

Retraction

Retracted: Modeling and Optimization of Ship Waste Heat Utilization System Based on Genetic Algorithm and Sensing

International Transactions on Electrical Energy Systems

Received 3 October 2023; Accepted 3 October 2023; Published 4 October 2023

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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- [1] L. Lyu, "Modeling and Optimization of Ship Waste Heat Utilization System Based on Genetic Algorithm and Sensing," *International Transactions on Electrical Energy Systems*, vol. 2022, Article ID 9917212, 8 pages, 2022.

Research Article

Modeling and Optimization of Ship Waste Heat Utilization System Based on Genetic Algorithm and Sensing

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Received 12 July 2022; Revised 30 July 2022; Accepted 8 August 2022; Published 29 August 2022

Academic Editor: Nagamalai Vasimalai

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In order to solve the optimization problem of ship waste heat utilization system, the modeling and optimization method of ship waste heat utilization system based on genetic algorithm and sensing is proposed. The 6S50ME-C8.2 volume method model was established based on Matlab/Simulink simulation platform. According to the test data of the 6S50ME-C8.2 diesel engine, the simulation value is very close to the test value, which verifies the accuracy of the simulation model. The experimental results show that the thermal efficiency of high-power medium and low-speed two-stroke diesel engines is high, the exhaust temperature of the main engine is generally maintained at about 230°C, and the energy content of exhaust gas is relatively low. If no other measures are taken, the waste gas is directly channeled into the waste heat boiler, which cannot effectively recover the heat in the waste gas. *Conclusion.* The model can well simulate the actual working condition of the diesel engine, and the exhaust temperature has reached 298°C. The energy quality of waste gas at the inlet of the waste heat boiler is improved to meet the requirements of the waste heat recovery system.

1. Introduction

Up to now, the progress of science and technology and the development of the economy cannot be separated from the promotion of energy. Energy is a necessary condition for the survival of human society. Take China as an example. BP World Energy Statistical Yearbook statistics show that by 2015, China's energy consumption has accounted for 23% of the global total, and the net growth of energy consumption has accounted for 34% of the global total growth, surpassing other developed countries and becoming the largest energy consumption country in the world. By 2035, China's energy consumption is expected to reach or exceed 25 percent of the world's total. Worldwide, the use of fossil fuels has caused serious environmental pollution. Therefore, optimizing energy structure, improving energy efficiency, and reducing pollution emissions have become an important research topic in China and even the world.

2. Literature Review

Wang et al. said that energy is the material basis for human survival and development. Energy is closely related to our work, production and life, and our future living environment, which promotes the rotation of machines. The combination of machine and man has formed advanced productive forces, which have promoted the continuous development of human society [1]. Tang et al. said that throughout the development history of human civilization, every major change of human civilization was accompanied by the improvement and replacement of energy [2]. Koshevyi et al. said that with the rapid development of the social economy, human's demand for energy is also increasing, especially for the exploitation and utilization of oil resources, which is far beyond the tolerable range of nature, and oil resources are on the verge of exhaustion [3]. Kauko et al. said that since the energy supply failed to catch up with the increase of demand, two world oil crises broke out

successively in the 1970s. The rise of oil prices led to global economic recession and social unrest [4]. Martinez Cesena et al. said that in the middle of this century, with the exhaustion of fossil fuel resources, the surge of energy demand for economic development and the change of energy consumption structure will inevitably lead to a global energy crisis again and ultimately destroy the whole modern market economy [5]. Kamminana et al. said that the energy crisis, a worldwide problem, is attracting more and more attention and strong concern from governments of all countries [6]. In the era of economic globalization, the trade between countries is frequent. Huang et al. said that due to the huge advantages of sea transportation, the transportation volume of sea transportation has accounted for 90% of the total amount of international trade, and all countries rely on sea transportation for trade, resulting in a sharp increase in the holding and tonnage of large ships [7]. Yong et al. said that with the rise of international oil prices, the uncontrolled development of ships in the golden age of shipping, and the significant impact of the economic crisis, excess shipping capacity was caused, and shipping enterprises had to strive to reduce shipping costs and improve the economy of ships [8]. Singh et al. stated that when a ship is running normally at sea, the ship's main engine, as the ship's main propulsion device, needs to operate continuously for 24 hours, consuming 70%–90% of the ship's total fuel [9]. Nandan et al. said that in order to meet the normal operation of the ship and the daily life of the crew, the ship is also equipped with various auxiliary equipment to provide the electricity and heat needed by the ship, consuming 10–30% of the ship's fuel [10]. When the ship's main engine is running, the fuel is burned in the combustor and the chemical energy is mainly converted into mechanical energy and heat energy. About half of the energy is used in the propulsion device, and part of the remaining half of the energy is recycled for the preheating of the fuel tank. A large portion of the energy enters the atmosphere through diesel exhaust, while the rest is released to the environment in a variety of ways. Taking MAN 12K98ME/MC low-speed two-stroke diesel engine as an example, the main engine consumes fuel to drive the ship sailing at the specific fuel consumption rate of 171 g/kWh. The modeling diagram of the ship waste heat utilization system is shown in Figure 1.

