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Research paper

Development of A Novel Ship Design for Enhanced Stability and Safety

P. Rajan *, K. R. Chidambaram

Department of Marine Engineering, AMET University, Kanathur, Tamil Nadu, India
**Corresponding author E-mail: prabhakaranrajan@ametuniv.ac.in*

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Abstract

A ship is regarded as a sophisticated product that is made up of several different kinds of materials, numerous types of machinery, and numerous electrical and plumbing systems. For the dismantling of such a sophisticated structural system to be safe, environmentally friendly, and effective, meticulous planning and close supervision are necessary at every stage. A vessel's design, including its functional characteristics, hull shape, propulsion, space and weight distribution, and technological and economic efficiency, is designed to suit the special needs of its owner or the goals of a society or governing body. One of the key features of marine transportation is ship stability, which directly affects the ship's performance and safety. The combination of art, technology, and business purpose is the basis of ship design. The most recent developments in propulsion, freight management, and navigation equipment have a significant impact on the finished product. A more sophisticated ship design must be built more often as a result of the rapidly growing number of cargoes transported by sea. Although the aforementioned is tough to understand, human nature dictates that he will constantly try to find a solution. There is a need for an even better product when a solution is discovered sooner rather than later. This means that the procedure must be restarted, but we must remember that a successful advancement yields larger benefits. Of all industries, shipping is the most international, and it is served by all commercial vessels. The transportation of cargoes and passengers was always the primary objective of this industry, which was established in the most largely forgotten antiquity. This custom continues to this day, and the ship's commercial life belongs here.

Keywords: *Novel Ship Design; Enhanced Stability; Safety; Materials; Business.*

1. Introduction

After roughly 25 years of operation, ships are no longer viable for additional maintenance, repair, or conversion. A ship is said to be decommissioned when it is permanently removed from service and then brought to a dismantling site. Ship recycling is the best choice for obsolete ships and promotes sustainable development, according to the International Maritime Organization (IMO). Important aspects of ship recycling include removing old, dangerous, and unproductive ships from operation and reusing or recycling salvageable equipment, onboard building materials, and other items. The final step of a ship's life cycle, ship recycling, involves a variety of activities that begin with the preparation of an old ship at an offshore location and end with the disassembly of the last onboard component. As defined by the International Maritime Organization (IMO), "ship recycling" is the process of breaking down a ship, either partially or completely, at a ship recycling facility, with the aim of recovering reusable parts and materials while safely dealing with hazardous contaminants. The term has been updated by the IMO to encompass related activities such on-site component and material storage and treatment, but not additional processing or disposal in different facilities. Historically, ship design was more of a craft than a science, depending on the judgment of experienced naval architects who had a mix of practical knowledge and a good grounding in a range of scientific and engineering subjects. To find their way around the design space, or the set of possible solutions to design problems, naval architects used heuristic methods – techniques evolved by trial and error over many years, which gave useful insights and approximations [4]. Trial and error methods eventually gave place to knowledge gained, which ultimately produced a knowledge base that contained semi-empirical approaches and statistical data regarding successful designs and existing ships.[1] The ship can be viewed as a complex system that integrates various subsystems and their component parts, including subsystems for propulsion, crew and passenger accommodations, navigation, energy and power generation, cargo handling and storage, and more, according to a modern, systems-based approach to ship design. Ship operations can be divided into payload operations and fundamental ship operations. In the case of cargo ships, payload operations encompass the provision of cargo compartments, handling, and treatment facilities to move cargo safely and effectively. Ship design must take the whole life cycle into account, including phases ranging from conceptualization and detailed design to construction, operation, and final scrapping or recycling. Optimizing the intricate ship system throughout its entire life cycle produces the optimum ship design, underlining the need for a holistic approach [2]. In order to ascertain whether a ship heels or trims excessively when in a stable situation, as well as whether it maintains stability in still water, its floating posture is studied. The upper boundaries of these restrictions are set by regulatory bodies. The maximum draught is examined in conjunction with the floating position to see whether it satisfies the needs of the stakeholders. In order to allow it to sail through a sea lock, river, or canal or still moor in a port, the maximum draught is usually fixed at a certain number of meters. Unbroken Stability A ship should fulfill a number of stability requirements when operating normally. For example, the ship should be stable in all circumstances, including those with high loads[3]. The ship should also be able to navigate through severe weather conditions without capizing. of fact, a basic bulk carrier that solely travels inland is subject to less stringent restrictions than a transatlantic passenger ship. As a result, distinct rules are established for each type of ship. Stability of Damage: A ship shouldn't sink or capsize right away after a collision. It needs to be able to withstand some damage to certain areas or rooms within the ship [6]. The IMO and other regulatory bodies specify the rules for where the harm should occur. Each type of ship has its own set of laws, of course. Strength: A ship usually bends slightly in the midsection when it is laden with cargo [8]. The reason for this is that when a ship is completely laden, the water exerts upward pressure on it, but the weight of the cargo causes the ship to sag downward in the center. Hogging is the opposite of sagging and mostly happens when the ship is empty. [11] The governing authorities once more specify how much the ship may droop and hog. The ship should be strengthened sufficiently to avoid going over the maximum stress limit [10]. Naval architecture, or naval engineering, is a discipline of engineering which incorporates ideas from mechanical, electrical, electronic, software, and safety engineering to design, construct, maintain, and operate marine vessels and structures. During the lifespan of a vessel, naval architecture comprises research, designing, developing, testing, and calculations. Some of the primary responsibilities are preliminary design, detailed design, construction, testing, operation, maintenance, launching, and dry-docking. Naval architecture also includes ship design calculations for alteration, creating safety standards, and approving designs to regulatory and non-regulatory specifications. Hydrostatics, a key area of naval architecture, examines a ship's behavior at rest in water, particularly buoyancy, displacement, trim, and stability. This is analyzing a ship's capacity to remain afloat and regain inclinations due to wind, sea, or loading conditions.

