Projection on unmanned ships from the prospective of marine engineering

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Abstract

Unmanned ships are gradually entering the public's field of vision and are increasingly becoming a research hotspot for ships. Based on the field of marine engineering, this paper proposes several more feasible propulsion modes for unmanned ships: the "storage battery + electric motor" propulsion mode, the "multiple generators + electric motor" propulsion mode, and the "gas turbine + Liquefied Natural Gas (LNG)" propulsion mode. Firstly, the application status and historical development of various propulsion modes were introduced. Then, the advantages and disadvantages of the above various propulsion modes were analyzed separately, and the problems still existed in the application of various propulsion modes to unmanned ships were discussed. Finally, combined with the current engineering technology, it is pointed out that the core problem of unmanned ships is reliability.

Keywords

Marine engineering, unmanned ship, propulsion mode.

1. Introduction

In recent years, with the development of a series of technologies such as artificial intelligence, big data and cloud computing, unmanned driving technology has also made great breakthroughs, from the original unmanned aerial vehicles and unmanned vehicles to unmanned ships today. Unmanned ships refer to fully automatic boats with autonomous route planning, autonomous environment perception, autonomous navigation, non-autonomous remote control boats, and semi-autonomous boats that perform tasks according to built-in procedures [1].

Unmanned ships are becoming more and more popular because of their advantages such as safety and reliability, energy saving and emission reduction, increased cargo carrying capacity due to lack of crews, and reduction of accidents caused by human factor [2]. However, the current shortage of crew in the shipping industry provides an opportunity for the rise of unmanned ships [3]. Unmanned ships have a tendency to gradually replace traditional ships. As a subject with all machinery on board, machinery to machine, machine to person, and person to person as its research objects, marine engineering is closely related to ships. It can be said that the development of unmanned ships cannot be separated from the progress of marine engineering technology. Therefore, based on the current technical level of marine engineering, the development direction of unmanned ships is prospected, hoping to escort the unmanned ships.

2. Application of Electric Propulsion in Unmanned Ships

2.1 Section Headings

2.1.1 Sub-section Headings

The so-called ship electric propulsion refers to a technical mode in which a motor is directly used to drive a ship propeller or a ship propeller for propulsion, rather than a power device or a prime mover to directly drive the propeller. The prime mover here refers to a machine that directly uses wind energy, heat energy, wind power combining water power to generate power [4].The propulsion system of a ship is from the initial manual paddling, to sailing ships, to thermodynamic prime movers such as steam engines, internal combustion engines and turbines, and finally to the current electric

motors. If windsurfing is the first generation of non-human power devices, then the thermal prime mover is the second generation of non-human power devices, and today's electric propulsion is the third generation of non-human power devices.

At present, most ships use diesel engine as the main propulsion power unit, and the complexity of diesel engine determines the complexity of the control system, resulting in low response speed, low control precision, large maintenance workload and many control parameters, which make it difficult to control the main engine centrally while driving. Therefore, ships using diesel engine as the propulsion device are difficult to leave the engine personnel in the whole process. Unmanned ships, as its name indicates, are unmanned, which makes the traditional marine power source diesel engine unsuitable for unmanned ships. Electric powered ships are simple and reliable, with high control precision and fast response speed [4], which can realize remote control, reduce operating costs and improve the efficiency of ships [5]. Due to the above advantages, electric propulsion has become one of the propulsion methods that unmanned ships can take into consideration.

2.2 "Storage battery+ electric motor" mode

Electric propulsion ships can be divided into two types according to the presence or absence of storage batteries [3], and electric ships with storage batteries can be divided into two types: ① storage batteries are the main energy source; ② storage batteries as the center in the ship power station. When unmanned ships are propelled by battery power, these power supply modes may appear[3]: ①hybrid type of electricity and oil; ②Wind, light and electricity modes;③ Comprehensive charging mode. The so-called electricity-oil hybrid refers to the use of shore power and thermal generators (such as diesel engines) to supply electricity to the storage battery and then drive the motor to push the ship to run. The so-called wind-solar power mode refers to power the storage battery by using wind energy, solar energy and shore power and then drive the motor to propel the ship. The so-called integrated charging mode refers to the use of wind, light and oil electricity to power storage batteries and gas refers to fuel cells or gas (such as natural gas). The combination of storage batteries and fuel cells using wind, light and oil electricity as energy sources has not reached a practical level because fuel cells have not entered the stage of popularization and commercialization, so the integrated charging mode mainly refers to wind, light and oil electricity mode.

