Research on adaptive ship trim energy saving scheme based on intelligent loading

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Abstract: The system is a set of control system based on ship trimming energy-saving designed through deep learning algorithm, particle swarm algorithm and data optimization. Through the deep learning algorithm, the collected data is deep learning, the result of intelligent learning is used as the objective function, and the particle swarm algorithm combined with the loading software is used to adjust the loading state, sail with a fixed inclination angle and collect this fixed inclination angle during the voyage. A certain range of nearby data is systematically revised to make the system more perfect. Finally, a universal method can be obtained, which can be applied to different types of ships, and the corresponding trim optimization suggestions will be given to the complicated factors encountered in the navigation process.

1. Introduction

With economic, social and technological changes, including global environmental issues and the entry into force of relevant regulations, the types and practical applications of ships continue to develop. The impact of these changes on ship design depends on the reliable evaluation of ship hydrodynamic performance, and ship resistance performance is the basis and key content of hydrodynamic performance research [1]. The research methods of ship resistance performance are mainly divided into three types: ship model test, approximate estimation method and numerical simulation calculation of viscous flow field around the hull based on computational fluid dynamics (CFD) [2]. With the continuous improvement of computer capabilities and a series of breakthroughs in numerical calculation theory and methods, the application of CFD in the field of ship design has made great progress, and its advantages in economy, timeliness and reliability have become increasingly obvious, and it has become a hydrodynamic performance.

Figure 1: Wave making resistance distribution
Because the actual ship shape is very complicated, the fluid flow around it is also difficult to predict. When the flow velocity is different, the hull resistance is obviously different. How to ensure the ship work and the stability of the ship under the existing ship structure conditions? It may be small, and it can achieve the purpose of reducing navigational resistance. At the same time, it is necessary to comprehensively consider the economic benefits of loading cargo, ocean currents, weather and other seasonal factors in the route, so as to reduce the resistance while increasing the economic benefits as much as possible. Therefore, the actual use of ship trim is of great significance to ship energy saving and emission reduction.

2. Research status at home and abroad
At present, the IMO ship energy efficiency management plan provides the following energy-saving methods for ships that are already in operation: keeping the hull and propeller intact to avoid damage, using a lower economic speed, adjusting the main engine and propeller, and sailing at the best trim angle, etc. And the optimization of ship trim is the most effective way to save energy on ships. Our main principle when choosing energy-saving methods is to use the least investment to maximize the benefits. In the actual process, the operation of optimizing the trim of the ship is simple and the effect is obvious. In order to make the ship sail in the best trim state, it is not allowed to make too much changes to the overall structure of the ship, and only need to be adjusted properly. Can achieve the purpose. In the 20th century, my country launched a study on the influence of ship trim on resistance. The Shanghai Ship Transportation Research Institute of the Ministry of Communications conducted a trial study on the "door"-shaped cargo ship, and found that the ship is under different ballast, There is always an optimal trim angle at different speeds, and its energy-saving effect is very obvious. In 1991, 8 resistance tests under different trim angles and draught conditions were carried out on the "Songlin" wheel, and it was found that the best state is relatively the worst state.

3. Practical plan for energy saving of ship trim

3.1. Deep learning learning system
Through Flunt fluid simulation analysis, the influence of ship trim on resistance can be obtained, and there is an optimal trim, but there is no method to optimize ship trim for real ships. Real ship navigation cannot simply be considered as simulation. The best inclination angle obtained is the best inclination angle in actual sailing. For this problem, we propose to replace the real-time optimal solution with the global optimal solution, and use the route, time and speed to reflect the complex factors encountered in the navigation for systematic learning in the learning phase. Give different responses to the complicated situations encountered in navigation, and apply the method of trim optimization to practice through self-learning algorithms.

Regarding the angle record: Since the initial stage is a systematic learning process, a fixed power is used to sail during the sailing process, but the wind and waves will affect the ship speed to a certain extent during the sailing process, so the ship speed is not a constant value during this process. The route is divided into sections, each section measures different angles at different speeds, and one section corresponds to the angle collection method of different speeds and the same angle to reduce this error.