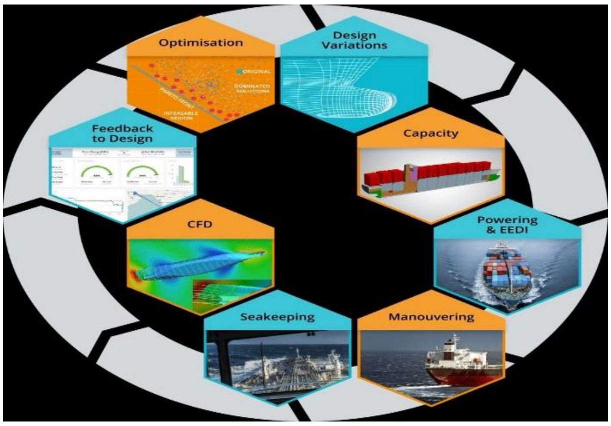

Fig. 1: Represents A Design Process for Ship Hull Optimization.

2. Literature review

One of the most important safety features is prevention from capsizing. Although capsizing is a rare catastrophe in modern times, when it does occur, the results are typically disastrous and the ship is lost, frequently with everyone on board. Public opinion responds to catastrophes with a high death toll almost hysterically, as was the case with the ESTONIA disaster, and the accident's effects on the marine industry can be rather severe. Protecting against capsizing is therefore a major concern. Criteria for ship stability were created to prevent the chance of capsizing. The International Maritime Organization (IMO) devised and suggested the most recent standards in the late 1960s and early 1970s, although some basic criteria were put forth as early as the middle of the eighteenth century. Some nations continue to utilize those standards today. The current criteria are design-oriented, and they basically provide critical values for certain stability metrics. The vast majority of ships are thought to be reasonably safe, despite the fact that several that met those requirements capsized.[12] However, certain contemporary ship types that incorporate innovative design elements might not meet the current standards. Because there is no past experience with the stability and safety of those ships, current criteria might not ensure the necessary level of safety. As a result, the IMO's Marine Safety Committee has added the requirement to create performance-based standards for ships of new ship types to its list of work items. According to this definition and the majority of members of the IMO SLF Subcommittee, performance-oriented criteria are those that consider situations in which a ship capsizes in the ocean. But the ship faces danger from more than just the sea's forces. According to an analysis of the causes of stability accidents, human error accounts for over 80% of fatalities; in the remaining accidents, variables like cargo shift, ice, or other heeling moments are frequently the first to occur. Applying the holistic and risk-based approach becomes possible if the purpose of this clause—which is frequently included in IMO instruments—is interpreted as defining the objectives. Insufficient resources were available to the author for a thorough risk study of the ship or group of ships in issue. As a result, risk analysis was carried out on a small scale, with a small number of experts in one group. The exercise's goals were to explore the potential for using a risk-based and holistic approach to stability issues and to establish a foundation for potential guidance material like that which was previously indicated. The remainder of the exercise will be published elsewhere; only a small portion of the analysis is discussed in the paper. Existing criteria are design guidelines that ought to be applied when creating a ship. Nevertheless, even the initial examination of stability casualties reveals that ship design elements are neither the most significant nor the most frequent source of casualties. The ship's stability mechanism is rather complex. Generally speaking, nevertheless, it can be categorized into four fundamental components: ship, environment, cargo, and operation. In many technical domains nowadays, risk analysis is done when planning extremely costly and sensitive businesses. The Marine Safety Committee recommended using this approach during the IMO rule-making process. Despite this advice and the fact that risk analysis is typically carried out in the offshore sector, for instance, stability specialists are reluctant to employ this strategy and still favor the creation of prescriptive criteria. A formula that establishes the upper and lower bounds of