3. Methods

At present, considering the complexity of ship owners and shipyards to the scheme of ship waste heat recovery and utilization system and the actual power consumption of ships in operation, the following three different types of ship waste heat recovery schemes are provided: this is the simplest and most economical scheme of ship waste heat recovery. The power turbine is driven by exhaust gas that bypasses the turbocharger and runs a generator through a gearbox to generate electricity. Power supply and parallel operation power supply are provided for the ship. The specific power generation depends on the bypass exhaust flow, and the waste heat recovery rate of 3–5% can be achieved [11]. Steam is used for power generation by

installing steam turbine generators [12]. With a steam turbine generator (STG) system, it is possible to recover 5–8% of the energy, depending on the host model, output power, and ambient conditions. For ships with high-power requirements, such as container ships, this combined system is an option. The power turbine and steam turbine are built on the same chassis and connected to the generator through a reduction gearbox. The system can meet the total power demand of the ship in a variety of circumstances, significantly reduce the fuel cost of the ship, and recover about 8–11% of the energy [13, 14]. When evaluating whether a waste heat utilization system should be installed in a new ship project, the payback period of system installation is always involved. To calculate the payback period of the project, a key factor that must be considered is the expected operating characteristics of the new vessel. The operating characteristics of ships vary according to ship types. Bulk carriers and tankers typically operate at sea at a set speed, while large container ships, which consume more fuel a day, have a more diversified operation model. When calculating the return on investment period of the waste heat recovery scheme according to the operation characteristics of the ship, the main engine load and its running time should be taken into account. The following takes a large container ship of 14000TEU as an example. According to its operating characteristics and WHRS output power, the investment return period of different waste heat recovery schemes of ships is calculated. The operating characteristics and WHRS output power of this container ship are shown in Figure 2.

The investment return cycle of different waste heat recovery schemes is shown in Table 1.

As can be seen from Table 1, the combined WHRS waste heat recovery scheme has a return on investment period of 4.3 years, but the ship owner may be more interested in his ship's 20 years of operation. Using the combined WHRS waste heat recovery solution can save \$36 million in fuel costs over the same ship life. The exhaust temperature of the 6S50ME-C8.2 waste heat main engine studied in this essay is about 298°C. On this basis, about a 5°C pipe temperature drop is subtracted, that is, the inlet flue gas temperature of the waste heat boiler is 293°C. According to the data, the main steam temperature of the waste heat boiler mainly depends on the exhaust temperature of the waste heat host, and the temperature difference between the hot end refers to the temperature difference between the exhaust temperature of the host and the main steam temperature. Lowering the temperature difference of the hot end can get higher superheat, so as to improve the quality of superheated steam. However, decreasing the temperature difference at the hot end will also reduce the logarithmic average temperature difference of the superheater, increase the heat transfer area of the superheater, and increase the metal consumption. The temperature difference at the hot end of the existing waste heat boiler is generally between 20°C and 40°C. By selecting several temperatures to calculate, the preferred main steam temperature is 270°C. Increasing the main steam pressure of waste heat boiler can improve the power capacity and increase the power generation. But by the boiler equipment cost and steam pressure itself and other factors, the main

