Marine diesel engine energy saving and emission reduction technology

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Abstract: Due to the changes in the global environment and people’s growing awareness of environmental protection, marine diesel engines have to be designed in different ways to save energy and thereby achieving energy saving and emission reduction. This paper will Based on the way of energy saving and emission reduction of diesel fuel, this paper thoroughly studies the energy saving and emission reduction technologies of marine diesel engines, proposes the specific application of energy saving and emission reduction technologies, and provides some theoretical foundations for future marine undertakings.

1. Introduction
Ocean transportation has a relatively wide coverage with respect to railway transportation, and its cost is also superior to air transportation. It is one of the most important modes of transportation in international logistics. With the continuous development of the shipping industry, more than 95% of the world's total trade volume is borne by the shipping industry, and its total energy consumption accounts for 3% of total energy. Marine diesel engine is the heart of ship work, and it is also the main place for energy consumption and pollutant generation. Based on this, determining the ways of energy saving and emission reduction of diesel engines and using corresponding technologies based on these routes is the main way to control the formation of pollutants.

2. Types of pollutants and causes
The exhaust gas generated by the marine diesel engine is mainly composed of the combustion products of the fuel and the remaining air. The main component of the composition that can cause pollution to the atmospheric environment and cause harm to human health is carbon monoxide, nitrogen oxides, hydrocarbons, sulfur oxides and particles. Insufficient fuel combustion in marine diesel engines is the main cause of carbon monoxide production. The sudden decrease in temperature in marine diesel engines, the lack of oxygen and the accumulation of reactants can cause fuel combustion to be insufficient. Excessive temperature in the diesel engine, excessive oxygen content, and excessive residence time of nitrogen and oxygen are the main causes of nitrogen oxides. The mechanism of hydrocarbon generation is very complicated, but the root cause is due to incomplete combustion of hydrocarbons. The formation of particles is closely related to the running state.

3. Ways to save energy and reduce emissions of diesel engines

3.1 Improve fuel injection system
The performance of the injection system has a direct impact on the combustion of the materials in the
diesel engine. Improving the operation of the injection system can improve the efficiency of the diesel engine operation, reduce the use of fuel, and control the emissions. At present, many ships use low-speed diesel engines. The injection system of this type of machinery is a plunger pump type injection system. Due to structural defects, it is difficult to meet the requirements of low emission of diesel engines. At the same time, some diesel engines have also added a variable timing structure, but the number of ships used is small, and the reliability of operation needs to be improved.

After the injection system has been improved, it needs to have the following properties: First, it has a higher injection pressure, and the pressure can be adjusted in time according to the operation of the ship; Second, accurately control the timing of injection and the amount of oil to achieve flexible control of the amount of oil; Third, the entire machine can be flexibly combined. Based on these three properties, a high pressure common rail injection system can be produced. The use of these injection systems allows for flexible adjustment of the amount of fuel injected and the pressure generated by the injection, in line with the economic development requirements of diesel engines.

3.1.1 Fuel injection system optimization technology. The nozzle aperture is reduced, the fuel injection pressure is increased, the fuel atomization effect is more ideal, the air and the gas are thoroughly mixed, the combustion efficiency is improved, and the carbon emission is finally reduced. From the development level of modern science and technology, the number of nozzles of modern EFI engines can be flexibly selected according to actual needs, and even the length of discharge time can be controlled to achieve better injection requirements. This minimizes fuel consumption constraints, maximizes economic efficiency, lowers operating costs, and ultimately minimizes carbon emissions; The way to reduce carbon dioxide is to control the final emissions of carbon dioxide through slow and rapid fuel injection rules.

3.1.2 Overall improvement in fuel quality. In terms of fuel combustion performance, cetane number must be well controlled. If nitrite, nitrate or other peroxides are added to the diesel, the cetane number will gradually increase and will burn ahead of time. On the one hand, if the heat of combustion increases only at an early stage, but other parameters do not change, the maximum temperature will increase; on the other hand, if the performance of the fuel is unstable, this will inevitably have a bad effect on combustion, and the use of additives will also cause secondary pollution. Therefore, in the specific operation process, the combustion performance, load and speed of the diesel engine must be considered as a whole to determine the high cetane number.

3.2 Improve the ventilation process

Whether the diesel engine's ventilation is perfect, directly affects the power of the internal combustion engine and the load generated by its operation. When the diesel engine is fully ventilated, fresh air enters the cylinder in large quantities, and the exhaust gas is squeezed out, consuming very little unit power.