different parameters is the traditional prescriptive approach to the safety problem that has been in use for a long time [5]. This method is currently replaced by risk analysis and safety assessment. New risk-based requirements, which are focused on achieving the goal of system safety, have replaced strict formulas, which have the drawback of being insufficiently flexible to innovate the system and that can only be altered by taking tiny steps. Traditional stability requirements are prescriptive in nature and usually rely on deterministic computations. According to their wording, a ship's size or another attribute (such as metacentric height, for instance) must either be greater or less than a specified threshold. On the basis of data, model tests, and large-scale trials, prescriptive regulations could be created. In certain cases, probabilistic computations may also serve as the foundation for prescriptive regulations. The main difference in how safety criteria are conceptualized is between a prescriptive and a risk-based approach. Prescriptive restrictions' primary drawback is that they restrict designers and prevent the development of innovative design ideas. Since they are predicated on knowledge of preexisting items, they are inappropriate for novel sorts. Usually, they were changed following significant casualties. It is unknown how risky and safe the implementation of prescriptive regulations will be. The risk-based approach is the antithesis of the prescriptive regulations. Safe object performance is one of the objectives that must be met in the risk-based approach. The term "risk-based approach" refers to a performance-based, goal-oriented strategy that typically uses probabilistic computations. It is conceivable to envision, though. The benefits of a risk-based strategy are clear [13]. They truly permit making the best choices from an economic perspective, and the danger to the environment and public is evaluated and accepted. They also provide designers the freedom to create new solutions. Every stability regulation in place is prescriptive in nature. However, the necessity of using a risk-based approach is currently acknowledged and even advised. However, there haven't been many attempts to use this method to address stability issues, at least not yet.

Fig. 2: 3D-Rendered Model of A Container Feeder Vessel, Specifically A 2000 TEU (Twenty-Foot Equivalent Unit) Class Ship. the Vessel Has A White and Red Hull with the Logo “ABB” on Its Side.

3. Methodology

Design restrictions and requirements: The main criteria for technical ship designs are that they be large enough and arranged for their intended use, which means they must be able to transport a certain amount of cargo and have enough room for people, fuel, and machinery, among other things. Floats at the proper draught: indicates that the force from buoyancy (a function of ship form) is equal to the total of the lightship's weight and deadweight. indicates sufficient stability because it floats upright. Achieving the right speed requires installing the appropriate engine or engines and making adequate estimates of resistance and propelling force (plus margins). Structurally safe or sound refers to a construction that can sustain stresses in a maritime environment; it is usually constructed in accordance with a classification society's specifications. satisfies maneuvering, course-keeping, and seakeeping criteria; this suggests the selection of an appropriate hull design. conforms with international safety norms and IMO criteria. An "iterative process of analysis and synthesis," or a repeating procedure in which the design is broken down into basic components and pertinent calculations are conducted, the components are then integrated to create the overall ship design, will be used to derive a workable technical design.