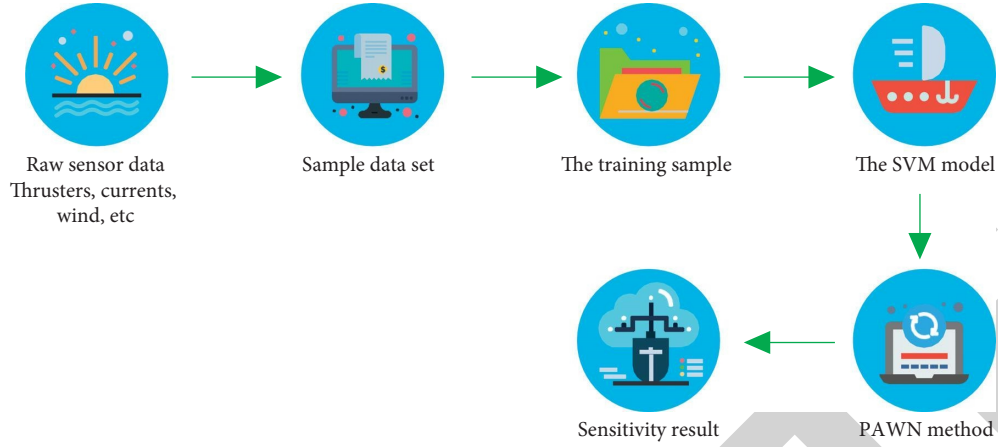


FIGURE 1: Modeling diagram of ship waste heat utilization system.

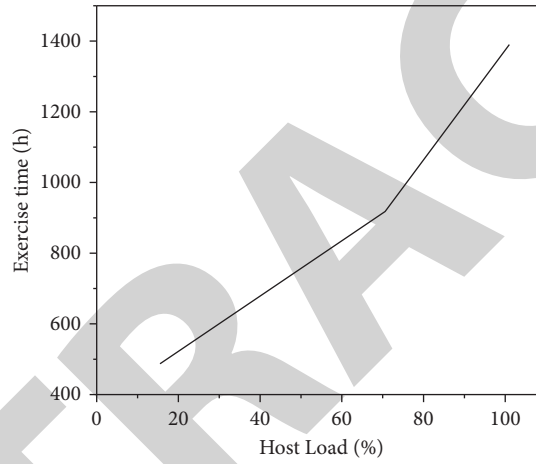


FIGURE 2: Operation characteristics and WHRS output power of large container ships.

TABLE 1: Calculation table of investment return period of waste heat scheme of large container ships.

	Modular generating unit	Steam turbine generating unit	Power turbine generating unit
Total fuel cost savings per year (\$)	2,617,674	1,577,689	937,069
Additional fuel required per year (\$)	284,954	284,954	284,954
Total investment cost of waste heat scheme (\$)	10,000,000	7,500,000	2,300,000
Actual payback period/year	4.3	5.8	3.5

steam pressure cannot be increased indefinitely, so there is an extreme value of the main steam pressure. Based on the discriminant method of stable flow entropy equation, this essay determines the extreme value of the main steam pressure of the waste heat boiler [15, 16]. It is assumed that the heat exchange process of the waste heat boiler is a stable flow process, without considering the heat absorption of the furnace body itself, and the heat released by the waste gas of the main engine flowing through the waste heat boiler is all used for heating water supply. Therefore, exhaust gas, water supply, and steam constitute an open heat system. Let the mass flow through waste heat boiler exhaust gas be m_s , and the specific heat capacity be c_p . The temperature drops from

T_{s1} to T_{s2} , the steam flow rate of superheated steam is T_{s2} , the temperature is T_1 , the ambient temperature and the feedwater temperature are T_0 , and the corresponding feedwater enthalpy is h_0 and entropy is s_0 according to the table of thermodynamic properties of water and steam. The enthalpy of superheated steam is h_1 , the entropy is s_1 , and the heat loss coefficient of the boiler is η . The steady flow entropy equation of the thermodynamic system is shown in the following formula:

$$\sum (ms)_{\text{out}} - \sum (ms)_{\text{enter}} - \frac{Q}{T_0} \geq 0. \quad (1)$$

Entropy change of flue gas in waste heat boiler is shown in the following formula:

$$\Delta S_s = \int_1^2 \frac{\delta Q}{T} = m_s c_p \ln \frac{T_{s2}}{T_{s1}}. \quad (2)$$

