Container Ship (KCS) was considered to provide data for both explication of flow physics and Computational Fluid Dynamics (CFD) validation for a modern ship with bulbous bow. The large cargo ship intended for transportation of containers developed in the Korea Research Institute for Ships and Ocean Engineering (KRISO). No full-scale ship ever exists. Korea Research Institute for Ships and Ocean Engineering performed towing-tank experiments to obtain resistance and wave field. Ship Research Institute of Japan performed towing-tank experiments to obtain hull surface pressure and velocity fields. Estimation of total ship resistance has been an essential topic in ship hydrodynamics. Successful design and optimization of marine structures require information about the flow problem on both integral and field quantity levels. In order to estimate both total resistance and flow properties around a ship, many studies have been done. The methods which are based on potential theory may be insufficient in case of complexity in ship geometry. Also, the viscosity phenomenon is neglected in potential theory.

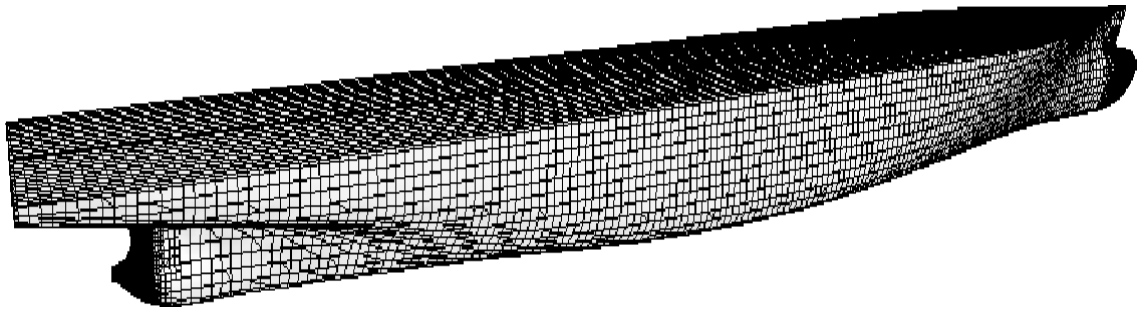


Figure 1.10 A Numerical application to predict the resistance and wave pattern of KRISO container ship

1.6 KELVIN HYDRODYNAMICS LABORATORY

1.6.1 WHAT IS KELVIN HYDRODYNAMICS LABORATORY

The Kelvin Hydrodynamics Laboratory is hydrodynamic test tank that can indicate how a vessel or an offshore structure will behave in realistic conditions.

It also can determine the survivability of damaged ships, fluid structure interaction for slender structures, sporting fluid dynamics and marine renewable energy.



Figure 1.11 Kelvin hydrodynamics laboratory tank

The Kelvin Hydrodynamics Laboratory tank provides excellent conditions for measuring the performance of surface ships and a wide variety of floating and underwater structures.

The motions of floating vessels and structures are measured using an infrared camera system. And it uses a resistance dynamometer for force measurement.

1.6.2 WHAT KELVIN HYDRODYNAMICS LABORATORY USED FOR

The Kelvin hydrodynamics laboratory used for a wide range of hydrodynamics tests including measurement of:

Ship resistance and sea-keeping
Unsteady motion of ships and floating bodies
Survivability of damaged ships
Hydrodynamics of towed surface-piercing and submerged bodies
Ocean engineering studies including vortex-induced vibration and vortex-induced motion

Wave impact and slamming studies

Marine renewable energy studies including device performance and maintainability

1.7 EXPERIMENTAL ANALYSIS

1.7.1 PROBLEM AND SOLUTION

Ships require large quantities of fuel to generate the propulsive power required to overcome drag and frictional resistance resulting from their motion across ocean surfaces. The exhaust releases by products such as nitrogen oxide, carbon dioxide and Sulphur oxide emissions which significantly contribute to the global climate change and acidifications of ocean. Sailing cost will be increased due to large usage of fuel it will affect the profit of the company. All these problems can be eliminated by reducing the power required to overcome drag and frictional resistance without affecting the sailing speed.

Drag and frictional resistance can be overcome by reducing the frictional contact between ships surface and water surface through the introduction of air lubrication in the bottom of hull. The injection of air requires constant pumping power and if the ship sails too slowly it represents a significant part of the propulsive power. The bubble sizes and location of the injection points are important parameters in the persistence of drag reduction. The scope of this work is to compare the resistance of the ship with air lubrication system and without air lubrication system numerically.

1.7.2 AIR LUBRICATION SYSTEM

Air lubrication system is a method to reduce the resistance between the ship's hull and seawater using air bubbles. The air bubble distribution across the hull surface reduces the resistance working on the ship's hull, creating energy saving effects. With the right ship hull design, the air lubrication system is expected to achieve up to 10 – 15% reduction of CO2 emissions, along with significant savings of fuel. Air lubrication system can offer reduction in CO2 emission of up to 35% as compared with conventional container ships.

Fuel savings and reduction in carbon emissions is possible through Air lubrication system when combined with other promising green ship technologies.

1.7.3 WORKING PRINCIPLE

Air Lubrication system works on the simple principle of tapping a layer of air bubbles beneath the ship's hull. An air blower or a dedicated system is used to generate air bubbles to pass them continuously beneath the ship's surface which is shown in **figure 1.12.** Air bubble outlets are created at different locations along the bottom of the hull, symmetrically on both the sides of the ship's center line. The air blown at a constant rate to form a layer of bubbles, which reduces the drag and resistance between ship and the seawater.



Figure 1.12 Air Lubrication system

1.7.4 AIR CAVITY CONCEPT APPLIEID ON A SHIP HULL TO IMPROVE HULL RESISTANCE

The fundamental tests with the air cavity concept applied on a flat plate, which was conducted in the Emerson Cavitation Tunnel of Newcastle University (Slyozkin et al., 2014), this paper explores the same concept only this time applied on an existing container ship model to investigate whether it benefits in frictional drag reduction, whilst producing a net energy saving. The middle section of this 2.2 m ship model was modified to accommodate a 0.43×0.09 m² air cavity in the bottom of the hull and then various model scale tests have been conducted in the towing tank of Newcastle University. The model experiments produced results ranging from 4% to 16% gross drag reduction. Upon applying scaling factors, it is estimated from the experimental results that around 22% gross energy could be saved in a full-scale application with just a 5% reduction in the wetted surface area. Further complementary model tests were also conducted to explore the effect of the air cavity on the stability of the model and on the vertical motion responses in a regular head and following wave. While the cavity did not affect the vessel stability the motion response behavior seemed to be affected non-linearly by the effect of the air cavity.

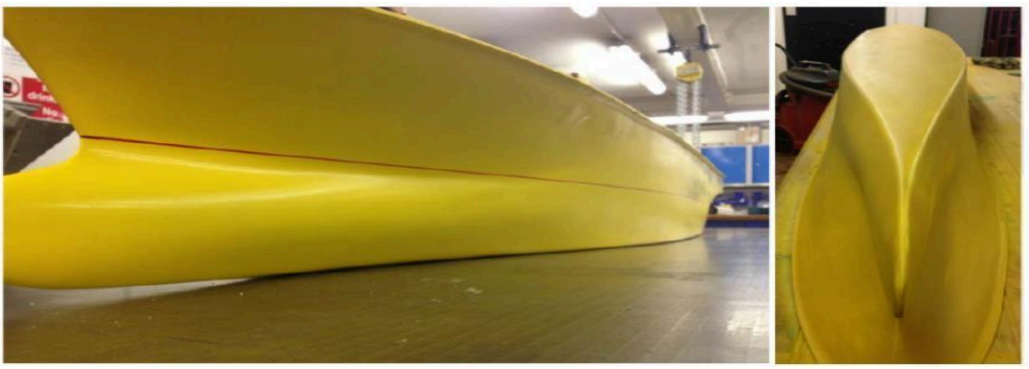


Figure 1.13 Scaled datum hull model



Figure 1.14 Air cavity accommodated on the bottom of the hull

Chapter 2

Resistance

Chapter 2
2.1 RESISTANCE
Resistance and propulsion. In reality the two are closely interdependent although in practice the split is a convenient one. The resistance determines the thrust required of the propulsion device. Then propulsion deals with providing that thrust and the interaction between the propulsor and the flow around the hull.

