Ship Structure Analysis and Design Optimization

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Abstract: Ship structure analysis and design optimization are important research contents in the field of ship engineering. The purpose of this paper is to discuss the methods of ship structure analysis and design optimization strategies to improve the safety, economy and reliability of ships. Firstly, the basic methods of ship structure analysis are introduced, including static analysis, dynamic analysis and fatigue analysis. In addition, corresponding optimization strategies are proposed for the key technical problems in ship design, including material selection, structural form optimization and structural size optimization. The application of ship structural analysis and design optimization in ship engineering is described.

1. Introduction

As an important means of transportation, the safety, economy and reliability of ships are pivotal to the development of China's marine industry. With the continuous progress of ship technology, ship structure analysis and design optimization have become a research hotspot in the field of ship engineering. The purpose of this paper is to discuss the basic methods of ship structure analysis and design optimization strategies to improve the safety performance, economy and reliability of ships. By analyzing and optimizing the design of ship structure, it helps to promote the innovation and development of ship technology and contribute to the prosperity of China's ship industry.

2. Ship structure analysis method

2.1 Static force analysis

Ship static analysis refers to the process of researching and calculating the structural forces on the ship when it is in a static state. Through static analysis, the force characteristics of the ship under various working conditions can be determined, so as to ensure the safety performance of the ship. In ship static analysis, the following aspects are often involved in the calculation: hull bending, stress, strain and stability. First of all, hull bending refers to the phenomenon of bending and deformation of ship structure under external force. By analyzing and calculating the hull bending, the stiffness and deformation of the hull structure can be evaluated to ensure that the ship has sufficient structural strength in the static state. Secondly, the ship static analysis also includes the calculation of stress and strain in the hull. Stress refers to the force borne by the hull structure per unit area under the action of force, and strain refers to the degree of deformation of the object under the action of stress. By analyzing the stress and strain distribution of the hull, it can be determined whether the strength of the ship structure meets the design requirements and the necessary optimization of the structure can be designed. In addition, the ship static analysis also needs to consider the ship's stability. Stability refers to the ability of the ship to remain stable after being subjected to external forces in the equilibrium state. By analyzing the ship's stability, the risk of capsizing can be assessed and the appropriate ship load, center of gravity position and hull shape can be determined to ensure the safety and stability of the ship[1].

2.2 Dynamic and fatigue analysis

Ship dynamics analysis is the process of studying the structural forces of a ship under its running state. Through ship power analysis, it can determine the influence of various power loads on the structure of the ship during navigation to ensure the economy and reliability of the ship. In ship power

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analysis, it mainly includes the calculation of the following aspects: ship vibration, impact and fatigue. First of all, ship vibration refers to the structural vibration produced by the ship under the action of waves and other external loads during navigation. By analyzing and calculating the ship vibration, the response of the ship structure to the vibration can be evaluated, so as to determine the structural strength and stability of the ship under different sailing conditions, and to ensure the safety and reliability of the ship in the sailing process. Secondly, ship power analysis also needs to consider the impact loads on the ship. These loads include the impacts of collision, grounding and other accidents that occur during navigation. By analyzing and calculating the impact loads on the ship, the damage degree of the ship can be assessed, providing basic data for ship maintenance and structure renewal. In addition, ship power analysis also needs to consider the fatigue problem of the ship. During long-term navigation, the ship will be constantly subjected to the impact of waves and structural vibration, and these effects will have a gradual accumulation of influence on the hull structure. By analyzing the fatigue of the ship, the life and durability of the ship structure can be assessed, so as to determine the maintenance and renewal cycle of the ship, and ensure the long-term reliable operation of the ship[2].

3. Ship structure design optimization strategy

3.1 Material selection

The selection of ship structure materials has a direct impact on the safety performance, economy and reliability of the ship. In order to realize the optimized design of ship structure, it is necessary to consider the ship's operating environment, working conditions and design requirements, and select materials with excellent performance. First of all, the strength requirements of ship structure need to be considered in material selection. Ships will be subject to waves, wind and hull weight and other loads during navigation, so it is necessary to choose materials with sufficient strength to meet these mechanical requirements. Common ship structure materials include steel, aluminum alloy and composite materials. Steel has high strength and stiffness and is suitable for use in large merchant ships and marine engineering facilities. Aluminum alloys have low density and good corrosion resistance, and are suitable for high-speed ships and light ships. And composite materials have excellent specific strength and specific stiffness, suitable for high-performance ships and special-purpose ships. Secondly, the stiffness of the material also needs to be considered in the material selection. The stiffness of a ship directly affects its structural stability and vibration response. Ship structure needs to have enough stiffness to resist the deformation and vibration caused by waves and loads. Generally speaking, steel has high stiffness and can meet the requirements of most ship structures. For some high-speed or special-purpose ships, lighter, higher-stiffness materials, such as aluminum alloys or composites, may be required. In addition, corrosion resistance is also one of the factors to be considered when selecting ship structure materials. Ships operate in the marine environment and are subject to corrosive media such as seawater, moisture and salt spray. Therefore, selecting materials with good corrosion resistance can extend the service life of ship structures and reduce the cost of maintenance and repair. In this regard, stainless steel and aluminum alloys are commonly used materials that have good corrosion resistance and can effectively resist the erosion of the marine environment. In addition, wear resistance is also a factor to be considered. During the operation and maintenance of ships, ship structures may be subject to mechanical effects such as friction, collision and abrasion. Therefore, when selecting materials, their wear resistance needs to be considered to ensure the service life and reliability of ship structures. Some special alloys and composites have better wear resistance and are suitable for parts that need to resist abrasion. Finally, economy is also one of the important factors to be considered in material selection. The cost of materials for ship structures as well as the cost of processing and maintenance all have a direct impact on the cost of manufacturing and operating the ship. Therefore, when making material selection, it is necessary to comprehensively consider factors such as the price, availability and processing difficulty of the material in order to realize the economy of ship structure design.