However, when unmanned ships adopt the "storage battery + electric motor" mode as the ship propulsion mode, the issue of endurance should be considered first. The so-called endurance refers to the maximum mileage that a ship can travel at a certain speed under certain working conditions between two energy supplements. Obviously, the available capacity, energy, electricity and other indicators of the battery are important factors affecting the endurance. Theoretically, when the unmanned ship uses a single battery or wind-solar battery for direct-to-alternating and direct-to-direct propulsion, it can ensure the normal operation of the unmanned ship along the inland river coast. When the unmanned ship uses the hybrid electric-oil charging mode with battery for direct-to-alternating-to-direct electric propulsion, the unmanned ship can realize long-distance navigation. However, the main factors restricting the application of batteries in unmanned ships are new energy and batteries. Due to the high cost and poor continuity of new energy sources such as wind energy and solar energy, storage batteries cannot utilize these energy sources in cloudy or windless environments. However, storage batteries currently available for ships cannot store sufficient energy to ensure long-range navigation of ships because of their own performance problems. In addition, there are four basic problems in applying storage batteries to unmanned ships to replace traditional diesel engines as ship main propulsion devices [3]: ⑴ Energy balance; (2) Electric motor control strategy; (3) Battery use; (4) Improving ship performance index.

The so-called energy balance problem refers to how to ensure the normal supply of energy on the premise that unmanned ships require an certain endurance. Due to the frequent charging of storage batteries and low energy of storage batteries, their dependence on shore power will be high. Frequent use of shore power to supply energy to storage batteries will surely make unmanned ships berth at

ports frequently, which will definitely increase the operating cost of unmanned ships. When unmanned ships use wind energy and solar energy to power storage batteries, the "wind energy + solar energy" mode has the disadvantages of unstable energy supply, poor continuity, low efficiency and high cost due to its greater dependence on the weather. Therefore, energy balance is the first problem to be solved before batteries are applied to unmanned ships. In a word, the problem of energy balance is the issue of increasing revenue and reducing expenditure. Open source refers to a series of measures to increase the energy input to ships, such as the adoption of new wind and solar energy sources and the improvement of battery performance.

In addition to using onshore electricity to power storage batteries, consideration should also be given to using new energy sources such as wind energy and solar energy to power storage batteries and to improve the utilization level of new energy sources. Compared with electric vehicles, unmanned ships have more advantages in the use of new energy. Electric vehicles have higher requirements for streamline when working at high speed, which makes it difficult to use wind energy. The small surface area of electric vehicles makes it difficult to use solar energy. In contrast, unmanned ships have larger surface area, which makes it possible to use wind energy and solar energy greatly. However, the existing problems are mainly that the stability of wind and solar energy is poor, and the cost of building wind and solar energy generators is relatively high, but this is only a technical problem, and the solution to the problem is only a matter of time. The battery for electric vehicles has been developed more mature enough to enable electric vehicles to enter the market.

In terms of improving the battery performance, reference can be made to the concept of battery for electric vehicles, such as the fast charging technology of battery. At present, the battery for electric vehicles is relatively mature in this respect. The charging time of the battery for unmanned ships should also be shortened, at least not much longer than that for traditional ships. Throttling refers to a series of measures to reduce energy consumption, such as optimizing the ship line type to reduce ship resistance, reducing ship shafting arrangement to reduce mechanical loss, optimizing motor control strategy to improve energy efficiency, etc. In fact, unmanned ships adopt the "storage battery + electric motor" mode as the ship propulsion mode, without diesel engine and its complicated shafting, gear box, fuel oil and oil sliding pipe system, and cancel the setting of engine room, which in itself reduces the weight of the ship, reduces the resistance of the ship, and meets the requirements of battery-powered ships in terms of throttling.

The so-called motor control strategy problem refers to the control mode of the motor. Since unmanned ships use the storage battery as the main energy source, the output current of the storage battery is direct current, which is distinguished from the direct output alternating current of the generator. The main purpose of solving the problem of motor control strategy is to obtain good control performance and excellent energy saving effect. The main content is the optimal combination of battery and motor. The control performance mainly refers to the starting, speed regulation, braking, direction change and load control of the motor, as well as the ability to adapt to grid voltage fluctuation and peak avoidance. In terms of starting, it is hoped that soft start can be realized (i.e. high starting torque can be realized at low speed and low frequency, which not only reduces the impact on the grid but also improves the starting speed).