When a body moves through a fluid it experiences forces opposing the motion. As a ship moves through water and air it experiences both water and air forces. The water and air masses may themselves be moving, the water due to currents and the air as a result of winds. These will be of different magnitudes and directions. The resistance is studied initially in still water with no wind. Unless the winds are strong the water resistance will be the dominant factor in determining the speed achieved.

2.1.1 FLUID FLOW

Classical hydrodynamics leads to a flow pattern past a body of the type shown in Figure 2.1. As the fluid moves past the body the spacing of the streamlines changes, and the velocity of flow changes, because the mass flow within streamlines is constant. Bernoulli's theorem applies and there are corresponding changes in pressure. For a given streamline, if p, ρ, υ and h are the pressure, density, velocity and height above a selected datum level, then:

$$\frac{p}{\rho} + \frac{v^2}{2} + gh = \text{constant}$$

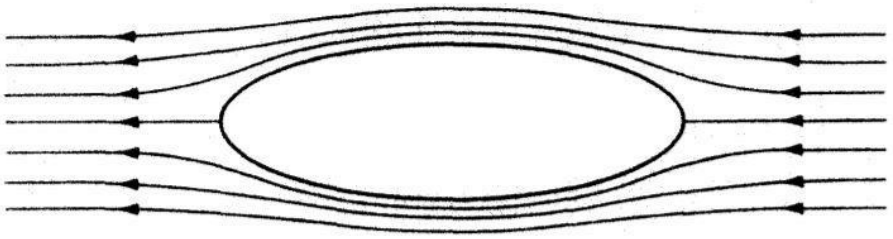


Figure 2.1

Simple hydrodynamic theory deals with fluids without viscosity. In a nonviscous fluid a deeply submerged body experiences no resistance. Although the fluid is disturbed by the passage of the body, it returns to its original state of rest once the body has passed. There will be local forces acting on the body but these will cancel each other out when integrated over the whole body. These local forces are due to the pressure changes occasioned by the changing velocities in the fluid flow. In studying fluid dynamics it is useful to develop a number of nondimensional parameters with which to characterize the flow and the forces. These are based on the fluid properties. The physical properties of interest in resistance studies are the density ρ, viscosity μ and the static pressure in the fluid P. Taking R as the resistance, V as velocity and L as a typical length, dimensional analysis leads to an expression for resistance: $R = f\left[L^a V^b \rho^c \mu^d g^e p^f\right]$

The quantities involved in this expression can all be expressed in terms of the fundamental dimensions of time, T, mass, M and length L. For instance resistance is a force and therefore has dimensions ML/T2, p has dimensions M/L3 and so on. Substituting these fundamental dimensions in the relationship above: $\frac{ML}{T^2} = f\left[L^a \left(\frac{L}{T}\right)^b \left(\frac{M}{L^3}\right)^c \left(\frac{M}{LT}\right)^d \left(\frac{L}{T^2}\right)^e \left(\frac{M}{LT^2}\right)^f\right]$

The expression for resistance can then be written as: $R = \rho V^2 L^2 \left[f_1\left(\frac{\mu}{\rho VL}\right), f_2\left(\frac{gL}{V^2}\right), f_3\left(\frac{p}{\rho V^2}\right)\right]$

Thus the analysis indicates the following non-dimensional combinations as likely to be significant:

$$\frac{R}{\rho V^2 L^2}, VL\frac{\rho}{\mu}, \frac{V}{(gL)^{0.5}}, \frac{p}{\rho V^2}$$

The first three ratios are termed, respectively, the resistance coefficient, Reynolds' number, and Fronde number. The fourth is related to cavitation. The ratio μ/ρ is called the kinematic viscosity and is denoted by υ. At this stage it is assumed that these non-dimensional quantities are independent of each other. The expression for the resistance can then be written as:

$$R = \rho V^2 L^2 \left[f_1\left(\frac{\nu}{VL}\right) + f_2\left(\frac{gL}{Vft1^2}\right)\right]$$

Consider first /2 which is concerned with wave-making resistance. Take two geometrically similar ships or a ship and a geometrically similar model, denoted by subscripts 1 and 2.

$$R_{w1} = \rho_1 V_1^2 L_1^2 f_2\left(\frac{gL_1}{V_1^2}\right) \quad \text{and} \quad R_{w2} = \rho_2 V_2^2 L_2^2 f_2\left(\frac{gL_2}{V_2^2}\right)$$

The form of f_2 is unknown, but, whatever its form, provided $gL_1/V^2_1 = gL_2/V^2_2$ the values of f_2 will be the same. $\frac{R_{w2}}{R_{w1}} = \frac{\rho_2 L_2^3}{\rho_1 L_1^3}$ or $\frac{R_{w2}}{R_{w1}} = \frac{\Delta_2}{\Delta_1}$

For this relationship to hold $V_1/(gL_1)^{0.5} = V_2/(gL_2)^{0.5}$ assuming ρ is constant.

Putting this into words, the wave-making resistances of geometrically similar forms will be in the ratio of their displacements when their speeds are in the ratio of the square roots of their lengths. This has become known as Fronde's law of comparison and the quantity $V/(gL)^{0.5}$ is called the Froude number. In this form it is nondimensional.

The other function in the total resistance equation f_1, determines the frictional resistance. Following an analysis similar to that for the wave-making resistance, it can be shown that the frictional resistance of geometrically similar forms will be the same if: $\frac{\nu_1}{V_1 L_1} = \frac{\nu_2}{V_2 L_2}$

This is commonly known as Rayleigh's law and the quantity VL/υ is called Reynolds' number.

As the frictional resistance is proportional to the square of the length, it suggests that it will be proportional to the wetted surface of the hull. For two geometrically similar forms, complete dynamic similarity can only be achieved if the Froude number and Reynolds' number are equal for the two bodies. This would require $V/(gL)^{0.5}$ and VL/υ to be the same for both bodies. This cannot be achieved for two bodies of different size running in the same fluid.

2.1.2 THE FROUDE NOTATION

In dealing with resistance and propulsion Froude introduced his own notation. This is commonly called the constant notation or the circular notation. The first description is because, although it appears very odd to modern students, it is in fact a non-dimensional system of representation. The second name derives from the fact that in the notation the key characters are surrounded by circles.

Froude took as a characteristic length the cube root of the volume of displacement, and denoted this by U. He then defined the ship's geometry with the following:

Ⓜ = Length constant = $\frac{wetted\ length}{U}$

Ⓑ = Breadth constant = $\frac{wetted\ breadth}{U}$

Ⓓ = Draught constant = $\frac{draught\ at\ largest\ section}{U}$

Ⓢ = Wetted surface constant = $\frac{wetted\ surface\ area}{U^2}$

Ⓐ = Section area constant = $\frac{section\ area}{U^2}$

To cover the ship's performance Froude introduced:

Ⓚ = $\frac{speed\ of\ ship}{speed\ of\ wave\ of\ length\ \ U/2}$

Ⓛ = $\frac{speed\ of\ ship}{peed\ of\ wave\ of\ length\ \ L/2}$

Ⓒ = $\frac{1000\ (resistance)}{\Delta\ Ⓚ^2}$

With subscripts to denote total, frictional or residuary resistance as necessary.

This diagram was used by Froude to present data from model resistance tests. Resistance is plotted as Ⓒ - Ⓚ curves, corrected to a standard 16ft model. Separate curves are drawn for each ship condition used in the tests. Superimposed on these are curves of skin friction correction

needed when passing from the 16ft model to geometrically similar ships of varying length. The complete elements of form diagram includes, in addition, the principal dimensions and form coefficients, and non-dimensional plottings of the curve of areas, waterline and midship section.

2.2 TYPES OF RESISTANCE

When a moving body is near or on the free surface of the fluid, the pressure variations around it are manifested as waves on the surface. Energy is needed to maintain these waves and this leads to a resistance. Also, all practical fluids are viscous and movement through them causes tangential forces opposing the motion. Because of the way in which they arise the two resistances are known as the wave-making resistance and the viscous or frictional resistance. The viscosity modifies the flow around the hull, inhibiting the buildup of pressure around the after end which is predicted for a perfect fluid.

This effect leads to what is sometimes termed viscous pressure resistance or form resistance since it is dependent on the ship's form.

The streamline flow around the hull will vary in velocity causing local variations in frictional resistance. Where the hull has sudden changes of section, they may not be able to follow the lines exactly and the flow 'breaks away'. For instance, this will occur at a transom stern. In breaking away, eddies are formed which absorb energy and thus cause a resistance. Again, because the flow variations and eddies are created by the particular ship form, this resistance is sometimes linked to the form resistance. Finally, the ship has a number of appendages. Each has its own characteristic length and it is best to treat their resistances (they can generate each type of resistance associated with the hull) separately from that of the main hull. Collectively they form the appendage resistance.

