Research on Optimization of Ship Welding and Structure Design

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Abstract: In recent years, China's shipping industry has developed rapidly. Ship welding technology is one of the key technologies in modern shipbuilding mode. Advanced ship high-efficiency welding technology plays a very important role in improving ship construction efficiency, reducing ship construction cost and improving ship construction quality, and is also an effective way for enterprises to improve economic benefits. Ship structural design is of great significance to the application of ships. The key to good navigation performance lies in ship design, and hull structure design is one of the most important links in ship design. Like other engineering designs, the design of ship structures should know what method to use to carry out the design. According to the actual situation, this paper puts forward analysis on the design method of ship's main hull structure and the optimization level in the future.

1. Introduction

With the continuous development of the shipping industry, ships, as important means of transportation, are getting more and more attention, and the design and construction of ships are getting more and more attention. On the premise that the ship's main dimensions are determined, the increase in deadweight means the improvement in energy efficiency. In order to increase the ship's deadweight, the empty ship weight must be reduced [1]. During the construction of the ship structure, it includes many characteristics such as reliability, usability and maintainability. The most important one among them is reliability, which, as a prerequisite for ships to work effectively, specifies the carrying capacity that ships should have [2]. Vigorously promote high-efficiency welding technology, speed up the pace of welding technology transformation, efforts will be made to transform the comparative resource advantage into a competitive advantage in science and technology, and promote the progress of the shipbuilding industry and industrial upgrading. The welding quality of ships is particularly important to the structural strength of ships. Many average accidents are related to the defects existing in ship welding. Therefore, in the process of ship construction inspection, attention should be paid to the inspection of ship welds to ensure the quality of ships [3]. From different stages of structural design and its influence on construction, this paper summarizes and discusses some key details and puts forward improvement measures, which have achieved good results.

2. Existing Problems in Ship Welding

2.1 Welding Pollution Problem

During welding, toxic or harmful gases, such as CO, NO, HF, H_2P, H_2S and O_3, will be generated from welding materials, base metals and their metallurgical reactions. These poisonous and harmful gases are discharged into the air, causing serious pollution to the air and posing a great threat to the safety and health of welders. The greater the linear energy, the greater the welding deformation. Welding deformation increases with the increase of welding current and arc voltage, and decreases with the increase of welding speed. Excessive undercut not only reduces the working cross section of the parent metal, but also causes stress concentration at the undercut. For important hull structures, the undercut depth is strictly limited, especially the undercut is not allowed for key

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components [4]. In addition to a part of dust being collected and treated, another large part is scattered in the workplace or floating in the air. During welding, under the high temperature of the welding arc, the liquid metal at the end of the welding rod and the coating undergo severe metallurgical reaction and evaporate, and are rapidly oxidized and condensed in the air to form welding soot. During fillet welding, the fillet arc is drawn too long. During submerged arc welding, the welding speed is too fast or the welding seam is uneven. During welding, the current of the alternating current welding machine and the arc current are constantly changing, and the changing electric field generates a changing magnetic field, and part of the energy is used for providing energy required for welding; The other part radiates into the surrounding space in the form of electromagnetic waves, which is harmful to human body.

2.2 Energy Consumption in Welding

Although there are many kinds of welding methods, but in the welding production of ships, especially in the welding production of military products, the electrode arc welding still accounts for a large proportion. However, arc welding power source is one of the electrical equipment with large power consumption. Its power generation efficiency is low and no-load consumption is large, so it is not ideal in terms of energy saving. During welding, the bubbles in the molten pool cannot escape during solidification and form a void. Due to the existence of pores, the effective cross-section of the weld is reduced. Excessive pores will reduce the strength of the weld and destroy the compactness of the weld metal [5]. The temperature fields of continuous welding and intermittent welding are different, resulting in different thermal deformation. Usually continuous welding deformation is larger and continuous welding deformation is smallest. At present, governments of all countries have taken reducing energy consumption, improving the effective utilization rate of energy and popularizing the concept of energy conservation as their top priorities. With the continuous development of China's shipbuilding industry, the energy problem is becoming increasingly prominent. Therefore, how to save electric energy in ship welding is not only of great economic significance, but also related to the sustainable development of the entire ship industry.

