Influencing factors and optimization of ship energy efficiency under the background of climate change

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Abstract. Shipbuilding industry is a modern comprehensive industry that provides technical equipment for water transportation, marine development and national defense construction, and is an important part of advanced equipment manufacturing industry. The development trend of ship spare parts management must be combined with information technology to make it more integrated, intelligent and networked, and distributed processing information system will be developed and adopted in large quantities. Under the background of climate change, it is necessary to study the synergistic effect of clean energy utilization between ships and routes, and effectively improve energy utilization efficiency, so as to realize the real-time collection, monitoring, management and early warning of ship energy consumption data, and improve the comprehensive management level of ship energy.

1. Introduction

With the world entering a period of great marine development, the development of marine resources and the utilization of marine energy are highly valued by all countries [1]. Under the background of climate change, with the development of large-scale ships and the increase of the number of ships, the GHG emissions from ships to the atmosphere also increase rapidly. The trade volume between countries is increasing, and shipping industry plays a very important role in international trade. Nearly 80% of the goods in the world are transported by sea. At the same time, for the sake of our maritime traffic and energy, we must vigorously develop our shipbuilding industry and information technology [2].

Energy efficiency is a complex topic that can be described at many different levels. EEOI (Energy Efficiency Operating Index) is an overall figure describing CO2 emissions generated by shipping at a high level, while the improvement of energy efficiency is often discussed at a lower level, such as operating speed, propeller efficiency and specific fuel consumption of diesel engines [3]. China's energy development is faced with the challenges of energy conservation and emission reduction that developed countries have never experienced during the industrialization process. Therefore, an advanced energy management information system is established by using information technology, which can effectively improve the information level of energy management from the aspects of energy consumption collection, control, early warning and intelligent scheduling. On the one hand, equipment energy conservation is realized by controlling the state of equipment, pipelines and valves; on the other hand, system energy conservation is realized by comprehensive analysis and balanced scheduling of energy.
2. Present situation of energy management in shipbuilding enterprises

As far as China is concerned, at present, most shipping enterprises lack enough attention to energy conservation and emission reduction, and their management institutions are not sound enough. A few shipyards have initially established energy management systems, mainly power systems, which are limited to energy management at the equipment level. Relevant research shows that in the period of low economic development, the industrial energy consumption is almost negligible, so the industrial energy consumption intensity is close to zero [4]. When industrial production enters the peak period, the intensity of industrial energy consumption will increase obviously; The distribution of energy consumption and the evaluation of energy efficiency of existing ships will play an important guiding role in improving the energy utilization efficiency of ships. But this does not mean that the ship does not consume energy. In fact, most pure electric ships are heavier than diesel-powered ships, because the batteries required increase a lot of weight, so they consume more energy.

There is no doubt that the reduction of unit cost caused by the increase of container ships' scale is the fundamental driving force of the continuous increase of ship scale. Hull, various devices, equipment and most parts are made of steel. After the ship leaves the factory, it is in contact with water most of the time. Compared with navigation and operation, the way of energy efficiency management lags behind, and it is mostly a summary way, which does not control the specific details in the whole voyage. But in fact, for windsurfing and solar photovoltaic systems, their operational efficiency is largely restricted by the specific conditions of marine environment such as wind speed and irradiation intensity during navigation, which is closely related to ship routes. Energy data analysis method is single. In the past, 90% of shipyards used manual statistics to make analysis reports [5]. Low efficiency, heavy workload, inaccurate statistical data, lack of accurate statistics and quick historical data query and analysis for some fault moments and consumption of special equipment.