2.2.1 WAVE MAKING RESISTANCE

Wave-making resistance is a form of drag that affects surface watercraft, such as boats and ships, and reflects the energy required to push the water out of the way of the hull. This energy goes into creating the wave.

2.2.1.1 THE WAVE PATTERN

The nature of the wave system created by a ship is similar to that which Kelvin explained for a moving pressure point. Kelvin showed that wave pattern had 2 main features: diverging waves and transverse waves.

As the diverging waves on each side of the pressure point with their crests inclined at an angle to the direction of motion while the transverse waves with curved crests intersecting the centerline at right angles. The angle of the divergent waves to the centerline is just under 20°.

The diverging waves are readily apparent to anybody on board. The waves move with the ship so the length of the transverse waves correspond to this speed, that is their length is $2\pi V^2/g$.

The pressure field around the ship can be approximated by a moving pressure field close to the bow and a moving suction field near the stern.

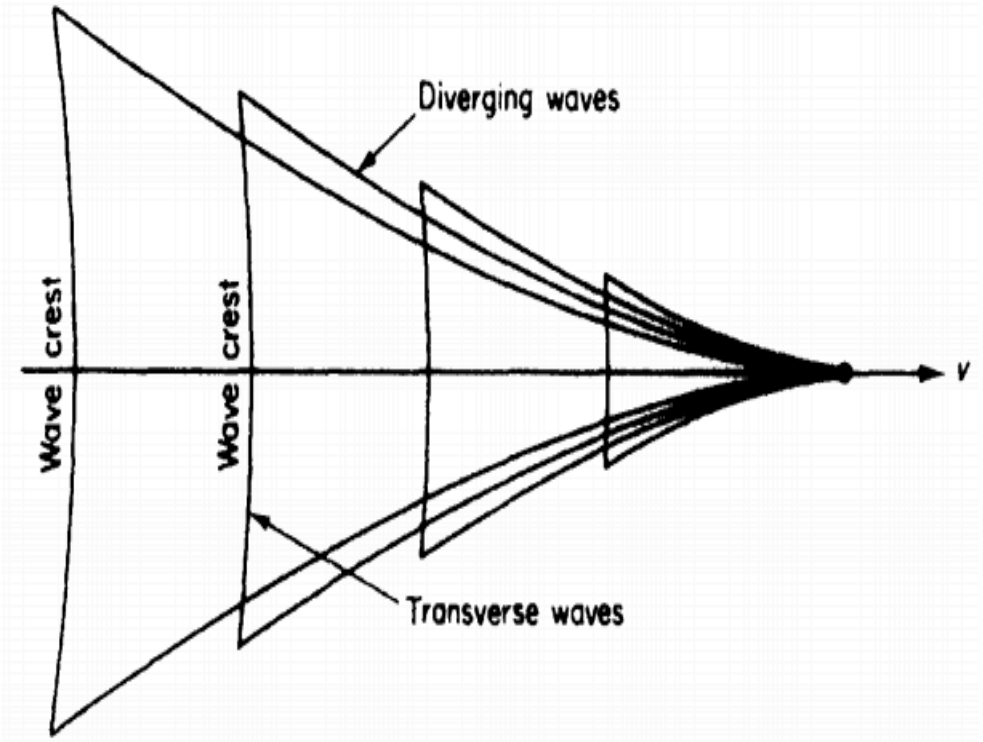


Figure 2.2 Pressure point wave system

2.2.1.2 INTERFERENCE EFFECTS

Others waves may be created by local discontinuities along the ship's length. The qualitative nature of the interference effects in wave-making resistance are illustrated by considering just the bow and stern systems. When they reach the stern-generated waves they interact with them. If crests of the two systems coincide the resulting wave is of greater magnitude than either because their energies combine. If the crest of one coincides with a trough in the other the resultant energy will be less.

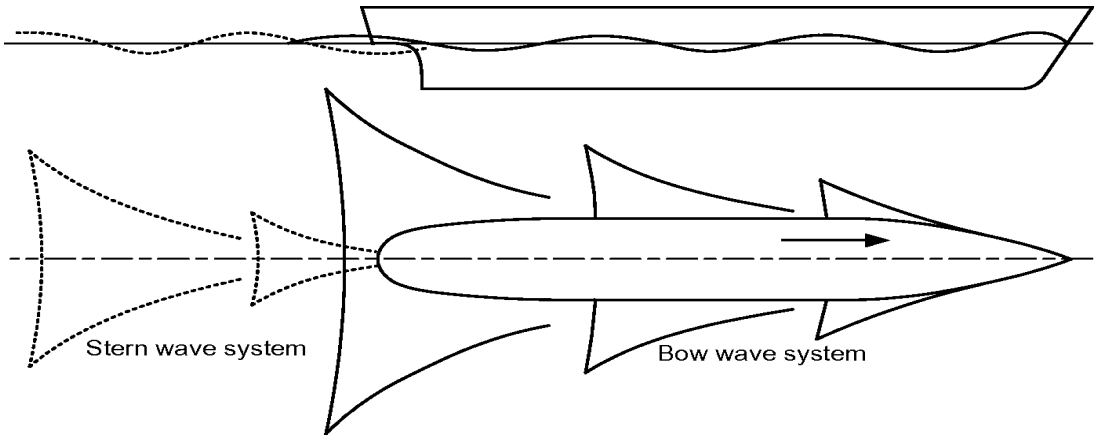


Figure 2.3 Bow and stern wave systems

Whilst it is convenient to picture two wave systems interacting, in fact the bow wave system modifies the pressure field around the stern so that the waves it generates are altered. As ship speed increases the wavelengths increase so there will be times when crests combine and others when crest and trough become coincident. The ship will suffer more or less resistance depending upon whether the two waves augment each other or partially cancel each other out.

The residuary resistance was taken as the total measured resistance less a calculated skin friction resistance. Now the distance between the two pressure systems is approximately 0.9L. The condition therefore that a crest or trough from the bow system should coincide with the first stern $V^2/0.9L = g/N\pi$ trough is:

2.2.1.3 SCALING WAVE-MAKING RESISTANCE

it has been shown that for geometrically similar bodies moving at corresponding speeds, the wave pattern generated is similar and the wave-making resistance can be taken as proportional to the displacements of the bodies concerned. This assumes that wave-making was unaffected by the viscosity and this is the usual assumption made in studies of this sort. In fact, there will be some viscosity but its major effects will be confined to the boundary layer.

2.2.2 FRICTIONAL RESISTANCE

According to the laws of fluid friction, the frictional resistance for fluids in motion varies considerably with temperature for laminar flow and slightly with temperature for turbulent flow. Hence, the frictional resistance becomes independent of the nature of the surface contact.

The frictional resistance for fluids in motion is
a) Proportional to the velocity in laminar flow and to the square of the velocity in turbulent flow
b) Proportional to the square of the velocity in laminar flow and to the velocity in turbulent flow
c) Proportional to the velocity in both laminar flow and turbulent flow
d) Proportional to the square of the velocity in both laminar flow and turbulent flow

Water is viscous and the conditions for dynamic similarity are geometric similarity and constancy of Reynolds' number. Due to the viscosity, particles immediately adjacent to the hull adhere to it and move at the speed of the ship. At a distance from the hull the water is at rest.

Frictional resistance is associated with Reynolds because of the study he made of flow through pipes. He showed that there are two distinct types of flow. In the first, laminar flow, each fluid particle follows its own streamlined path with no mass transfer between adjacent layers. This flow only occurs at relatively low Reynolds' numbers. At higher numbers the steady flow pattern breaks down and is replaced by a more confused flow pattern called turbulent flow.

Laminar Flow	Turbulent Flow
It is a fluid flow in which the fluid layers move parallel to each other and do not cross each other.	It is a fluid flow in which the fluid layers cross each other and do not move parallel to each other.
The laminar flow generally occurs in the fluid flowing with low velocity.	The turbulent flow occurs when the fluid flows with high velocity.
Laminar flow occurs in small diameter pipes in which fluid flows with low velocity.	Turbulent flow occurs in large diameter pipes in which fluid flows with high velocity.
The fluid flow is laminar when the value of Reynolds number is less than 2000.	The fluid flow is turbulent when the value of Reynolds number is greater than 4000.
Shear stress in laminar flow depends on viscosity of fluid and independent of density.	Shear stress in the turbulent flow depends upon the density of the fluid.
The fluid flow is very orderly, there is no mixing of adjacent layers of the fluid and they move parallel to each other and also with the walls of the pipe.	The fluid flow is not orderly, there is mixing of adjacent layers of fluid with each other and they do not move parallel to each other and also with the walls of the pipe.