2.3 Welding Quality Problem

During ship welding, defects such as cracks, air holes, inclusions, incomplete fusion, incomplete penetration and unqualified weld size often occur due to unreasonable preparation of welding process, outdated welding production equipment, unqualified welding materials, inadequate welding management and other reasons. The original manual arc vertical welding process has the disadvantages of low production efficiency, high labor intensity, high requirements on welder operation technology and unstable welding quality. Welding rod or flux is not baked as required; Corrosion of welding core or deterioration and peeling of coating, etc. In addition, when welding low hydrogen electrode, the arc is too long and the welding speed is too fast. High arc voltage of submerged arc automatic welding is the cause of blowholes. Assembly welding procedure can cause changes in rigidity and center of gravity position of components in different assembly stages, which has great influence on controlling welding deformation of components. Unqualified welds have great potential quality hazards, which will not only increase repair work hours, prolong production cycle and increase shipbuilding cost, resulting in huge waste of human and material resources, but also cause ship failure and threaten personal safety.

3. The Way of Ship Structure Design

3.1 The Design Concept of Ship Structure Design

For the design of ship structure, the design concept and construction content must be analyzed in detail. The first step is to analyze the total number of tasks to be carried out by the ship in the future. Ship design involves many independent disciplines such as rapidity, seakeeping, maneuverability, general arrangement, structural strength and economy [6], which is a typical multidisciplinary design optimization problem. The hierarchical optimization design method for ship structures is

based on this, and its basic idea is to optimally allocate the entire material of the first stage, and to optimize the size of the specific structure of the second stage.

Fig. 1 shows the optimization of overlapping forms of ribs and ribs. In addition, a certain clearance should be reserved at the joint between the ribs and the deck beam when contacting with the deck or the outer plate to facilitate installation so as to avoid secondary manual cutting of the end due to slightly longer profile size caused by construction factors.

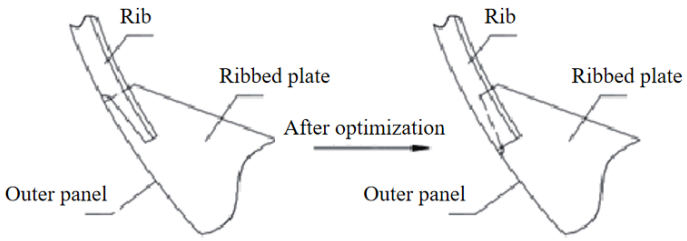

Fig.1 Connection Form of Ribs and Ribbed Plates

In this process, the standard calculation is the most important. Therefore, the plate thickness and component size should be calculated in strict accordance with the standard by region and section. For example, the calculation of outer plate thickness and superstructure component size in the standard is based on the region and section regulations. The component size calculated in each region should be differentiated and cannot be blindly selected according to the larger. Strict management is carried out according to the detailed process of managing shipbuilding, which mainly includes the design of construction drawings, auxiliary scheme design, preparation and management of construction.

3.2 Design Requirements for Hull Structure Design

The design of hull structure must have usability, and specific appearance design and beautification shall be carried out under the condition of ensuring the safety of ship navigation [7]. The safe navigation of ships in the sea is an important guarantee for all work. During the design process, the stability of ships must be ensured and the principle of mechanical construction must be complied with. There are many fuzzy factors in the optimization design process, constraints, evaluation indexes and other aspects of the ship structure. To realize the optimization problem of fuzzy factors, we must rely on fuzzy mathematics to realize multi-objective optimization design.

Fig. 2 shows the optimization of the cross-sectional form of the L-shaped elbow plate. But at the same time, attention should be paid to the following: when designing the details of the elbow plate, the relevant hull structure design requirements in the codes and standards should also be strictly implemented, which is the basic condition to ensure the perfect handling of the details of the components and the reasonable design of the ship.

