Research on ship electric propulsion

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Abstract: Ship electric propulsion is widely favored in the marine industry due to its good economics, maneuverability and low noise. The modeling and simulation research of the ship's electric propulsion system is carried out, and the steady state and dynamic working process of the system are reproduced. The inherent laws of the system are revealed, which is of practical significance for guiding the design and use of the ship's electric propulsion system. The ship's electric propulsion system is a complex and variable nonlinear system. In addition, its propulsion motor has the characteristics of large capacity and large moment of inertia. It is very important to accurately model and simulate it. The main content of this paper is the systematic research and development prospects of marine electric propulsion systems.

1. Introduction
The earliest electric propulsion ship used DC motor as the propulsion motor. The DC motor is bulky and difficult to manage during operation, which limits the development of electric power. In the 1990s, the advent of the pod-type propulsion method greatly promoted the development of electric propulsion. The successful development of new main propulsion systems and control systems by ABB, Siemens and other companies on icebreakers and luxury cruise ships marks an important step forward in power advancement. Ship electric propulsion system includes frequency converter, propulsion motor and propeller.

For traditional diesel-powered ships, ships with electric propulsion have smaller original prime movers, and have the advantages of low noise, small mass, high efficiency, and convenient speed regulation. The electric propulsion technology converts the mechanical energy of the prime mover into electric energy first, and then directly drives the propeller through electric energy. This propulsion mode reduces the transmission device such as the reducer, and can obviously improve the efficiency of the ship driving, especially under the low speed sailing of the ship. Work efficiency can be increased by about 25%. A new generation of electric motors represented by PWM inverter driven AC induction motors have been widely used in various types of planning boats and small ships. With the development of ships in the direction of intelligence, integration and digitalization, electric propulsion technology still has great application potential.

2. Ship AC Propulsion System Overview
Ship electric propulsion usually includes two categories: DC propulsion and AC propulsion. There are currently three mainstream electric propulsion systems in the world, namely the shafting propulsion system, the omnidirectional propulsion system and the pod propulsion system.
(1) In a shafted propulsion system, the propeller is usually driven by a variable speed motor, and the direct connection between the variable speed motor and the propeller shaft or the gear unit can be used to connect the motor to the propeller shaft.

(2) The omni-directional propulsion system is free to rotate and can generate thrust in any direction, and its thrust can be controlled by a fixed-speed adjustable pitch propeller or a variable-speed pitch propeller. The motors inside the omnidirectional propulsion system usually include two types: horizontal motor + Z gear transmission, vertical motor + L gear transmission. The omnidirectional propulsion system is usually unable to reverse rotation to generate thrust.

(3) The pod propulsion system is free to rotate and produces thrust in any direction. The propulsion system integrates the motor and propeller in a closed nacelle unit, and the propeller is mounted directly on the motor shaft. The transmission efficiency of the pod propulsion system is higher than that of the omnidirectional propulsion system, and its mechanical structure is relatively simple. The pod-type propulsion system can be either push-type or pull-type.

3. Analysis of the composition of electric propulsion system

3.1 Power Equipment
The power generation equipment in the electric propulsion system is mainly a generator set formed by a power generation mechanism, generally using diesel and heavy oil as fuel, and some using a gas engine, a gas turbine, a steam turbine, etc. as driving equipment. The diesel engines used in the diesel electric propulsion system are medium and high speed engines. Compared with the engines in the traditional mechanical propulsion system, the diesel engine is of lower quality and more economical, using AC or DC generators.

3.2 Power distribution equipment
The function of the power distribution equipment is to receive and distribute the ship's electric energy, control the generator and the power grid, adjust the generator in time, and conduct scientific measurements. When the total installed capacity of the generator is 20 MW, the 11 kV voltage system should be used, and the total installed capacity is (4-20) MW, using a 6.6 kV voltage system, and with a capacity below 4 MW, using a 690 V and below voltage system.

3.3 Motor frequency converter
The motor frequency converter is also a commonly used device in the electric propulsion system, and is mainly divided into a voltage source type inverter, a circulating frequency converter, a current source type frequency converter, and a direct current frequency converter. Among them, the voltage source type inverter is the most commonly used, and has the advantages of flexibility and good performance.

3.4 Propeller device
In the ship, the electric propulsion device is divided into one, the shaft propeller propulsion, and the omnidirectional propulsion; the second is the pod propulsion device. The shaft propeller propulsion system uses a variable speed motor as a driving source to connect the horizontal motor to the propeller shaft, and the system structure is simpler and more stable; the omnidirectional propulsion system is a freely movable device, and thrust in any direction can be generated; The pod propulsion equipment is also free to rotate, but the pod propulsion unit integrates the motor and propeller shaft into the enclosed compartment, immersed in water.

3.5 Control System
The control system is a core part of the electric propulsion system, and the control system includes a propulsion remote control system, a power management system, and a ship management system. The speed of the propeller is controlled mainly by controlling the speed, and the speed and torque are controlled within the range of science. The power management system mainly meets the power demand
of the ship's actual operation and realizes real-time monitoring of the generator set. The ship management system is mainly used to assist the ship's operation. It can realize manual control and semi-automatic control, including various valves, HVAC systems, load-bearing systems and cargo control. The control system also includes alarm system and safety system.