3. Energy saving related technologies

3.1. Composite material

Using composite materials to build the hull can reduce the weight of the hull, reduce fuel consumption, and reduce the emission of harmful gases and greenhouse gases. That is to say, the energy conversion, transmission, utilization and loss of devices or equipment are analyzed only from the angle of energy quantity, so as to determine the energy utilization rate of the system. Voyage cost is mainly divided into two parts, voyage fixed cost and voyage variable cost, in which voyage variable cost mainly refers to the cost of sailing at sea, which is related to the cost of fuel oil and port dues. The energy information network is responsible for the network transmission of data in the whole energy management information system, including energy collection data, analysis and processing process data, and energy management orders. This is mainly due to the fact that the wetted area increases with the square of the ship's length, while the cargo capacity increases with the cubic of the length. Therefore, the power demand increases more slowly than the transportation capacity.

The metal sheet can be aluminum alloy plate or steel plate, and the main material of polymer can be reinforced by carbon fiber or glass fiber. Under the condition of outputting the same power, the capacity requirement of the power electronic conversion device is reduced; And the motor has small moment of inertia, large pulse torque and good dynamic performance. It includes detailed inquiry of archive data stored in archive server, display of real-time dynamic monitoring pages of the system, such as process flow chart, area chart and other graphic frames, and control instruction operation objects such as switch buttons and opening adjustment controls. If the optimal ship type design is adopted, the fuel consumption can be reduced by up to 10%. If the speed is reduced by more than 30%~40% from the design speed, the fuel consumption per unit distance will usually increase rather than decrease [6].
3.2. Ship without ballast water
The hull shape of a ship without ballast water below the water surface is similar to an inverted triangle, which makes it possible to ensure sufficient draught and resilience even without ballast water. The cost of sailing is determined according to the distance of sailing, and the fuel consumption of ships sailing in ports is different from that at sea. Ensuring a certain number of ship spare parts can be replaced during navigation can not only ensure the safety of navigation, but also improve the operating rate of shipping enterprises and reduce economic losses. The importance of spare parts is beyond doubt. Through the correct design, some losses of the hull and propeller in operation can be recovered, especially the friction loss of propeller in the wake of the hull.

Considering that the speed and route of ships are easily affected by marine environmental factors (wind, wave, current, etc.), in order to analyze the impact of marine environment on EEOI more accurately, it is necessary to reflect the marine environment in real time and finely. Because different clean energy sources have different characteristics, their applications on different ships show different degrees of adaptability. Therefore, the fuel cost of ships in different ports is also different. Actual data are adopted for the fuel cost of ships in different ports [7]. When considering logistics, economy and other factors, whether low-speed ships are more efficient is another focus. However, compared with conventional ships, it is also possible to choose a treatment equipment with smaller capacity. The miniaturization of the treatment equipment reduces the overall weight and power consumption, which can reduce the fuel consumption.

3.3. Hybrid propulsion system
Propeller is optimized to produce high efficiency and good cavitation characteristics without causing great vibration on board. Unfortunately, these three aspects cancel each other out, and a good propeller is always a compromise among the three. The design concept of hybrid propulsion system is to combine traditional axial propeller propulsion with pod propeller, which can improve the shortcomings of the above propulsion system. Similarly, it is easy to wear during use and has a short service life; However, the RF card can be read and written without direct contact, which is very convenient to use. Because of non-contact identification, the mechanical wear is reduced and the service life is prolonged [8]. Such as optimal speed control, making optimal route, optimizing ship inclination, etc. The weather routing based on the latest weather and sea state data can accurately understand the real-time weather conditions. Compare the actual energy consumption with the expected energy consumption calculated according to the actual production parameters, and provide it to the leaders or management departments of shipping enterprises for planning, observation and scheduling.

4. Energy management application platform
4.1. Energy collection and monitoring
Using RFID system, the whole process of materials transported in transit can be visualized, so that in case of war, the war center can temporarily allocate the demand and transportation of combat materials according to the fighting situation, and can ensure that military materials can be distributed in a timely, appropriate and appropriate manner. Using AIS information and numerical prediction results, we can calculate the speed strategy that ships should adopt under different wind, waves and currents. Route optimization is a multi-objective optimization of navigation safety, the shortest flight time, the comfort of personnel and the minimum cargo loss on the basis of considering regional characteristics, marine hydrology and meteorological conditions. Therefore, it is not a problem of complete description, which sometimes leads to wrong conclusions. If you want to compare the design efficiency, you must compare it at the same speed.