Reynolds showed that different laws of resistance applied to the two flow types. Further, if care was taken to ensure that the fluid entered the mouth of the pipe smoothly the flow started off as laminar but at some distance along the tube changed to turbulent. This occurred at a critical velocity dependent upon the pipe diameter and the fluid viscosity. For different pipe diameters, d, the critical velocity, Vc, was such that Vcd/v was constant. Below the critical velocity, resistance to flow was proportional to the velocity of flow. As velocity increased above the critical value there was an unstable region where the resistance appeared to obey no simple law. At higher velocity again the flow was fully turbulent and resistance became proportional to V raised to the power 1.723. Reynolds' work related to pipes but qualitatively the conclusions are relevant to ships. There are two flow regimes, laminar and turbulent. The change from one to the other depends on the critical Reynolds' number and different resistance laws apply. William Froude carried out the first important experiments in the early 1870s, using a series of planks

with different surface roughness. He tried fitting the results with a formula such as: $R_f = fSV\hat{}n$

2.2.3 EDDY MAKING RESISTANCE OR VISCOUS PRESSUER RESISTANCE

In a non-viscous fluid, the lines of flow past a body close in behind it creating pressures which balance out those acting on the forward part of the body. With viscosity, this does not happen completely and the pressure forces on the after body are less than those on the fore body, also where there are rapid changes of section the flow breaks away from the hull and eddies are created. The effects can be minimized by streamlining the body shape so that changes of section are more gradual. Other eddy creators can be appendages such as the bilge keels, rudders and so on. Bilge keels are aligned with the smooth water flow lines, as determined in a circulating water channel, to minimize the effect. At other loadings and when the ship is in waves the bilge keels are likely to create eddies. Flow break away can occur on an apparently well-rounded form. This is due to die velocity and pressure distribution in the boundary layer. The velocity increases where the pressure decreases and vice versa.

2.2.4 APPENDAGES RESISTANCE

Appendages include rudders, bilge keels, shaft brackets and bossings, and stabilizers. Each appendage has its own characteristic length and therefore, if attached to the model, would be running at an effective Reynolds' number different from that of the main model. Thus, although obeying the same scaling laws, its resistance would scale differently to the full scale.

2.2.5 WIND RESISTANCE

The wind resistance is explained as the resistance when a wind is blowing both the front and back resistance force will depend upon its direction and speed.

The concept of an ahead resistance coefficient:

ARC= $\frac{front\ and\ back\ component\ of\ wind\ resistace}{\frac{1}{2}\rho V_R^2 A_T}$

The ARC values ranged from 0.7 in the light condition to 0.85 in the loaded condition and were sensibly steady for winds from ahead and up to 50° off the bow. For winds astern and up to 40° off the stern the values were -0.6 to -0.7. Between 50° off the bow and 40° off the stern the ARC values varied approximately linearly. Two cargo ships showed similar trends but the ARC values were about 0.1 less.

2.3 CALCULATION OF RESISTANCE

Having discussed the general nature of the resistance forces a ship experiences and the various formulations for frictional resistance it is necessary to apply this knowledge to derive the resistance of a ship. The model, or data obtained from model experiments, is still the principal method used. The principle followed is that stated by Froude. That is, the ship resistance can be obtained from that of the model by:

1) Measuring the total model resistance by running it at the corresponding Froude number
2) Calculating the frictional resistance of the model and subtracting this from the total leaving the residuary resistance
3) Scaling the model residuary resistance to the full scale by multiplying by the ratio of the ship to model displacements
4) Adding a frictional resistance for the ship calculated on the basis of the resistance of a flat plate of equivalent surface area and roughness
5) Calculating, or measuring separately, the resistance of appendages
6) Making an allowance, if necessary, for air resistance.

2.3.1 ITTC METHOD

The resistance coefficient is taken as C- (Resistance) /$\frac{1}{2}$ ρsv^2. Subscripts t, v, r and f for the total, viscous, residual and frictional resistance components.

$C_{vm} = (1+K)\, C_{fm}$

Where k is a factor

$C_{rm} = C_{tm} - C_{vm}$

Coefficients for the ITTC 1957 model-ship correlation line

Reynolds' number	C_f	*Reynolds' number*	C_f
10^5	0.008333	10^8	0.002083
5×10^5	0.005482	5×10^8	0.001671
10^6	0.004688	10^9	0.001531
5×10^6	0.003397	5×10^9	0.001265
10^7	0.003000	10^{10}	0.001172
5×10^7	0.002309	5×10^{10}	0.000991

2.3.2 FROUDE METHOD

$\text{©}_f = \frac{1000\, FR}{\Delta \text{ⓚ}^2}$

A selection of O and F values are presented in the next Table these apply to a standard temperature of 15°C (59°F). The ©$_f$ value is increased or decreased by 4.3 per cent for every 10°C (2.4 per cent for every 10°F) the temperature is below or above this value.

2.3.2.1 FROUDE'S FRICTIONAL DATA

Length (ft)	*O*	*f*	*Length* (ft)	*O*	*f*
5	0.15485	0.012585	80	0.08987	0.009309
10	0.13409	0.011579	90	0.08840	0.009252
15	0.12210	0.010925	100	0.08716	0.009207
20	0.11470	0.010524	200	0.08012	0.008992
25	0.10976	0.010269	300	0.07655	0.008902
30	0.10590	0.010068	400	0.07406	0.008832
35	0.10282	0.009908	500	0.07217	0.008776
40	0.10043	0.009791	600	0.07062	0.008726
45	0.09839	0.009691	700	0.06931	0.008680
50	0.09664	0.009607	800	0.06818	0.008639
60	0.09380	0.009475	1000	0.06636	0.008574
70	0.09164	0.009382	1200	0.06493	0.008524

2.3.3 EXTRAPOLATION TO SHIP

The method of extrapolating to the ship from the model is illustrated diagrammatically in figure 2.4, there will be no difference in the value of total resistance calculated for the ship. That is the actual frictional resistance taken is not critical as long as the error is the same for model and ship and all the elements making up the residuary resistance obey the Froude law of comparison.

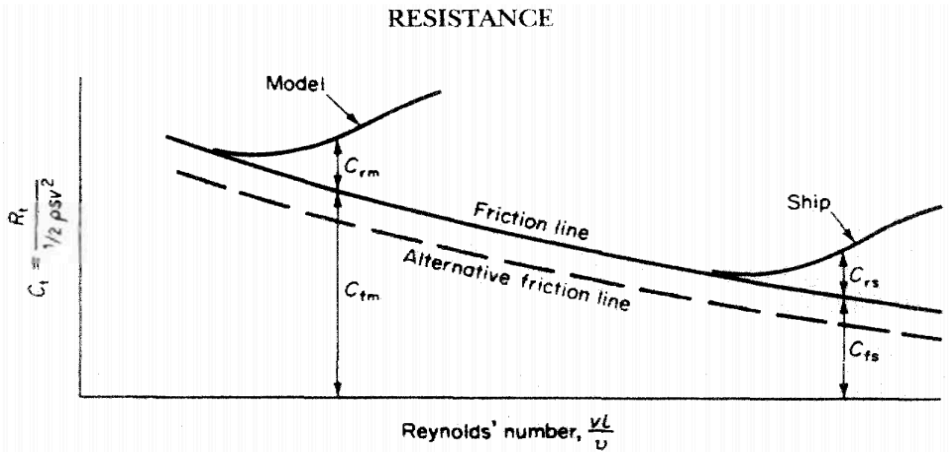


Figure 2.4

2.3.4 WETTED SURFACE AREA

To obtain the frictional resistance it is necessary to calculate the wetted surface area of the hull. The most direct way of doing this is to plot the girths of the ship at various points along its length to a base of ship length. The area under the curve so produced is approximately the desired wetted surface area. This is the way Froude derived his circular S values and the method should be used when using Froude data. For a more accurate value of the actual wetted surface area some allowance must be made for the inclination of the hull surface to the centerline plane especially towards the ends of the ship. This can be done by assessing a mean hull surface length in each section and applying this as a correction factor to the girth readings. Alternatively, an overall mean surface length can be found by averaging the distances round the waterline boundaries for a range of draughts.