In the aspect of speed regulation, it is hoped to realize broad stepless speed regulation characteristics so as to facilitate ship control. In terms of braking, it is hoped that kinetic energy can be recovered. For the load, it is hoped that the propulsion characteristics suitable for the propeller can be obtained. As the output voltage of the storage battery decreases with the increase of time, it is required that the motor can adjust the voltage and adapt to this voltage change environment. Due to the limited total energy of the ship power station, under the premise that other loads work together with the motor, the propulsion motor is required to have peak-avoiding capability and improve the operation quality. Finally, the key point in the optimal combination of storage battery and motor is speed regulation. For this reason, there are usually three kinds of combination schemes [3]: ① armature voltage regulation and excitation current regulation of DC motor; ②AC motor frequency conversion voltage

regulation; ③permanent magnet motor is adopted, and DC square wave frequency conversion regulation or AC sine wave frequency conversion regulation is adopted.

The so-called battery usage problem refers to improving the usage method of the battery. When battery is the main energy source of unmanned ship and the center of ship power station, the life performance of battery directly affects the endurance of unmanned ship. The storage battery has high requirements for use and environment. A series of reasons such as overcharge, over discharge, long-term charging and not using, long-term charging and not using or excessively high ambient temperature will affect the service life of the battery. However, the ship's environment is quite changeable and unstable, and when batteries are applied to unmanned ships, the number of batteries is large, and the failure of one battery will affect the normal use of a group of batteries. Therefore, in order to ensure the good operation of the battery, reasonable charging and discharging and self-generating reverse charging must be done [3]. In the production process of storage batteries, the failure rate of a single storage battery should be controlled to the minimum accuracy so as to ensure that the failure rate of a group of storage batteries is within the safety permission range. In the process of installing the storage battery, for a large number of joints existing in the storage battery, some processes should be adopted to ensure that these joints will not loosen in the shaking environment of the ship. In short, the use of battery will be one of the core technical difficulties for unmanned ships propelled by battery power.

The so-called improvement of ship performance index refers to the improvement of unmanned ship's endurance, speed, carrying space, battery charging convenience, ship size and other issues. In order to improve the ship's performance index, the ultimate goal is to properly use the storage battery and increase revenue and reduce expenditure. In the hull aspect, optimize the line type and reduce the resistance. In the electrical aspect, combine the wind and solar energy with battery energy. In addition, unconventional technologies such as high voltage technology, permanent magnet motor technology and superconducting technology can be adopted.

2.3 “Multiple generators + electric motor”

When an unmanned ship does not use a storage battery as the main energy source of the ship, multiple generators can also be used to generate electricity to directly drive the motor to propel the ship. When “multiple generators + electric motor” is adopted as the propulsion mode of unmanned ships, it refers to generating electricity through turbines and transmitting electricity to the motors in an alternating-alternating manner, thus driving the motors to run. The energy supply mode of this propulsion mode is fuel-turbine generator-motor or frequency converter-propulsion motor. Its advancement lies in the adoption of AC-AC frequency conversion speed regulation [3].Compared with the “ storage battery + electric motor” mode, the “multiple generators + electric motor” mode can reduce the dependence on external energy sources such as shore power and wind and solar energy. There is no doubt that the ship in this mode can be self-sufficient in energy.

However, as an unmanned ship, it is no longer required to rely on engineer management, and the generators under “multiple generators + electric motor” mode are mostly heat engines, such as diesel engines and turbines. These heat engines have complex structures, low control precision and heavy maintenance workload, which cannot achieve continuous good operation without engineers. In addition, many non-linear electronic power components are inevitably doped in the electric propulsion system. These electronic power components will bring irregular sine waves (i.e. harmonics, to the power grid during the working process). The existence of harmonic wave will cause harm to electric propulsion system and bring harmonic pollution. This requires frequency conversion technology to suppress harmonics. To sum up, when “multiple generators + electric motor” is adopted as the propulsion mode of unmanned ships, reliability becomes the top priority that needs our consideration.

3. Gas turbine mode

Compared with the traditional marine diesel engine, the gas turbine has large power, small volume, light weight, large power-to-mass ratio, good reliability, good maintainability, high degree of automatic control, good dynamic response, small NOX emission and long service life [6,7]. Before that, gas turbines have been widely used in high-speed ferries. The disadvantages of gas turbines, such as poor fuel economy and large fuel consumption, limit their use in civil ships. However, in the past, marine gas turbines used the technology of transplanting aviation gas turbines for reference, and both the diesel-fueled hybrid power plant and the power cycle of gas turbines themselves have been improving day by day. The wide application of gas turbine in warships indicates that the wide application of gas turbine in civilian ships (including unmanned ships) is just around the corner. After decades of research, development and application, it is generally believed that gas turbine is the preferred engine for large and medium-sized ships.