In marine application, the load torque of electric propulsion system changes greatly, which requires high space occasions, harsh working environment and high low-speed performance. Some losses can be recovered by inducing reverse rotation. The typical system is on both wings of propeller and
twisted rudder, and the contrarotating propeller also works in the same way, while reducing the propeller load can further improve the efficiency. Shipping enterprises reduce the number of large ships calling ports through the connection and transit of large hub ports, so as to reduce the operating costs of enterprises and improve the service quality.

4.2. Energy consumption early warning
According to the energy consumption quota experience accumulated by shipbuilding enterprises for many years, the key energy consumption influencing factors are proposed and summarized by professionals and designers who know the process, and the changes of energy consumption caused by the changes of main influencing factors are scientifically calculated. Under the energy consumption early warning system of shipping enterprises, the energy consumption early warning threshold is set, the warning level is established and the early warning model is established [7]. The choice of engine is usually the result of weighing different aspects of operation, but diesel engine is the absolute dominant choice today. When the ship on the main route of the radial network model adopts a larger ship type, it will increase the difficulty of ship financing. The positioning and tracking system using RFID technology mainly measures the specific spatial position of the object according to the characteristics that the tag can identify the displacement of the object, and then according to the RF communication signal strength between the tag attached to the object and the RF reader. When a ship goes downstream or upstream, it is necessary to adjust the speed reasonably to ensure the stability of the speed.

The cost structure of container liner shipping is shown in Table 1. Among these transportation costs, ship depreciation and ship loan interest rate are the capital costs of ships, plus fuel cost, ship operation cost and management cost, which account for about 66.5% of the total cost and will change with the increase of ship size [9].

| Projects                | Specific gravity (%) | Projects                | Specific gravity (%) |
|-------------------------|----------------------|-------------------------|----------------------|
| Port charges            | 2.3                  | Management cost         | 5.6                  |
| Handling cost           | 20.7                 | Ship depreciation       | 11.7                 |
| Ship operating cost     | 9.6                  | Interest on ship loans  | 26.1                 |
| Fuel cost               | 12.1                 | Container depreciation  | 4.6                  |
| Container operating cost| 3.7                  | Interest on container loans | 3.9                |

It can be seen from the results in Figure 1 that, as expected, the daily variable cost and daily fixed cost of a single container decrease with the increase of ship type, and the total daily shipping cost of a single container undoubtedly has economies of scale. It shows that ships not only have the advantages of economies of scale in the cost of a single container, but also have good economies of scale in the marginal cost of a single container.
Figure 1. Relationship between container load and daily cost of a single container

In fact, improving the efficiency of clean energy use on a specific voyage through route optimization is to use weather routing technology to determine the optimal route, so as to achieve the best effect of energy saving and emission reduction. The voyage in the calculation formula of ship energy efficiency operation index does not refer to the shortest voyage from the starting point to the destination or the distance on the planned route, but the actual voyage of the ship. If a spare part is judged to be unqualified due to frequent replacement, the RFID system can monitor the situation of the spare part in time and try to minimize the impact of spare parts on the use of equipment. Every development is the fundamental driving force, which is to reduce the transportation cost by reducing the transportation time and exerting the scale economy of transportation network.

However, how to stipulate the terms of the charter party has already stipulated the energy efficiency contract. Although the standard clauses are included in the charter party, it should be considered to cover all operational aspects. If the propulsion system adopts a single power generation mode, it can exert the highest efficiency when it runs within the design conditions. However, when the power generation and power supply are changed, the power generation efficiency will be affected. At the same time, due to the introduction of integral controller, the shortcoming of low steady-state precision of fuzzy control is overcome, and the static error of the system is reduced or even eliminated, which has better control effect. However, this practice will inevitably affect the service efficiency of shipping enterprises and increase the voyage time. The development of hub-and-spoke network model balances the relationship between large-scale ships and regular service.