4. Advantages and disadvantages of marine power systems

4.1 Advantages of electric propulsion systems

4.1.1 Flexible configuration space
It is well known that diesel engines of almost all ships are installed in the lower part of the stern. It is necessary to use a transmission to connect the propellers. The electric propulsion system generator is closer to the propeller, and the transmission shaft is not used, which can save a lot of space. The equipment in the electric propulsion system can be reasonably configured according to the actual needs of the ship, and is not affected by the motor and the propeller. The electric propulsion system can be placed in the cabin, which is very flexible and can be set in different compartments if safety considerations are taken into account.

4.1.2 Energy saving and economy
The traditional diesel propulsion system is characterized by high mechanical efficiency, but high fuel consumption and high long-term operating costs. When the diesel engine is running at low or high load, the mechanical efficiency is gradually reduced and the fuel consumption is extremely high. The electric propulsion system has the advantages of energy saving and economy. It should be estimated according to the ship's demand for electric energy. A certain number of generators can be used to build the generator set. If the ship's electricity demand is reduced, a diesel engine can be used. If the power is required, then turn on multiple generators, each generator is in the ideal load working state. The cost is lower. The fuel consumption is small and the equipment maintenance cost is low.

4.1.3 The ship is highly maneuverable
Ship maneuvers generally use the adjustment of the machine speed to adjust the speed and manipulate the rudder angle to change direction. The speed of the ship in the electric propulsion system mainly depends on the drive control device to adjust and change. The drive controller can control the running speed of the motor. The nacelle unit can realize 360° rotation. The direction of the nacelle unit is consistent with the propeller propulsion direction. It is possible to rotate the nacelle by 180°. It is easier to change the speed of the propeller. This advantage is especially obvious when the ship is turning. It is easy to cancel the rudder angle and make the ship control easier.

4.1.4 Less noise and less vibration
When the ship uses an electric propulsion system, there is no rudder and drive shaft. The overall weight of the ship is reduced by more than 30% compared to the weight of a conventional diesel-powered ship, and the ship's capacity is reduced. This advantage is obvious for large passenger ships. And the electric propulsion system does not generate large noise and vibration when it is running, which is the key to gain recognition and affirmation of the electric propulsion system.

4.1.5 Ship safety
In the traditional diesel propulsion system, the steering gear and the transmission shaft are easy to malfunction, and in serious cases, the ship is suspended and there is a barge phenomenon. If it is in the marine environment, it is easy to cause a safety accident. With the electric propulsion system, multiple generators can be used, and even if individual units fail, it will not affect the navigation of the ship. In general, ships using electric propulsion systems have more than two sets of propulsion systems, so that remedial measures can be made in time for failures. Wind turbines can also be installed on ships, by
wind power generation and rechargeable batteries as backup power sources to improve the safety and economy of ship operations.

4.2 Insufficient power propulsion system
In addition to the above advantages, the electric propulsion system also has some shortcomings. For example, the ship construction cost increases, and the electric propulsion system requires a large amount of investment in construction and installation. The operating cost is still very low. Secondly, the energy conversion during the operation of the generator and the propeller is complicated, and the loss of the transmission equipment is large, which is an inevitable problem. When the power propulsion system is used, professional operators and technicians must be equipped to increase training costs and talent introduction costs.

5. The future development direction of marine electric propulsion system
At this stage, the electric propulsion system mainly consists of a DC motor, an AC motor or a synchronous motor. In the future, this technology will gradually mature, so it is necessary to continuously innovate and explore new motor devices. Permanent magnet motors and superconducting machines are the future research directions. Permanent magnet motors are made of permanent magnet materials that provide excitation without the use of field windings to increase the efficiency of the motor. In recent years, some developed countries have developed permanent magnet synchronous motors, which are small in size and high in quality, but run at a faster speed. The UK has begun to develop transverse flux machines, which are more suitable for use in ships. Compared with the traditional electric propulsion device, the superconducting machine is lighter in weight and higher in work efficiency. The use of ultra-early materials is more environmentally friendly. It is necessary to pay attention to the use of liquid nitrogen equipment during development, so it is difficult to popularize. The gradual development of low temperature technology in China has also provided convenient conditions for the research of superconducting force propulsion systems.

6. Conclusion and Outlook
At present, in the field of ship propulsion technology, attention to electric propulsion is increasing day by day. For the moment, AC electric propulsion, superconducting force propulsion, fuel cell propulsion and integrated full electric propulsion are the key technological development directions in this field. With the continuous development and improvement of related technologies, electric power propulsion will eventually occupy a place in the field of ship propulsion.

The research and innovation of marine electric propulsion system technology is not a one-step thing. This is a complicated system engineering. Although there are still many shortcomings in the application of electric propulsion system, with the efforts of professional research and technical personnel, the future propulsion technology meeting of ships Gradually improve, the power system with high efficiency, energy saving, environmental protection and economy will be developed, which will promote the rapid development of China's shipbuilding and navigation industry.

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