The entropy change from feed water to superheated steam is shown in the following formula:

$$\Delta S_v = m_v (s_1 - s_0). \quad (3)$$

Entropy change caused by heat dissipation from the thermal system to the external environment is shown in the following formula:

$$\Delta S_e = \frac{Q}{T_0} = \frac{\eta m_s c_p (T_{s1} - T_{s2})}{T_0}. \quad (4)$$

According to the energy balance, the amount of steam is shown in the following formula:

$$m_v = \frac{(1 - \eta) m_s c_p (T_{s1} - T_{s2})}{h_1 - h_0}. \quad (5)$$

The results of the above types are shown in the following formula:

$$\frac{(s_1 - s_0)}{h_1 - h_0} \geq \frac{\ln(T_{s2}/T_{s1})}{(1 - \eta)(T_{s1} - T_{s2})} + \frac{\eta}{T_0(1 - \eta)}. \quad (6)$$

According to formula (6), when the equal sign is established, it is a reversible process, corresponding to the limit steam parameter of the actual heat exchange process of the waste heat boiler. The heat loss coefficient on the right side of the inequality is determined by experience, and the inlet and outlet temperature of boiler flue gas has been determined, so the right side of the inequality can be considered as a constant value. So when you choose the vapor pressure on the enthalpy entropy diagram, you can choose a point on the isotherm as long as you make sure that this formula is satisfied. When both sides of formula (6) are equal, the corresponding steam pressure is the theoretically desirable limit pressure. Referring to the structure size of the waste heat boiler that has been determined, according to the basic principle of heat transfer, the heat transfer coefficient of the waste heat boiler is calculated to determine its design value. Flue gas heat release is shown in the following formula:

$$Q = C_p G_z (T_{in} - T_{out}), \quad (7)$$

where C_p is the specific heat of flue gas at constant pressure, J/(kg·K); G_z is the diesel engine exhaust mass flow, kg/s; T_{in} is the inlet flue gas temperature, K; and T_{out} is the outlet flue gas temperature, K.

The countercurrent temperature difference is shown in the following formula:

$$\Delta t = (\Delta t_j - \Delta t_x) \ln \frac{\Delta t_d}{\Delta t_x}, \quad (8)$$

where Δt_d is the temperature difference between flue gas and steam inlet, K and Δt_x is the temperature difference between the flue gas and steam inlet, K.

The flow rate of flue gas is shown in the following formula:

$$w = \frac{G_z (t + 273)}{3600 F^* 273 \gamma_y}, \quad (9)$$

where t is the flue gas temperature, K; F is the flue gas circulation area, m²; and γ_y is the flue gas severity, kgNm³.

The convection heat transfer coefficient of flue gas is shown in the following formula:

$$\alpha_d = 0.15 C_z C_s \frac{\lambda^*}{s} \left(\frac{d}{s}\right)^{-0.54} * \left(\frac{h}{s}\right)^{-0.14} * \left(\frac{ws}{v}\right)^{0.65}, \quad (10)$$

where λ is the thermal conductivity of average temperature of airflow, kW/(m²·C); C_z and C_s are tube row correction coefficient; S is the equivalent radiation thickness, m; d is the tube diameter, m; h is the fin height, m; and v is the Actual kinematic viscosity of flue gas, m²/s.

4. Experiment and Analysis

The simulation modeling of the marine diesel engine involves a wide range of fields and is very complicated, so modular modeling is adopted, that is, a complex diesel engine model is divided into many sub-modules. Models are established for all sub-modules, and each sub-module is finally encapsulated [17]. In general, the whole model can be divided into the in-cylinder working process model and a dynamic model when the volume method is used to model the diesel engine. Comparatively speaking, the modeling of dynamics is relatively simple, and the modeling of diesel engine in-cylinder working process is extremely complex, including multiple working processes, which need to be further refined [18]. At the same time, in order to ensure the dynamic operation of the model, the electronic control unit module and load module are further added. Generally speaking, the model is composed of three parts, namely the diesel module, load module, and ECU module. ECU module is the electronic control unit. The load module is used to calculate the propeller by adjusting the circulating fuel injection amount and timing of a single cylinder. These two modules are relatively simple [19, 20]. The diesel module describes the whole working process of diesel engine, its model is extremely complex, and is the core of the whole model. The module contains multiple layers of modules nested layer by layer. The diesel module can be divided into the MCylinder module, the intake module, exhaust module, InterCooler module, turbocharger module, and kinetics module. In addition, the exhaust gas bypass module and power turbine module are added after exhaust module in the exhaust heat main engine of the ship waste heat utilization system. MCylinder module describes the calculation process of 6 cylinders of diesel engine. In fact, it is based on the calculation data of one cylinder and multi-cylinder superposition calculation, that is,