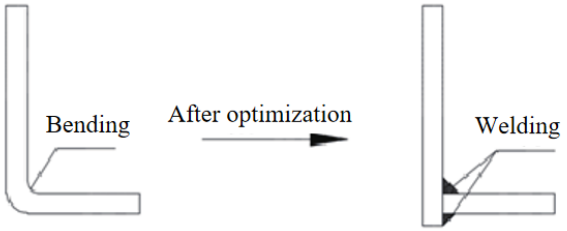

Fig.2 Section Form of l-Shaped Elbow Plate

Special attention should be paid when designing the connection form and end shape of these profiles. For example, when connecting ordinary ribs to bilge, the secondary processing of the end of the profile should be reduced as much as possible, because bending and cutting in the secondary processing of the profile are complicated and difficult to achieve the desired effect. The quality of construction materials must be ensured during construction. For example, the plates used in ship

construction must be adequate to the bending degree of the hull and of moderate thickness. Can't use inferior materials in order to pursue cost excessively [8]. Reasonable design methods and advanced design concepts can be adopted to meet the structural strength, rigidity and use requirements of the hull while minimizing structural weight and maximizing economic benefits.

3.3 Steps of Hull Structure Design

3.3.1 Preliminary Scheme

This step refers to the structural construction of the task according to the relevant technical standards and design objectives, drawing the basic design drawings, checking the budget plan according to the original plan and design objectives for the type and dosage of the required raw materials and generating corresponding reports, and then designing the size and structural posture of the ship. This will increase the possibility for designers to choose the optimal scheme and enable designers to have a deeper understanding of the form of the design scheme. Special materials can be reasonably selected when ordinary steel cannot meet the use requirements, and the weight of the hull structure can be reduced on the premise of meeting the strength and rigidity requirements. For example, the high-speed ship can meet the speed requirements due to its high speed. The whole ship or some parts of the ship are made of aluminum alloy to reduce the weight of the hull and meet the speed requirements.

3.3.2 Detailed Design

At the beginning, the most important thing is the construction of a large framework. After that, some details should be added. Compared with the traditional tractor, the positioning time of the robot is very small. Because there is no intelligent equipment available, the traditional tractor must be accurately positioned along the welded joint. China has basically realized the localization of welding materials in the construction of major ocean-going ships, but some welding materials still depend on import. When designing details, corresponding adjustments must be made in accordance with relevant standards and superior's approval opinions. On the basis of full consideration of details, a systematic scheme must be designed according to the type and material of materials, and submitted to relevant departments for review after drawing.

3.3.3 Production Design

This link is the requirement put forward in the design of the ship, which requires the design process to strictly follow the established plan for material selection, construction and optimization.

4. Optimization Measures for Ship Structure Design

The theory and method of ship structural reliability can obtain different optimal design criteria of structural reliability according to different requirements of design objectives. Generally divided into the following three [9]:

According to the reliability $R\bullet$ of the structure, it is required that the weight $W\bullet$ of the structure is the lightest, namely:

$Min(X), s.t.R \geq R\bullet$

According to the maximum bearing weight $W\bullet$ of the structure, the structure is required to have the maximum reliability or the minimum damage probability, i.e.:

$Min\ Pf(X), s.t.w(X) \leq W\bullet$

Considering the weight and reliability of the structure or the probability of breakage, the satisfaction degree of a certain combination is maximized, namely:

$Max[a_1 uw(X) + a_2 upf(X)]$

In the formula, a_1 and a_2 respectively represent the importance degree of structural weight and damage probability, and meet $a_1 + a_2 \geq 1.0$, a_1 and $a_2 \geq 0$; uw and upf respectively represent the corresponding satisfaction.

There are more and more researches on reliability optimization design methods of ship structures, which gradually become an important direction in ship structure optimization design.