4.3. Energy consumption balance and scheduling

In a specific environment and system application has been selected, building a database and its supporting application software to achieve a more perfect database model depends on database design for planning. Affected by special sea conditions, it is difficult for ships to sail according to the established route, so it is necessary to study the control optimization of ship route in actual sea conditions. Route optimization is a multi-objective optimization of navigation safety, the shortest flight time, the comfort of personnel and the minimum cargo loss on the basis of considering regional characteristics, marine hydrology and meteorological conditions. Therefore, at present, large hub ports still face many challenges. In order to meet the needs of hub-and-spoke network operation, in addition to improving operating conditions and increasing operating equipment such as loading and unloading suspension bridges, it is also necessary to vigorously develop collection and distribution, improve the efficiency of container transfer and shorten the transfer time.

Heat balance analysis, also known as energy balance analysis, is an energy quantitative analysis method based on the first law of thermodynamics. That is to say, the energy conversion, transmission, utilization and loss of devices or equipment are analyzed only from the angle of energy quantity, so as to determine the energy utilization rate of the system. The expression is:
The first law of thermodynamics per unit mass of the system is expressed as:

\[ \Delta E = Q - W + \Delta E_m \]

Formula is applicable to any working medium and any process. However, the vast majority of thermal equipment in engineering has material exchange with the outside world, which is an open system.

Table 2 shows the comparison of diesel engine energy consumption. Under sailing conditions, marine diesel engine is the energy source of ships. If the energy consumption of marine diesel engine can be improved in practice, the energy consumption level of ships will be greatly improved. Therefore, radiation heat dissipation should be reduced as much as possible in practice. Reducing energy loss is the goal of energy saving. According to the analysis results, combined with the characteristics of kunlun, the energy management suggestions of energy system are put forward for the purpose of energy saving in daily management.

| Energy consumption kW | Actual operation result | Test running results |
|-----------------------|------------------------|---------------------|
| Fuel heating kW        | 9523                   | 9107                |
| Output power kW        | 4500                   | 4109                |
| Exhaust gas energy kW  | 2000                   | 1899                |
| Pressurized air kW     | 1306                   | 1207                |
| Cylinder liner cooling water kW | 882 | 624 |
| Take away the oil kW   | 493                    | 315                 |
| Radiative heat dissipation kW | 418 | 329 |

When a ship sails in wind and waves, the energy consumption increases. If enough batteries are prepared in the power supply system, uninterrupted and stable power supply can be guaranteed. Based on the balance and scheduling model, the whole process of energy from purchase and storage, processing and conversion, transportation and distribution to terminal use can be graphically displayed, the balance monitoring of energy supply in each production area/workshop can be realized, and the system automation prompt of scheduling requirements can be realized. The embedded fuzzy controller is used as the outer loop regulator of the vector control system of permanent magnet synchronous motor to control the output speed of the motor; Moreover, when communicating with users of the system first, it can be more clearly reflected to users, so that users can have a more intuitive understanding of the system design and put forward their own suggestions.

5. Conclusion
Using clean energy is the future development direction of ships. It is precisely because air routes are closely related to clean energy utilization that it is very important to study the synergy between them. The essence of ship energy efficiency management is not only to reduce the consumption of ship fuel, but also to pay more attention to the improvement of fuel use level and efficiency. With the advanced and mature RFID technology, the system adopts the combination of CAN bus and Ethernet communication, which realizes the high reliability of data acquisition and transmission and reduces the construction cost of the system on the premise of making full use of existing resources. The construction of energy management information system will improve the energy management level of shipyards, tap greater energy-saving potential for enterprises, create greater economic and social benefits, promote the energy-saving and emission-reduction work of the whole shipbuilding industry, and improve the international competitiveness of the shipbuilding industry.
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