the output of the diesel engine single cylinder model is calculated, and then superposition calculation is carried out according to the ignition sequence of the diesel engine and the crankshaft Angle is delayed successively, and finally the simulation data of the whole diesel engine is obtained. The SYN module and Syntotime module are used to realize the superposition of six cylinders [21]. This method cannot investigate the influence of the performance change of one or several cylinders on the performance of the whole diesel engine. Because the main content of this essay is the simulation calculation of exhaust temperature and performance of the waste heat utilization system of a low-speed two-stroke diesel engine, it is not necessary to consider the influence of the performance change of a cylinder on the performance of the whole diesel engine. Therefore, this method can greatly reduce the workload of calculation and speed up the calculation. In the simulation of the diesel engine, the crankshaft angle is the independent variable of the calculation inside the cylinder, and the time is the independent variable of the calculation outside the cylinder. Therefore, these parameters with crankshaft rotation angle as independent variable need to be converted from angle domain to time domain, and then delay stacking, such as mass flow, heat flow, and these variables are stacked with Syntotime module. Some state variables, such as the pressure and temperature in the cylinder, do not need to be converted and can be directly delayed by the SYN module. In this essay, the heat release law of diesel engine combustion in a cylinder is simulated using a double web curve. In the process of simulation, the parameters of diesel engine such as speed, structure size, fuel injection timing, working medium state in the cylinder at the compression end point, and excess air coefficient have a certain influence on the shape of fuel combustion heat release rate curve, and the calculation is complicated [22]. When the diesel engine is running according to the propulsion characteristics, the diffusion combustion cycle is short. In the case of the variable load operation, there is little change, and generally the value of rated operating condition is calculated. When diesel engine is running under stable conditions, θ is determined by fuel injection timing, which directly affects the law of combustion heat release. The premixed combustion lead Angle τ and the number of diffused combustion fuel Q can be determined from the measured indicator plots, and the parameter values under variable conditions can be calculated by linear interpolation as shown in Table 2.

For the simulation model of a marine large low-speed two-stroke diesel engine, the volume method is usually used to build the model, as shown in Figure 3.

In the ship waste heat recovery system, there are many kinds of waste heat recovery devices with different utilization effects. Comparatively speaking, the utilization of Marine diesel engine exhaust gas energy is very necessary and the effect is good. There are two ways to recover the exhaust gas energy of the main engine. One is to use the exhaust gas of the main engine to directly drive the power turbine to do work. The other is to recover the heat energy in the exhaust through the waste heat boiler to generate steam to drive the steam auxiliary, drive the turbine generator set to generate electricity, and integrate it into the ship power station. At