Haslar had proposed in the circular notation: Ⓢ = $3.4 + \frac{Ⓜ}{2.06}$

2.4 METHODICAL SERIES

Beside the tests of individual models, a big deal of work has gone into finding out the impact of hull form on resistance. The tests begin with a parent form and then vary systematically.

Such a series of tests is called a methodical series or a standard series. The comes about can show how resistance changes with the form parameters used and are valuable in assessing power for modern designs before the model can be run. .

One methodical series was made by Admiral D.W. Taylor. He took variables as the prismatic coefficient, displacement to length ratio and beam to draught ratio. With eight, five and two values of the variables respectively he tested 80 models. Taylor made his results as a standard, the ship length was 500ft (152m) and the wetted surface coefficient is 15.4. He plotted contours of $\frac{R_f}{\Delta}$with $V/L^{0.5}$ and $\boldsymbol{\Delta}/(L/100)^3$ as in Figure. $\frac{R_f}{\Delta}$Was in pounds per ton displacement. Taylor also presented correction factors for length and contours for wetted surface area correction. The residuary resistance, R_f was plotted in a similar way but with prismatic coefficient in place of V/L° 5 as abscissa, see Figure 2.5.

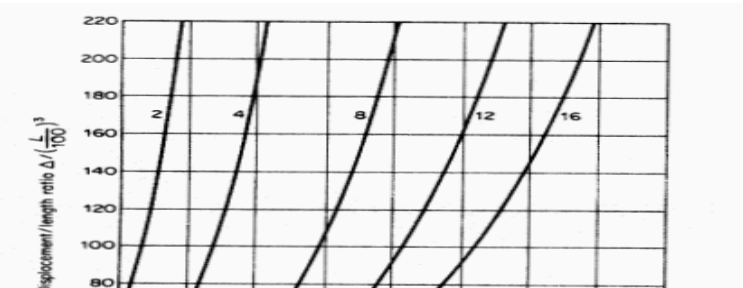


Figure 2.5

Taylor's data was re-analysed using C_f and C_t instead of resistance in pounds/ton of displacement. Frictional resistance was calculated from the Schoenherr formula rather than being based on the Froude data used by Taylor.

A typical chart from the re-analysed data is given in Figure 2.6.

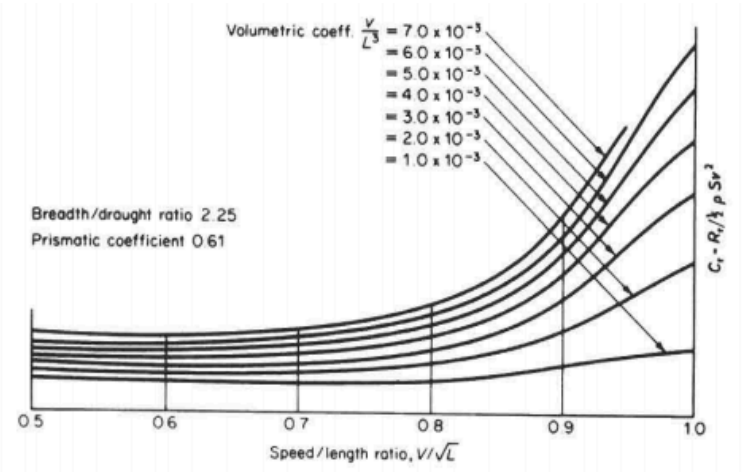


Figure 2.6

2.4.1 ROUGHNESS:

It’s clear that apart from the wetted surface area and speed the biggest factor in determining the frictional resistance is the roughness of the hull. For slow ships the frictional resistance is the biggest bit of the total and it is crucial to make the hull as smooth as it can be.

Roughness can be considered under three headings:

1. Structural roughness

This depends on the design and method of construction. These are avoided in modern welded construction but in welded hulls the plating shows a waviness between frames.

2. Corrosion

Steel corrodes in sea water making a roughened surface. To decrease corrosion during construct and in operation, numerous ships are presently fitted with cathodic protection systems, either active or passive.

3. Fouling

Marine living beings such as weed and barnacles can connect themselves to the hull. This would represent a really serious roughening. Early treatments contained harmful materials such as compounds of mercury or copper which prevented the marine growth taking a hold on the hull. Shockingly these compounds moreover contaminate the general ocean and other treatments are presently utilized.

2.5 FORM PARAMETERS AND RESISTANCE:

In terms of resistance one form may be superior to another at one speed but inferior at another speed. Frictional resistance is specifically related to the wetted surface region.
Other form changes are likely to have most influence on wave-making resistance but may too influence frictional resistance.

Length:

An increase in length will increase frictional resistance but ordinarily decrease wave-making resistance. In this way quick ships will advantage generally from being longer than slow ships.

Prismatic coefficient:

the ratio of the volume of displacement of a ship to that of a prism equal in length to the

distance between perpendiculars of the ship and in cross section to that of the immersed midship section.

Fullness of form:

Fullness may be represented by the block or prismatic coefficient, for most ships resistance will increase as either coefficient increases. This is sensible as the full ship can be expected to make a greater disturbance because it moves through the water. Generally, the block coefficient ought to decrease as the ship speed increases.

Slimness:

Slimness can be characterized by the proportion of the length to the cube root of the volume of displacement (this is Froude's circular M) or in terms of a volumetric coefficient which is the volume of displacement divided by the cube of the length.

Breadth to draught ratio:

Generally, resistance increases with increase in breadth to draught ratio inside the ordinary working extend of this variable. This will once more be clarified by the angles at the ends of the waterlines increasing and causing a greater disturbance within the water.

Longitudinal distribution of displacement:

Even when the main hull parameters have been fixed it is possible to vary the distribution of displacement along the ship length. This distribution can be characterized by the longitudinal position of the center of buoyancy (LCB).

Length of parallel middle body:

The length over which the midship section remains unchanged

Section shape:

It’s impossible to generalize on the shape of section to adopt but slow to moderate speed ships tend to have U-shaped segments within the fore body and V-shaped segments aft.

Bulbous bow:

A bulbous bow is a protruding bulb at the bow (or front) of a ship just below the waterline. The bulb modifies the way the water flows around the hull, reducing drag and thus increasing speed,

range, fuel efficiency, and stability.

Triplets:

Changes are frequently fundamental within the early design stages and it is desirable that their results should be known. One way of accomplishing this is to run a set of three models early on. One is the base model and the other two are the base model with one parameter changed by a small amount. The form can be expressed as:

$$\frac{dR}{R} = \frac{a_1 dL}{L} + \frac{a_2 dB}{B} + \frac{a_3 dT}{T}$$

The values of a_1 etc, can be deduced from the results of the three experiments.

2.6 MODEL EXPERIMENT:

Full scale resistance trials are exceptionally costly. Most of the information on ship resistance has been picked up from model experiment. W. Froude was the pioneer of the model experiment method and the towing tank which he opened in Torquay in 1872 was the first in its kind. Models were connected to the carriage through the dynamometer and their resistances were measured by the extension of a spring. Models were made of paraffin wax. Early work on ship models was carried out in smooth water. Most resistance testing is still in this condition but presently tanks are fitted with wavemakers so the included resistance in waves can be studied. Such basins can be used to determine model performance when manoeuvring in waves.

2.7 SUMMARY

The different types of resistance a ship experiences in moving through the water have been identified and the way in which they scale with size discussed. In pracdce the total resistance is considered as made up of frictional resistance, which scales with Reynolds' number, and residuary resistance, which scales with the Froude number. This led to a method for predicting the resistance of a ship from model tests. The total model resistance is measured and an allowance for frictional resistance deducted to give the residuary resistance. This is scaled in proportion to the displacements of ship and model to give the ship's residuary resistance. To this is added an allowance for frictional resistance of the ship to give the ship's total resistance. Various ways of arriving at the skin friction resistance have been explained together with an allowance for hull roughness.