3.2.1 Intake optimization. Intake and cylinder liner combustion must be related to each other in actual work and cannot be separated. Not only the inlet temperature, pressure, and composition of the incoming fuel need to be considered, but also the effect of the intake pressure on the combustion in the cylinder. The most appropriate combustion optimization method must be used to reduce nitrogen oxide emissions. It can be used as follows: control the air loss of the intake valve. In the process of intake air, the flow cross-sectional area may be insufficient, or there may be a large gas flow resistance, which increases the flow loss of the gas. Therefore, in order to control the gas loss, the gas flow cross-sectional area of the intake valve may be appropriately increased. In order to allow a large amount of gas to enter, at the same time, it is also necessary to reduce the flow resistance, adjust the gas distribution structure in the machine, ensure the function of normal use while increasing the gas flow rate; control the loss of flow resistance, when the exhaust system is discharged, it will use the flow resistance, and the smallest cross section is at the position of the exhaust valve. If the valve lift is
small, the gas will flow out from the door gap after entering the exhaust passage, and the resistance and kinetic energy will be partially lost. Otherwise, the pressure energy is generated. Therefore, the design of the exhaust gas is to reduce the change of the cross-sectional area of the air flow and increase the impulse of the air flow; to control the temperature rise of the intake air, because after the gas in the machine enters, the temperature of each part will rise, and controlling the temperature change is to reduce the contact area between fresh air and parts.

3.2.2 Temperature optimization and inlet pressure. We know from practice that increasing the excess coefficient of the internal combustion engine can make the combustion more complete. According to the proportional relationship between the excess coefficient and the inlet pressure, if the inlet pressure increases, the excess coefficient will increase accordingly, which is called completely burning. Paradoxically, pressure and energy consumption are also proportional. If the pressure is high, the compression consumption will also increase, causing the maximum temperature to rise. At this time, it is difficult to reduce the emission of nitrogen oxides. However, if the intake air temperature is low, this time can absorb a certain amount of compression heat, which can also effectively control the maximum temperature and reduce NO\textsubscript{2} emissions. However, the inlet temperature is unlikely to decrease all the time, with a baseline value. From the current level of development, many research institutions are further studying how to adjust the intake air temperature and pressure to improve combustion.

3.2.3 Optimization of intake mode. The ventilation time of the diesel engine is generally short, and the ventilation effect cannot meet the actual working requirements. If the intake vortex is large at this time, the combustion flame communication effect will be well improved. Based on this principle, multi-valve technology emerges. This technology reasonably increases the ventilation area. The circumferential distribution of the valve and piston pit around the center of the cylinder nozzle effectively controls the maximum temperature on the one hand and meets the economic requirements on the other hand.

3.2.4 Optimization of intake air composition. The oxygen concentration of the intake air of the internal combustion engine is directly related to the combustion conditions. The ratio of N\textsubscript{2} and O\textsubscript{2} has a great correlation with the concentration of NO\textsubscript{2}. From the current level, it is mainly driven by the oxygen-enriched, humidified, EGR technology indirectly control the conditions of gas combustion. Nitrogen-free combustion maximizes the release of NO\textsubscript{2}.

3.3 Waste heat utilization

After the diesel engine gas is removed, the temperature can reach 400 degrees Celsius with medium waste heat temperature, and the exhaust gas is 20 times that of the fuel, so a large amount of energy can be found from the exhaust gas.

3.3.1 Using the Rankine Cycle for Waste Heat Utilization. The Rankine cycle is a cyclical way of converting thermal energy into mechanical energy. The ideal Rankine cycle includes isentropic compression, isobaric heating, isentropic expansion, and an isobaric condensation process. The working fluid is compressed and boosted in the circulation pump, then enters the evaporator and is heated and vaporized, enters the expander to expand work, and uses the combined turbine exhaust heat recovery system to output electric energy, and the low-pressure steam after work is condensed into liquid in the condenser and re-enter the circulation pump and complete a cycle.