present, most of the schemes about ship waste heat recovery systems are based on the integration and improvement of these two schemes. The heat efficiency of high-power medium and low-speed two-stroke diesel engines is high. The exhaust temperature of the main engine is generally maintained at about 230°C. The energy contained in the exhaust gas is relatively low. In order to improve the energy utilization rate of the waste heat boiler, it is necessary to adopt appropriate methods to raise the exhaust temperature of the main engine to above 290°C and increase the heat of waste gas at the inlet of the waste heat boiler. Taking 6S50ME-C8.2 diesel engine as the target engine, the method of exhaust gas bypass was adopted to improve the exhaust temperature based on the simulation model of the standard main engine above. However, compared with the standard host, the exhaust gas bypass method reduces the turbine flow capacity, and the flow through the compressor decreases. Because the turbine efficiency remains unchanged, the compressor efficiency also remains unchanged according to the power balance, and the boosting pressure increases and scavenging pressure gradually increases. As the turbine flow capacity decreases, the amount of air entering the cylinder decreases, the fuel combustion is insufficient, and the exhaust temperature after the cylinder is high, which leads to the rise of the exhaust temperature after the turbine. Therefore, the exhaust gas bypass method can raise the exhaust temperature of the main engine to about 290°C, thus improving the energy quality of waste heat boiler exhaust gas and meeting the limit of acid dew point temperature parameters of waste heat boiler. However, as the intake flow of the diesel engine is reduced, the excess air coefficient in the cylinder of the diesel engine becomes smaller, which leads to an increase in fuel consumption rate, the increase in the maximum burst pressure, the increase in heat load, etc., and reduces the working performance of the diesel engine [23]. Therefore, it is necessary to take new measures to ensure the power and economy of diesel engines. Taking all things into consideration, the 6S50ME-C8.2 diesel engine should rematch turbocharger and reduce fuel consumption rate and maximum combustion pressure by adjusting fuel injection timing and exhaust timing. However, with the increase of injection advance Angle, the pressure and temperature in the cylinder will increase, which is conducive to the generation of NO_x. NO_x is the main emission of Marine diesel engines. According to the decision of the 58th MEPC (Committee for Marine Environmental Protection) meeting, engines built and shipped after 2011 must meet the IMO-Tier II emission standard, that is, the engine NO_x emission is reduced to 14.4 g/kWh. In order to meet the emission requirements, it is not expected that the injection advance Angle is too large, so the injection advance Angle directly affects the economic performance and emission performance of diesel engine. In the selection of injection advance Angle, these two factors should be considered comprehensively. In addition, the injection advance Angle has a great influence on the maximum explosion pressure in the cylinder of diesel engine, which should be taken into consideration [24, 25]. This is because when the diesel engine runs at high working conditions, the maximum explosion pressure will increase with

TABLE 2: Parameters of combustion heat release law.

Rotational speed (r/min)	Load (%)	Fuel injection timing θ_z ($^{\circ}CA$)	Premixed combustion lead angle r ($^{\circ}CA$)	Diffused combustion fuel fraction Q_f
128	100	-1.5	25	0.16
120.4	84	-2.6	17	0.17
116.4	76	-4.3	19	0.22
100.8	50	-3.4	15	0.18

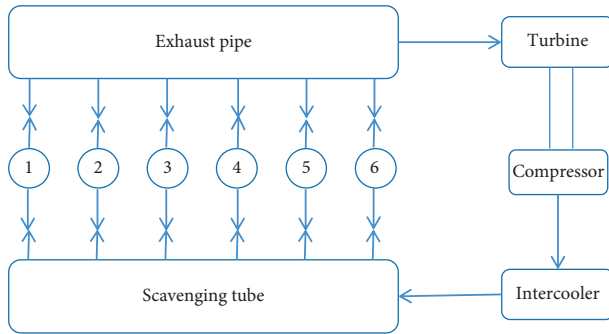


FIGURE 3: Schematic diagram of volumetric method model of large marine low-speed two-stroke diesel engine.

the increase of injection advance Angle, resulting in a great increase in the pressure and temperature in the cylinder. This will not only increase the mechanical and thermal load of the cylinder to bear, but also the increase of the pressure rise rate will lead to more rough combustion, and the diesel engine combustion noise will also increase. This will put forward higher requirements for material strength and noise control of diesel engine. In low working conditions, even if the injection advance Angle is increased, the combustion temperature in the cylinder does not change much, and the exhaust pressure is basically unchanged. Because the temperature and pressure in front of the turbine remain roughly constant, the efficiency of the turbine does not change much. The turbine power capacity is basically in a low state, and the exhaust temperature behind the turbine does not increase. To sum up, in order to meet the requirements of WHR engine fuel consumption rate, cylinder implosion pressure, and TierII emission standard, an appropriate injection advance Angle must be selected. The 6S50ME-C8.2 diesel engine adopts a variable fuel injection timing mechanism and is selected under different working conditions. Different injection advance Angle is used to meet the requirements of the economy, power performance, and TierII emission standard of diesel engine. Through simulation calculation, the injection advance Angle selected in each working condition is shown in Table 3:

In the working process of diesel engine, the opening time of the exhaust valve directly affects the scavenging process of diesel engine, and the scavenging ability determines the combustion performance of diesel engine. Therefore, exhaust timing has a great influence on diesel engine performance. In order to increase the maximum combustion pressure and improve the economy of diesel engine, the exhaust valve is opened in advance at the rated working conditions. This prolongs the diesel engine-free exhaust

TABLE 3: Injection advance angle of WHR main engine.