Chapter 3

Components

Chapter 3
Components

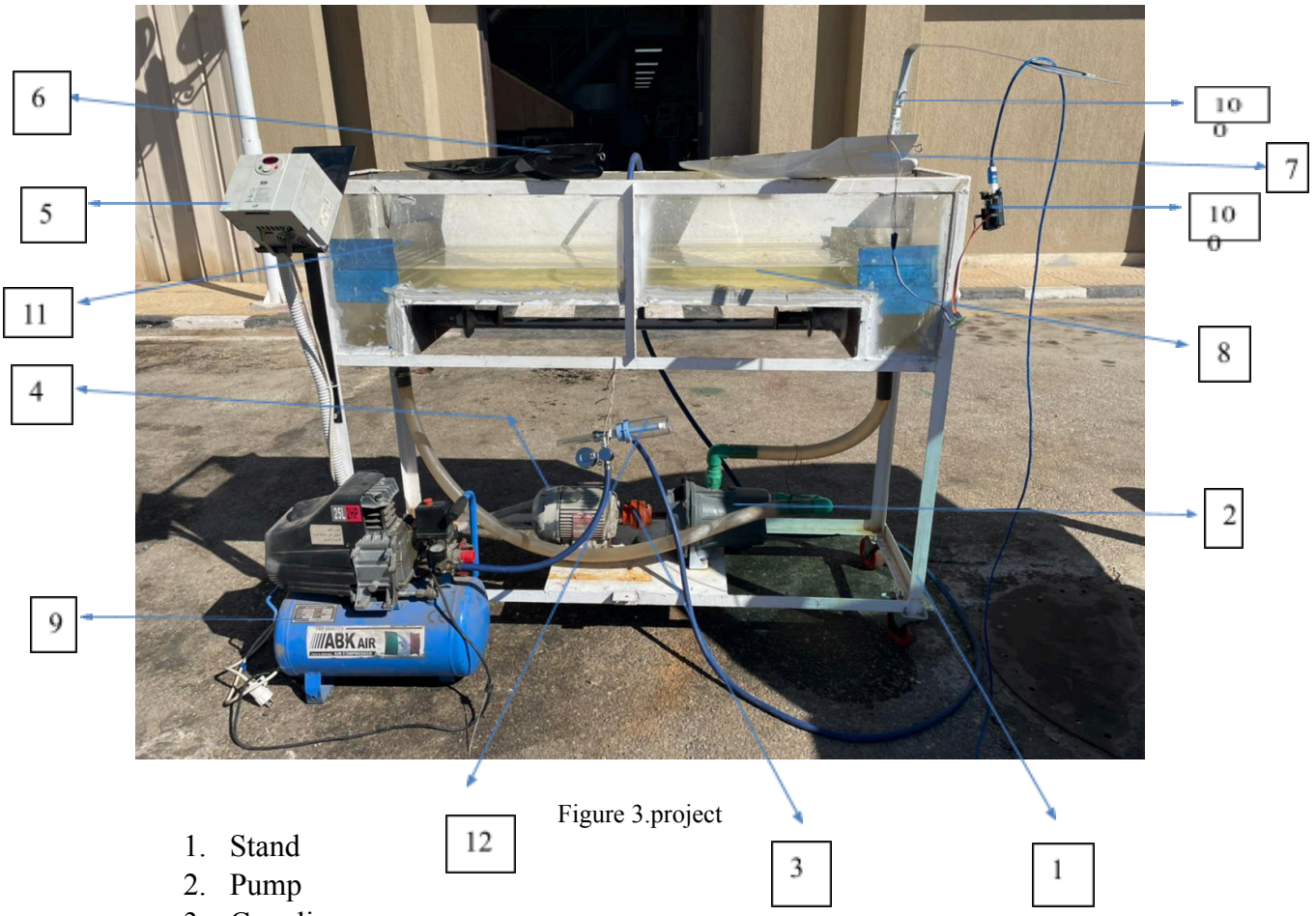


Figure 3.project

1. Stand
2. Pump
3. Coupling
4. Electric motor
5. Inverter
6. Black ship
7. white ship
8. Tank
9. Compressor
10. Electronic components
11. Aluminium sheets
12. Oxygen pressure controller

3.1 Stand

We make a 3d structure as a stand for the tank and a base of a thin metal sheet to weld the pump and the electric on it so they would not move.



Figure 3.1: stand

3.2 pump

Specifications

Water pump jet14	Hmax=52M
Qmax 60L/min	2850 RPM
Power=0.75kw 1hp	Fr=50 HZ

Function

The core concept of a water pump is to use a motor to convert rotational energy or kinetic energy and turn it into energy for moving fluid or for fluid flow, Centrifugal pumps work with an impeller, fluid enters through the rotating impeller and is expelled out through centrifugal force through the impeller's tips. The process of this increases the velocity and pressure of the fluid and directs it toward the outlet of the pump.

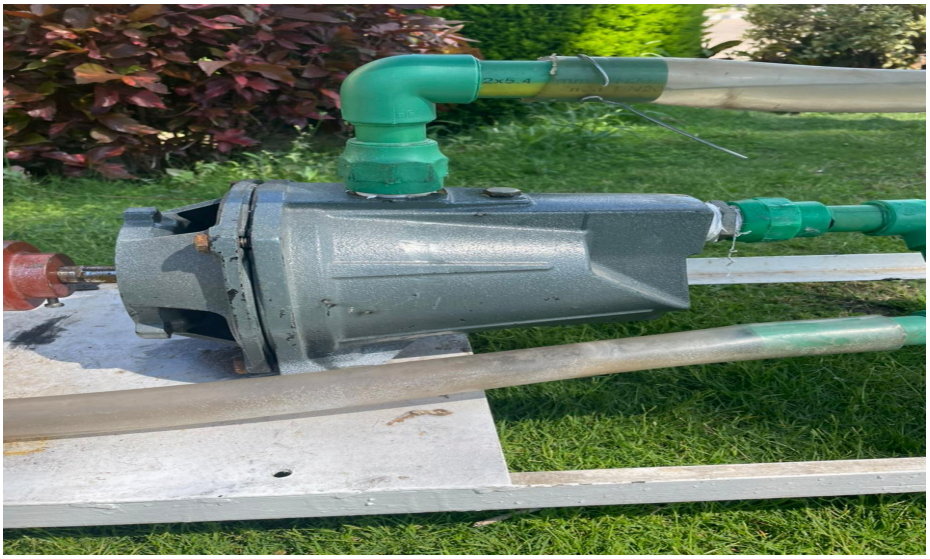


Figure 3.2:pump

3.3 coupling.

A coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. The primary purpose of couplings is to join two pieces of rotating equipment while permitting some degree of misalignment or end movement or both.

Or A coupling is a mechanical element part that connects two shafts together to accurately transmit the power from the drive side to the driven side while absorbing the mounting error (misalignment), etc. of the two shafts.



Figure 3.3: coupling.

3.4 Electric motor

We got electric motor 1HP to drive the pump that charge water in the tank to move the ships.



Figure 3.4: electric motor.

3.5 inverter

Specification

Input:200-230v ,16A 1 phase 50/60HZ
Output:0_input V ,8A 3 phase
0.01_400HZ
2HP/1.5KW

Function

A power inverter, or invertor is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC). The resulting AC frequency obtained depends on the particular device employed. Inverters do the opposite of rectifiers which were originally large electromechanical devices converting AC to DC



Figure 3.5: inverter

3.6 Black Ship

We got the design of the KCS ship from the internet, and we scaled it down from its original size to (75x10) cm, as for the printing process we divided the ship into 3 parts (front, rear and middle) so it can fit the working space of the 3d printer which was (50x50) cm, we made male and female parts inside the design of the ship and we used epoxy so we can connect the 3 parts