Like electric propulsion, when the gas turbine is running to propel the ship, the gas turbine runs smoothly, with little vibration and no noise pollution. Compared with diesel engines, gas turbines consume less lubricating oil, require less maintenance and require less maintenance management personnel, which is more in line with the requirements of unmanned ships. And using gas turbine as the main force device of the ship has the advantages of environmental protection, light weight, small volume [8], etc. With the increasing attention of the international community to environmental issues, more and more attention has been paid to ship emissions, and the restrictions on ship emissions are becoming more and stricter. Some studies have pointed out that [9] using LNG as ship fuel can reduce 35% of the operating cost and 25% of CO2.This also makes more and more ship owners choose LNG powered fuel ships.

For the sake of environmental protection, LNG powered fuel ships will become one of the development directions of ships in the future. However, in the future when unmanned ships gradually replace traditional ships, it is very likely that there will be an intersection between unmanned ships and LNG powered fuel ships. There are roughly five types of main power devices for LNG powered fuel ships [10]: hybrid power devices, steam turbines, gas turbines, dual fuel propulsion, and dual fuel electric propulsion. This article mainly discusses the situation of LNG as power fuel and gas turbine as power plant under the background of unmanned ships. By improving the material performance and cooling technology of the gas turbine, the initial temperature of the gas turbine is improved, and the efficiency of the gas turbine is improved. At present, gas turbines are mainly used as main power units on board ships [11]: steam turbine and gas turbine combined unit (COGAS), diesel engine and gas turbine combined unit, diesel engine and gas turbine alternate operation mode, gas turbine and gas turbine combined unit, etc.

At present, the gas turbine on board can be used for multiple purposes in one shaft. Before, most LNG ships used steam turbine as the main propulsion power unit. Due to the consideration of economic benefits, gas turbine is expected to replace steam turbine as the main propulsion power unit of LNG ships. However, there are still many problems in the application of gas turbine to unmanned ships [12]: the compressor performance of gas turbine becomes poor and the initial temperature of gas turbine decreases under variable working conditions; Compared with diesel engine, gas turbine cannot reverse. Reverse rotation of gas turbine requires reversing gear box, reversible hydraulic coupler, electric transmission device or variable pitch propeller, etc. The gas turbine engine has a large air circulation, so it needs a large-sized air intake and exhaust device. Installing a large-sized air intake and exhaust device will take up a large amount of space on the rear deck of the ship, thus reducing the carrying capacity of the ship.

In addition, drilling holes in the ship will affect the strength of the ship. In addition to the above-mentioned problems, the service life of the gas turbine overhaul is relatively short. Once repaired, the service life of the gas turbine will be greatly reduced, which is mainly related to the high and low temperature corrosion and high heat load of the gas turbine. When LNG is used as the power fuel and gas turbine is used as the power plant, the mode of combined driving of gas turbine and steam turbine

can be considered, or MT30 modified gas turbine developed by R-R Company of England can be considered, which is recommended by Shell Shipping Technology Company as the main propulsion power plant of the next generation LNG ship [12], and has passed Lloyd's Register certification for 250000m3.Therefore, for unmanned ships using LNG as power fuel and gas turbine as power plant, it can also be used for reference.

4. Conclusion

The rise of unmanned ships will definitely affect the marine engineering which dedicated in under the traditional ships before. Based on the technology of marine engineering, although it can be predicted that some electric propulsion modes such as “storage battery + electric motor” and “multiple generators + electric motor” may replace diesel engines to become the widely used propulsion mode on unmanned ships, these electric propulsion technologies still have shortcomings at present. For example, the energy of storage battery is limited, which determines the limited endurance of unmanned ships. Consequently, unmanned ships can only sail in coastal inland areas. Even with the help of wind energy and solar energy, the current technology still cannot make up for the shortage of usable capacity of the storage battery itself.

Although the short board problem of the storage battery can be solved by developing higher-performance storage batteries, it still cannot meet the requirements of ocean-going unmanned ships in a short period of time. Similarly, the “multiple generators + electric motors” propulsion mode is still need some time for being applied to unmanned ships because generators are mostly heat engines such as diesel engines, and the normal operation of marine heat engines cannot be separated from the management of engineers.

In addition to the above two propulsion modes, the “gas turbine +LNG” propulsion mode, due to the material reasons of the gas turbine, determines that the initial temperature of the gas turbine cannot be too high, which limits the power of the gas turbine. In addition, the normal operation of the gas turbine still cannot be separated from the management personnel. To sum up, the core problem of unmanned ships is the reliability of various components applied to unmanned ships. That is, how to ensure the good operation of these components under unmanned management is a problem in need of resolving. Once this reliability problem is solved, unmanned ships will definitely replace traditional manned ships with their obvious advantages.

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