3.3.2 Using waste heat for seawater desalination. When the ship is sailing on the sea, the crew needs a lot of fresh water, especially when sailing in the ocean. The large amount of freshwater navigation not only reduces the space of the ship, but also increases the load and increases the cost of navigation. If it can be taken locally, the seawater desalination device can be driven by the ship's exhaust gas to
achieve the goal of energy saving and emission reduction. The waste heat is the process of producing high-quality waste heat from the diesel engine as a heat source for distillation, heating and evaporating seawater, and generating steam by condensation to produce fresh water. Multi-effect evaporation (MED) technology is adopted. Multi-effect distillation is to connect a plurality of evaporators in series, and the seawater enters the first-effect evaporator and is indirectly heated by the hot steam to generate secondary steam. The generated steam enters the second effect evaporator as the heating steam, and the concentrated sea water also sequentially enters the next effect evaporator to continue heating and evaporation. The number of evaporators connected in series is called the number of stages, and the final effect evaporator is connected to the decompression device, so that the boiling point of the concentrated seawater is reduced, thereby ensuring the smooth progress of the entire process. At present, distillation is the most mainstream seawater desalination technology.

3.3.3 Other waste heat utilization. According to the difference of remaining heat temperature, it can be divided into the following two categories: First, the heat of the lower temperature is recovered by the heat exchange device, such as heat exchanger and heat pipe boiler, and the recovered waste heat can provide air conditioning heating on the ship. Fresh water is heated and insulated for the needs of life on board. Second, the high-temperature remaining heat is recovered by the fuel hot water heating device (waste heat boiler). The main engine of the ship has a large residual heat due to its exhaust gas. In order to reasonably recover a large amount of waste heat, the fuel hot water heating device is used to heat the water in the boiler and is heated to generate a large amount. Saturated steam and superheated steam are used to provide steam and heating for the crew's life and for the vessel's equipment.

3.4 Using a booster system and a supercharger

In order to improve the efficiency of diesel engine operation, reduce harmful gas emissions, and meet the new requirements of international maritime diesel engine gas emissions, turbocharged technology can be used to improve the system to improve the performance of diesel engines. It consists of two points: First, the development of two-stage turbo technology. At present, many ships' diesel engines use a first-stage turbocharging technology. The pressure generated by this technology is small, which limits the volume of the intake air and causes the fuel to not burn completely. In this way, not only is the use of fuel increased, but also the exhaust gas of the fuel machine is increased. Therefore, it is necessary to find the best way of supercharging based on the prior art. That is, the booster system uses two turbochargers and connects them in series. In the specific work, the exhaust gas will be collected first, the energy will be integrated from the exhaust gas, the booster with smaller capacity will be driven first by energy, and then the supercharger will be driven by the booster with less energy. The surrounding air is compressed, transferred to the cooler, and finally transferred to the compressor, before which the air has been compressed once. After the air is compressed twice, the volume of air entering the cylinder can be increased to fully burn the fuel and reduce the emission of harmful gases. It is also possible to develop a VAT supercharging technology. When the diesel engine is increased, the emission can be reduced, the power of the mechanical operation can be provided, the torque is increased, and the output of the torque is significantly increased. However, since the diesel engine must use the turbine as an auxiliary, affecting the rotational speed, if the diesel load is low, the operation of the turbocharger will be affected, resulting in insufficient gas for combustion. Therefore, the development of VAT technology is to allow the diesel engine to ensure the accuracy of the air intake according to the operating speed under the condition of any load, improve the combustion efficiency of the fuel, and control the emission of harmful gases.

4. Conclusion

All in all, the energy-saving and emission-reduction technology of modern marine diesel engines is a clear way to save energy and reduce emissions, optimize the operation effect of marine diesel engines, control the use of energy and fuel, improve combustion efficiency, ensure the combustion quality of
fuel, and recover heat energy. In order to further promote the development of the shipping industry, we should further study the energy saving and emission reduction technologies of marine diesel engines. Combining practical experience and advanced science and technology, we should propose more scientific and rational methods for energy saving and emission reduction of marine diesel engines, improve the power of marine diesel engines and reduce the waste discharge of marine dies.

References
[1] Wang Qi, Q. (2017) Discussion on Energy Saving and Emission Reduction Technology of Marine Diesel Engine. Environmental science, 11: 142.
[2] Tan Qinming, Q., Hu Yihuai, Y., Zhang Xusheng, X. (2015) Research on Energy Saving and Emission Reduction Technology of Modern Marine Diesel Engine. Environmental science, 33(7): 76-80.
[3] Liu Haiming, H., Zhang Benwei, B., Zhang Lei, L. (2015) Discussion on the development of energy saving and emission reduction technology for marine diesel engines. Technology and enterprise, (19): 117.
[4] Yang Sen, S., Yang Jie, J., Miao Chunhui, C. (2014) Summary of ship energy saving and environmental protection technology. Ship science and technology, (04): 1-4.
[5] Li, B. (2014) Marine diesel engine. Dalian Maritime University Press, Dalian, China.