Instructions for the first shipment: Because the basic data of the ship type is to be obtained for the first voyage, part of the cargo space must be sacrificed in exchange for a larger ballast water adjustment space to ensure the integrity of the curve and the integrity of the data obtained.

3.2. Load optimization
In actual transport ships, most of them are pre-configured with stowage software, and the trim value is set according to trim requirements or experience under the condition of meeting strength, without considering the effect of trim on ship resistance.

To this end, we have designed and implemented an intelligent loading optimization system, which can perform intelligent cargo distribution based on information such as cargo weight and ship cabin
distribution, so that the ship can use its own cargo to achieve a preset trim angle. The introduction of the intelligent loading optimization system can quickly obtain the result of cargo loading optimization under the condition of ensuring that the ship has sufficient strength.

4. Scheme realization

(1) Data acquisition and Kalman filtering:

In actual ships, the current fuel consumption can be directly read, and the ship’s trim angle and current draught can be read through the liquid level sensor installed on the ship. Usually in data collection, there will be error noise due to calculation and sensor accuracy. If we directly put the collected data into subsequent processing, the error will continue to accumulate. Therefore, it is necessary to use filtering algorithms to reduce system errors during data collection. In this project, we use Kalman filtering. The Kalman filter algorithm is an algorithm that uses the linear system state equation to make an optimal estimation of the system state through the input and output observation data of the system. The optimal estimation of the observation data can be regarded as a filtering project. The Kalman filtering algorithm is easier to implement than other filtering algorithms, the effect is better, and the collected data is relatively stable. The actual effect of Kalman filtering is shown in Figure 2:

![Figure 2: Kalman filter actual effect](image)

(2) Loading optimization system implementation:

This system is based on the input of the optimal trim angle and needs to optimize the cargo loading. Through the placement of cargo in different cargo holds, a pre-tilt angle can be set for the ship, which is used to reduce the number of times the ship's tilt angle is modulated during navigation. When placing goods, it is also necessary to meet the constraints of multiple ships to avoid problems such as ship capsize. Therefore, the particle swarm optimization algorithm is used in loading optimization to achieve the optimal assembly of ships under multiple constraints [8]. After the iteration, the global optimal solution corresponds to the cargo assembly at the optimal tilt angle.

![Figure 3: Particle swarm algorithm fitness decline](image)
(3) Realization of optimization adjustment of trim angle (PID control algorithm):
After setting the angle to the current optimal tilt angle through loading optimization, it is necessary to fine-tune the tilt angle of the ship within a certain small angle to achieve the purpose of energy saving and data collection. PID controller (proportional-integral-derivative controller) is a common feedback loop component in industrial control applications, suitable for adjusting the angle of the ship to the target angle. PID algorithm is composed of proportional unit P, integral unit I and differential unit D. Whenever there is an error between the inclination angle and the optimal angle, the error will pass through the PID controller. The proportional P can quickly react to the error. The integral I can eliminate the error after the system is stabilized but will bring overshoot. The derivative D can suppress the integral. The accumulated overshoot, and finally the output to the actuator can eliminate the error. By adjusting the P, I, and D parameters of the PID algorithm, and calling the PID algorithm at regular intervals to calculate the draft required by the ship’s ballast water system at the current moment, the angle of the ship can be controlled [9].

5. Conclusion
The theory based on trim energy saving is relatively mature. The basic idea is to first establish a three-dimensional model of the hull, then divide the mesh in the fluid mechanics analysis software, and set the corresponding boundary conditions to solve it. After calculating by changing the trim angle of the hull, comparative analysis results in the trim value corresponding to the least resistance. For the trim value and energy consumption (electric power) of the ship during navigation, the project simulates the fuel consumption of the actual ship by measuring the electrical power, and then reflects the energy consumption under different trims. In addition, intelligent learning is performed on the trim data and energy consumption data obtained by measurement, and the optimal trim value under different sailing conditions is predicted, which requires intelligent learning related theories. There are many related algorithms and the technology is relatively mature, especially the victory of the famous "Alpha Dog" shows a new height of artificial intelligence technology.

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