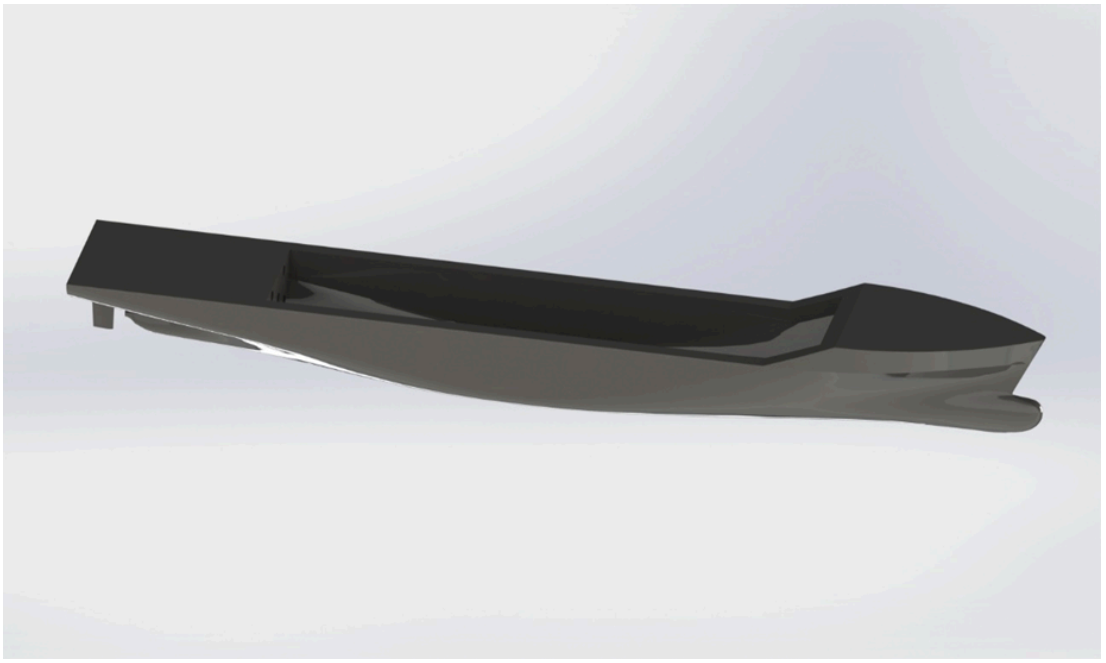


Figure 3.6 KCS Ship without holes

3.7 White Ship

We made the same for the white ship as we made in the black one, except that we realized that it's better to use bolts instead on the male and female parts as the epoxy has low surface finish and it took much time to dry. We added top part for the ship to compress the air in the top middle hole through 25 distributed holes in the bottom of the ship to make the air bubbles.

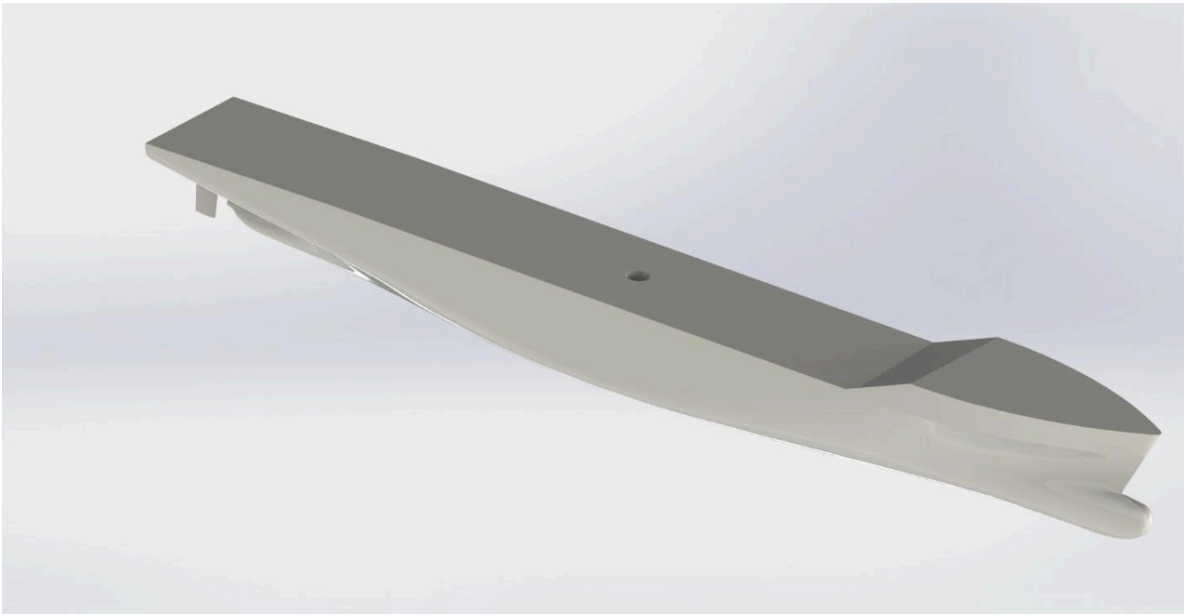


Figure 3.7 KCS Ship with holes

3.8 TANK DESIGN PROCESS

3.8.1 Phase 1

We made the dimension of the tank based on the dimension of the ship and the flow of the water so that we can control the linearity of the flow as possible as we can, with a dimension of (2114.49 x 450 x 400). We used a sheet of acrylic as the base material for the tank for its ability to be weld and bend.
The design itself was made on solid works as a sheet metal to be able to us flatten feature as it's the feature that's being used to mold and design the piece in the bending machine

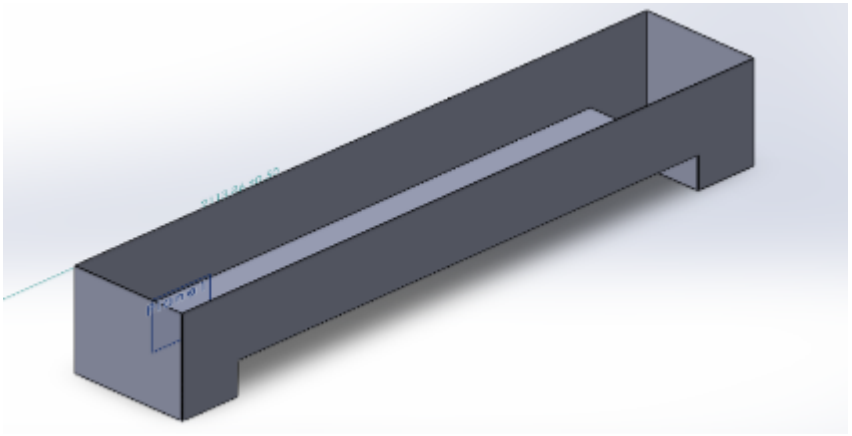


Figure 3.8.1: Tank

As there was no machine that we can reach that can cut and bend the sheet as it was 2x3 m we had to approach a different method.

3.8.2 Phase 2

As we couldn't make the tank by a bending machine we had to do it manually, we make a frame of the tank that was shallow and have no faces by making a base for the tank with a 2 mm metal sheet that was shaped like a W shape, then we make a 2 rectangles 1 for the base to use it as a support and the other one was for the top.
Then we make a rod supports to by the backbone of the tank then we welded those rods with the top windowed rectangle

3.8.3 Phase 3

As the faces was empty we got ½ acrylic sheet and cut it as following:
- 2 X (42.4x40cm)
- 2 X (149 x 19 x42.5 cm) as those would be the faces of the tank.



Figure 3.8.3: Tank after the assembly

3.9 Compressor

We got a compressor to pump air in the holed ship to make an air jacket inside it as it has 1 mm holes in the base of the hull, so that the pressure of the air in the air jacket will be higher than that of the water so the water wouldn’t get in the ship



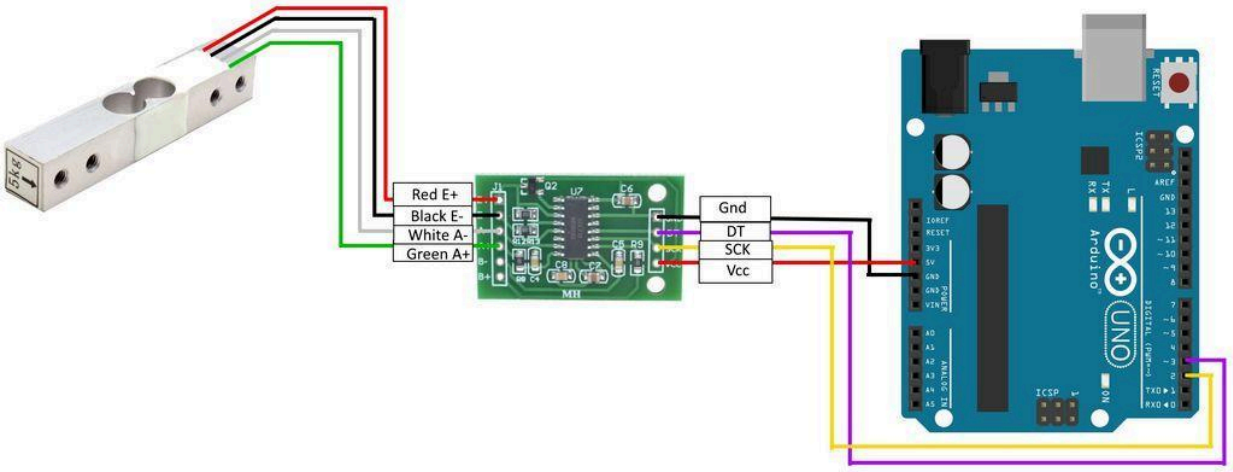
Figure 3.9 Air Compressor





3.10 Electronic components (HX711, 5kg Load Cell, Arduino)

The force sensor is basically **a resistor that changes its resistance depending on how much it has been pressed**. The harder you press on the sensor, the lower the resistance between the two terminals will be.