3.2 Structural form optimization

Ship structure form optimization refers to improving the safety performance, economy and reliability of the ship by improving the form of the ship structure. Structural form optimization mainly includes hull line optimization, hull structure form optimization and ship outfitting optimization. First of all, hull line optimization, hull line optimization mainly focuses on the hydrodynamic characteristics of the ship in the water under the state of free movement to carry out research, the purpose is to maintain the good sailing characteristics of the ship under the premise of reducing the water resistance of the hull to increase the speed and fuel saving. The optimization of hull line includes bow design, internal profile line, stern design and other aspects. For different types of boats, there are different optimization focuses. Secondly, hull structure optimization mainly involves optimizing and improving the hull's material, structure, and processes to enhance its strength, rigidity, durability, and reduce its weight. This aspect of the technology is extremely wide, can be improved from the choice of steel, welding process, composite material application and other aspects. For example, the use of high-strength steel, segmentation of the hull, reduction in the number of welds, and the use of all-welded structures can effectively improve the strength and reliability of the hull structure. Finally, ship outfitting optimization, ship outfitting mainly refers to the ship's various equipment, instrumentation, pipelines, valves, pumps and other ancillary facilities, which is the basis for the normal use and maintenance of the ship. Optimizing ship outfitting can improve the safety, reliability and economy of the ship. For example, reducing the length of pipelines, adopting energy-saving valves, and rationally designing the ship layout can effectively improve the economy and efficiency of the ship. In addition, in the optimization of ship structure form, there is another important technology is ship intelligent design and manufacturing technology. This aspect mainly includes the application of ship CAD, CAM, CAE and PLM technologies, which can provide the whole process of digital support for the design, manufacture and maintenance of ship structure, and greatly improve the optimization effect and production efficiency of ship structure[3].

3.3 Structure size optimization

Ship structure size optimization refers to optimizing the size of the structure in the ship design process to achieve the effect of reducing deadweight, improving strength, reducing water resistance and fuel consumption. Among them, hull structure size optimization is mainly concerned with the hull's internal shape line and hull segment manufacturing. On the other hand, ship outfitting size optimization focuses on the size of pipelines, instrumentation, equipment, and other auxiliary facilities. The ship's structural connection optimization considers the hull's structural dimensions and the structural connection between different parts of the structure. It aims to achieve the best connection effect. First of all, hull structure size optimization is an important part of ship structure optimization. The size optimization design of the hull structure is made by comprehensively considering the hydrodynamic performance, stability and safety of the ship and formulating the corresponding optimization scheme on this basis. Generally speaking, the optimization scheme usually includes ship type optimization, hull segment manufacturing, hull center of gravity adjustment and other aspects, aiming to achieve the optimization effect. For example, in ship shape optimization, the curvature of the hull line or the angle of the hull can be changed to improve the hydrodynamic performance of the ship. In hull segment manufacturing, modular design concepts and factory production methods can be used to achieve precise manufacturing and efficient assembly of ship pieces, improve construction efficiency and reduce construction costs. Secondly, the optimization of ship outfitting size is also very important. Ship outfitting refers to all kinds of equipment, appurtenances and pipelines on the ship, such as air-conditioning, heating, water supply, ventilation, lighting, fire fighting, etc. The selection of their sizes and installation locations have a great impact on the economy, safety and efficiency of the ship. For example, in sizing optimization of ship outfitting pipelines, hydrodynamic analysis and calculations can help us to determine the diameter and length of the pipelines in order to achieve the best possible cost saving and resistance reduction. In terms of size and fitting selection of ship outfitting equipment, outfitting equipment with good performance, low noise, high efficiency and easy maintenance should be selected according to the characteristics and functional requirements of different ship types, and should be laid out and installed according to the actual situation. Finally, the optimization of the connection size of ship structure is to improve the firmness of the connection and the strength of the overall structure by adjusting the structural size of the connection, so as to achieve the purpose of improving the safety of the ship. For example, for the connection between the hull and the deck, an asymmetric bridging method can be used, which greatly reduces the center of gravity of the hull and increases stability. At the same time, changing the position, angle and number of welding seams can be used to make the structural connection stronger and reduce the risk of structural fatigue damage.

4. Conclusion

Ship structure analysis and design optimization is an important research content in the field of ship engineering. By analyzing and optimizing the design of ship structure, the safety performance, economy and reliability of the ship can be improved. This paper introduces the basic method of ship structure analysis and the strategy of design optimization. The application of ship structure analysis and design optimization in ship engineering has important theoretical significance and practical value.

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