Analysis of computational fluid dynamics: Computational Fluid Dynamics (CFD) is a numerical method that uses computers to predict and simulate the behavior of fluids and gases by solving the governing mass, momentum, and energy conservation equations. Fluids are everywhere and provide us with countless methods to survive. The tremors Speech and hearing are made possible by the pressure waves that the voice chords create in the atmosphere. Anywhere fluid flow and heat transfer need to be predicted or the impacts of fluid flow on a system or product need to be understood, CFD is utilized. Among the factors that can be examined with CFD are a fluid's temperature, pressure, velocity, and density. Fluid flow is naturally difficult to model on a computer due to its complex nature. The intricacies that make fluid analysis so challenging include nonlinearity, unsteadiness, and multi-physics interactions. Interactions between multiple physics: Fluids typically move through, inside, and around buildings rather than in isolation. Consider how the trees are moved by the wind. The wind changes when the tree moves, and the tree changes when the wind changes. This combined fluid-structure interaction problem necessitates a Multiphysics modeling method. Ansys CFD software, such as Fluent and LS-Dyna, can address this type of fluid-structure interaction issue (often in conjunction with an Ansys Mechanical structural mechanics solver). Furthermore, many real-world situations involve multiple fluids (such as air bubbles rising through water) and/or changes to a fluid's chemical composition through reactions (such as the combustion flow inside an airplane engine or the chemical reactions taking place in your car's battery), even when the fluid is considered in isolation. These scenarios are especially well-suited for modeling using Ansys Fluent. Nonlinearity: This characteristic of the physical equations controlling fluid dynamics indicates that the fluid interacts with itself. The majority of engineering-relevant flows are turbulent. One instance of a nonlinearity in fluid dynamics is turbulence, which influences other quantities such as momentum and heat transfer, which in turn influence turbulence. We mean that the flow is chaotic, erratic, and non-deterministic when we talk of turbulence (yep, the kind the captain is referring to on the airplane). [7] Because of this unpredictability, the term "computational" is essential to computational fluid dynamics. These equations cannot be solved with a pencil and paper method due to nonlinearity and turbulence. Except for a few low-dimensional basic laminar flows, it has to be done on a computer. Even in that case, the computer's computed solution to a CFD problem—which involves converting a lot of calculus into algebra—is not a solution. Unsteadiness: Turbulence is characterized by unsteadiness. This shows that at any given fixed place in space, the flow quantities change over time. A highly accurate simulation necessitates a time-resolved solution if this unsteadiness is substantial (for example, when your car is traveling on a highway), which significantly raises the cost. The pervasive turbulence phenomena have perplexed scientists and engineers for many decades. Richard Feynman, a Nobel Prize-winning theoretical physicist, referred to it as "the most important unsolved problem of classical physics" because of how complex it is. Although CFD doesn't provide a mathematical solution to the turbulence problem, it does enable engineers to develop models that take turbulence effects into consideration when designing.[14].

4. Phases of ship designs

The Initial Iteration Loop of the Concept Design Feasibility Study is the starting point of the conversion of the ship owner's requirements into technical ship characteristics involving naval architecture as well as marine engineering considerations. This is in effect a feasibility study. Basic ship dimensions such as length, beam, depth, draft, block coefficient, and powering requirements are estimated in the early stages. The objective is to come up with the most economical design solution that addresses the needs of the owner, though this will not always be possible at this early stage [15].

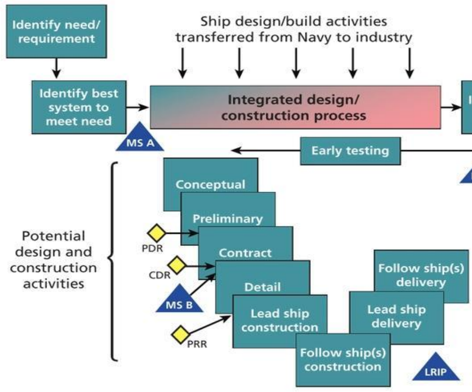

Fig. 3: Illustrates the Ship Design and Construction Process, Showing the Transition from Initial Requirements Identification to Final Disposal.