3.11 Aluminium sheets

I’ts function is to reduce waves and directs the water flow in straight lines.



3.12 Oxygen pressure controller.



Chapter 4

Conclusion & Results

Chapter 4

Conclusion & Results

The micro-bubble drag reduction is a very important process that if it is implemented right it would make a better significant difference, as it decreases the drag force of the ship hull, there will be a significant difference in the speed of the ship because of the thin layer of air bubbles that the pump will make between the ship lower surface and the water will decrease the friction.

We got 2 different drag force one for with the micro-bubble and the drag force without the micro-bubble

As it was calculated by the simulation and the model itself by 2 dynamometers, we fixed the 3D printed ships by 2 hinges so we can put the dynamometers in them and we made the water in the tank move by using a pump to make a moving flow that eject and sucks the water into and from the tank, by making an inlet and outlet in the two 90 degrees faces so there wouldn't be any vortex in the point where the ship is being fixed but the flow would be laminar so it wouldn't be an affecting factor in the calculation or give a false readings, as the vortex would form in the legs on the tank not in the middle part. That is reason why we made the tank in a W shape.

Table 3.1

Hz	Force (mN)
0	0
10	40
20	43
30	45
40	49
50	53
60	55

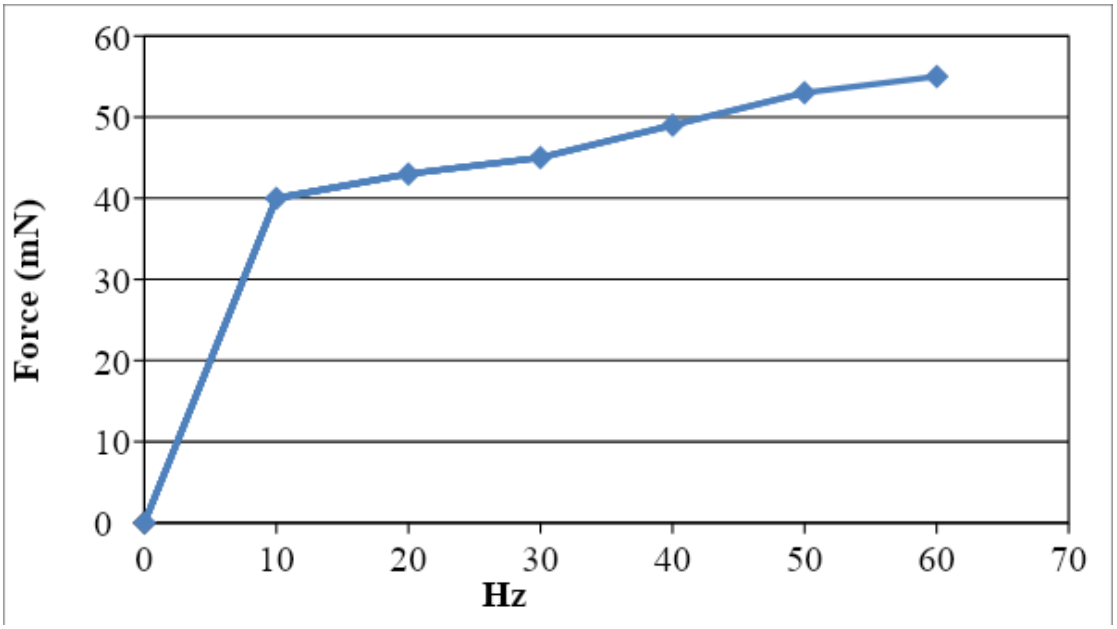
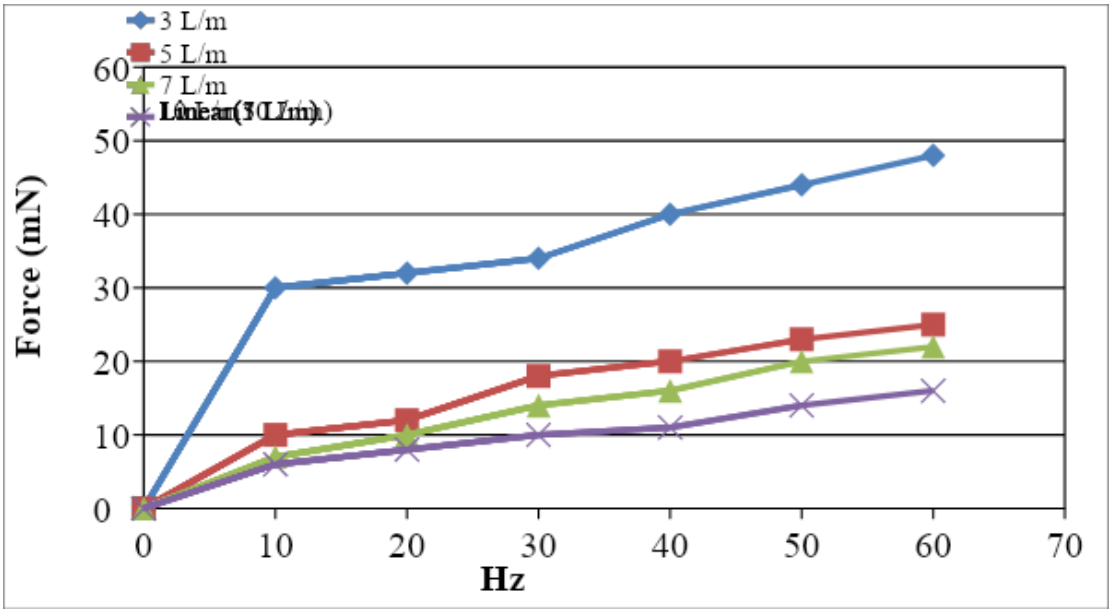


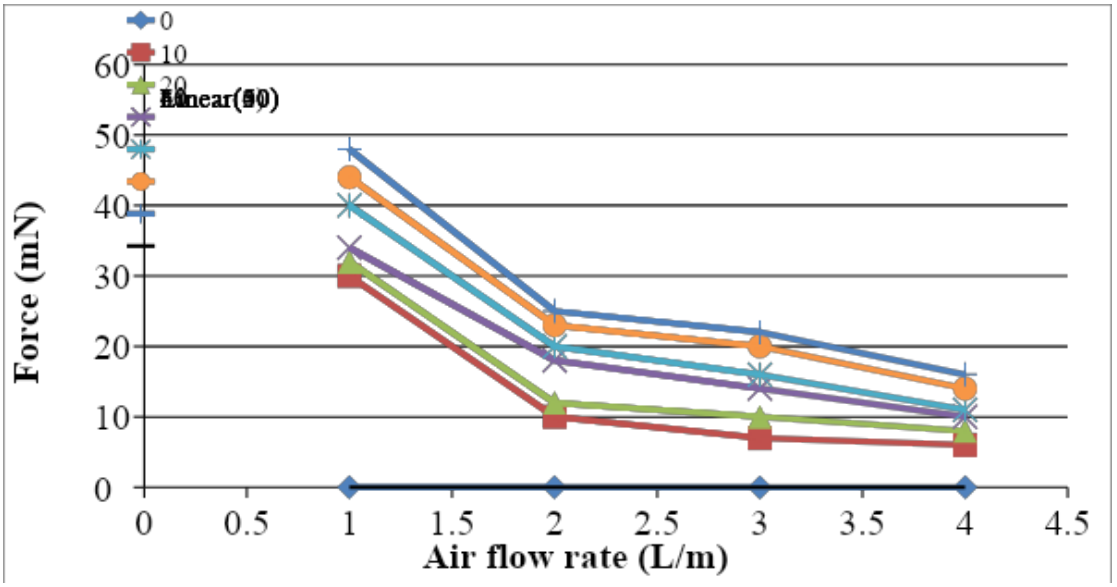
table 3.2

	3 L/m	5 L/m	7 L/m	10 L/m
0	0	0	0	0
10	30	10	7	6
20	32	12	10	8
30	34	18	14	10
40	40	20	16	11
50	44	23	20	14
60	48	25	22	16



Relation between frequency &force

for white ship



Relation between air flow rate & force

for white ship

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