4.1 Shorten Docking Period

We should better plan the ship's construction process in detail and rely on computers to simulate it. We should also divide the ship's manufacture into sections. On the basis of effective analysis, we should complete the welding design for the whole ship. In addition to the difficulties in large-scale stochastic nonlinear programming, an important difficulty in reliability optimization design lies in the complexity of the process of evaluating the reliability of ship structures and the large amount of computation. Secondly, through holes that need to be pre-opened due to turbine, electrical and other specialties in the production and design process should be opened before plate nesting, which can reduce the number of manual openings in sections, and is beneficial to the quality of openings and shorten the construction period. Single wire and multi-wire submerged arc automatic welding is also one of the main welding technologies in the shipbuilding industry, which is mainly applied to the welding of flat welds of spliced plates. Submerged arc welding has good welding quality and weld appearance, so shipyards attach great importance to it. It not only guarantees the strength, stability, frequency, rigidity and other general conditions of the hull structure, but also ensures that it has good mechanical properties, economic performance, service performance and technological performance. Optimize the overall hoisting in the dock to improve the hoisting efficiency.

4.2 Pre-Outfitting and Pre-Painting the Ship in Sections

The available space for ballast tanks of large and medium-sized ships is very narrow, and the transition interval from the beginning to the end is only one meter, which makes it difficult to better carry out construction during the sectional design, and the unsafe factors also gradually increase during the construction. For some large ships, the designer performs regional unit pre-outfitting in the bottom area of the engine room on the basis of basin outfitting. That is, the hull remains “basin-shaped” and most outfitting operations in this area are transferred to the inner yard to be made into outfitting units [10]. After the main section of the engine room is hoisted to the berth, the outfitting unit is hoisted to the main section, and finally the workers connect the units. In the whole design cycle of a ship, production design is the last and most important link. In order to promote the integration of hull and outfitting, it is necessary to change the phenomenon of too fine division of labor between workshops and jobs. In order to promote the integration of hull and outfitting, it is necessary to advance the pre-installation of parts and components of outfitting parts. When the hull operation reaches a certain stage, the outfitting operation can be carried out in time. Therefore, we should attach great importance to the construction of hull, outfitting and coating integration.

4.3 Large Ships Reasonably Plan the Fast Loading of Docks

As an independent part, the tank bulkhead in the ship is not affected by the shape of the ship's hull. Therefore, the double bottom and the separate total section in the bulkhead can be constructed first, and finally the broadside can be segmented and assembled backwards. The intelligent optimization design method has the advantages of strong creativity and weak reliability. Therefore, when analyzing and calculating various performance indexes produced by it, multi-objective fuzzy evaluation should be carried out, and when necessary, some parameters should be adjusted using classical optimization methods. The through-welding holes set on hull components shall be designed according to the ship type and regional functions. When welding is feasible in non-special areas, the through-welding holes shall be minimized to avoid adding unnecessary patch plates after welding with too large an opening. It can weld parts that welders need all-position welding, even in closed areas where large standard robots cannot be used. To improve the communication and cooperation ability of enterprises, eliminate the time-consuming, labor-consuming and money-consuming work around welding process evaluation in the shipyards of the two groups, realize the integration of enterprise resources, gradually establish the shipyard welding technology information integration system in the systems of the two groups, and unify the production management with welding standardization.

5. Conclusion

Although China has become the world's third largest shipbuilding country, it still lags behind advanced shipbuilding countries such as Japan and South Korea. There is a big gap in per capita shipbuilding tonnage and welding material consumption. The consumption of raw materials and energy is far higher than that of South Korea and Japan. Based on the research on the optimal design method of ship structure, we can conclude that many factors that restrict and influence each other are often involved in the optimal design of ship structure, which requires designers to weigh the pros and cons and conduct a comprehensive investigation. In this paper, the current process of ship design is divided into three levels to elaborate, and some correction opinions are put forward for some key points, hoping to provide a normative guidance for future ship design, and finally realize the goals of reducing costs and improving ship quality in ship structure construction.

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