Initial Design-Second to Fourth Loop of Iterations The different ship design steps that were partially covered in the first phase are expanded upon in this stage. This phase entails accurate calculations of the ship's main characteristics, such as length, beam, depth, draft, block coefficient, and power requirement, to satisfy the owner's requirements and improve the design according to a specified economic criterion. The findings of the preliminary design form the core of the shipbuilding contract between the shipbuilder and the owner. Interestingly, the initial amount of work put into this stage is usually 15 times more than is necessary to finish it [9].

The Contract Design phase, or Fifth Iteration Loop, seeks to complete required calculations and naval architectural designs, and establish technical specifications for the ship construction, an important component of the shipbuilding contract. This phase comprises developing a highly detailed faired ship lines plan, approximating powering demands by means of model testing, studying the behavior of the ship in waves and maneuvering characteristics, assessing alternative drive systems, outlining structural detail, arranging auxiliary networks, and making an accurate estimate of the weight components, overall weight, and centroids of the ship, which finally becomes the basis for the official shipbuilding contract between the shipyard and shipowner.

The Comprehensive Design phase is the last phase of the ship design process, wherein technical specifications for equipment fitting and construction are laid out, and complete designs of all structural components are submitted to the shipyard production units and external suppliers. Even though the professional engineers make the drawings and specifications, it is the technicians and foremen in the shipyard who execute the designs. Traditionally, this phase involved much effort, about 60,000 man-days, but with the improvement in IT and experienced designers, this period has been greatly shortened. After completing phases (a) to (d) of the ship design process, the Basic Design outcomes can be utilized to estimate accurately the main technical characteristics and cost of construction of an economically sound ship, allowing the shipyard to prepare a bid for the prospective ship owner. If the bid is accepted, then the more elaborate and detailed third and fourth stages of design are undertaken.

5. Conclusion

The main focus of naval architecture is shipping design, which is also the essential element of marine transportation networks, which are the backbone of the world economy. Novel ship designs often explore atypical hull forms, propulsion systems, and materials to improve capabilities, sustainability, and efficiency in order to meet safety and regulatory limitations. The design should be economical, staff-light, and not unduly vulnerable. It is impossible to overestimate the significance of the ship, its crew, and the environment in which it operates. The material utilized determines the construction. When using steel or aluminum, erection and launch come after the plates and profiles have been rolled, marked, cut, and bent in compliance with the structural design drawings or models. Other materials, such as glass-reinforced plastic and fiber-reinforced plastic, are joined using other methods. The construction process is carefully planned, taking into account all aspects such as ship arrangement, hydrodynamics, safety, and structural strength. There are new options to consider with each component, such as ship orientation and materials. The manner the ship's structure is altered is taken into consideration while assessing the structure's strength. To avoid more damage, the two ships have to rebound since the material used on the struck ship has elastic properties and will send back the energy it absorbed in the opposite direction. Due to this, material properties are thoroughly examined. Traditionally, naval architecture was a more craft than scientific profession. A prototype or half-model of a vessel was used to assess whether the shape of the vessel was appropriate. It was considered a defect to have awkward shapes or sudden changes. This covered the rigging, fixtures, and deck layouts. The more exact terminology of today was replaced by subjective descriptors like full, fine, and ungainly. The shape of a vessel was and is called "fair." The word "fair" refers to the shape being "right" and the smooth transition from fore to aft. Even today, the art of naval architecture involves figuring out what is "right" in a given circumstance without conclusive supporting analysis. CAD software is used a lot. Many have been developed each with its particular advantages. Computational Fluid Dynamics (CFD) analysis in ship design uses numerical methods to simulate and predict fluid flow around and within a ship, aiding in optimizing hull form, propulsion systems, and overall vessel performance. CFD services can be used to look at how well the engine, propeller, and rockets work in a ship’s propulsion system. This can help engineers improve the design of these parts to make them work better and use less fuel. The Boat Propeller's steady spinning is modeled using ANSYS CFX in this project.

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