Working condition	100%	95%	85%	75%	65%	50%
Injection advance angle ($^{\circ}CA$)	-1.5	-1.8	-2.3	-3.4	-4.5	-4

process, reduces the scavenging resistance, and increases the charging efficiency, fuel, and air mix fully, and combustion is good. However, the increase of temperature and pressure in the cylinder is beneficial to NOx generation, which affects the emission performance of diesel engine. In order to reduce NOx emissions and meet Tier II emission indicators, the opening time of the exhaust valve is delayed. This increases the pressure in the cylinder when the scavenging port is open, which is not conducive to fresh air entering the cylinder. After the scavenging process, the residual exhaust gas in the cylinder of the diesel engine increases. Because of its inertia, this part of the residual exhaust gas delays the combustion process and slows down the pressure formation process in the cylinder. The combustion temperature in the cylinder decreases, the combustion quality decreases, and the fuel consumption rate increases. As the exhaust temperature of the cylinder decreases, the temperature of the rear turbine decreases [26]. With the development of social science and technology, equipment manufacturing technology has been improved. At present, the efficiency of the designed turbocharger has reached a very high level, and the power capacity of the turbine has been significantly enhanced. Because the exhaust volume of a large low-speed Marine two-stroke diesel engine is very large in high working conditions, even if part of the exhaust gas is bypassed, it can meet the work needs of the turbocharger. Therefore, the turbocharger used by the marine two-stroke diesel engine will have a bypass valve at the turbine end. When the main engine runs in high working conditions, exhaust gas bypass is adopted to drive the power turbine to do work; When running under low working conditions, due to the small exhaust volume of the main engine, in order to ensure the intake gas of the diesel engine under low working conditions, the bypass valve is closed, and the exhaust gas is all passed into the turbine to meet the working performance of the supercharger under low working conditions. When the main engine runs in high working conditions, the exhaust gas bypass is adopted to reduce the exhaust volume flowing through the turbine and the power emitted by the turbine. According to the flow and power balance between the compressor and the turbine, the power capacity of the compressor decreases. The amount of air entering the cylinder decreases, resulting in a lower excess air coefficient in the cylinder and a higher diesel exhaust temperature. The

exhaust gas temperature after the turbine will also rise, which is conducive to the recovery of exhaust heat from the waste heat boiler and the increase of steam. However, if the side flux is too large, the pressure ratio of the compressor is reduced, and the joint operation point of the turbocharger moves to the surge line, which is likely to cause the compressor surge. The simulation model of the 6S50ME-C8.2 low-speed two-stroke diesel engine is established by Matlab/Simulink. By setting the parameters of injection timing, exhaust timing, and combustion starting point, the volumetric model of the diesel engine can not only calculate the characteristic parameters of diesel engine under steady-state conditions, but also simulate the variation of performance parameters in the dynamic process when the diesel engine load speed changes. Under the rated working condition, the calculated cylinder pressure curve is in good agreement with the test value and reflects the real situation of the pressure change in the cylinder [27, 28]. According to the established simulation model of the whole machine, according to the propulsion characteristics of the simulation calculation, and compared with the test value. The results show that the propulsive characteristics of the diesel engine are basically consistent with the experimental values, which indicates that the simulation model of the 6S50ME diesel engine is accurate and reliable, and can well simulate the steady-state characteristics of the diesel engine. In the step response of the model, the dynamic change process of the model accords with the actual situation of diesel engine and can reflect the instantaneous change of parameters such as turbine exhaust temperature and instantaneous speed. The diesel engine simulation model has good dynamic simulation ability. In order to improve the thermal efficiency of the WHR waste heat utilization system and improve the energy utilization rate of the waste heat boiler, a simulation model of the WHR main engine was established by matching tCA-55 turbocharger and adding a waste gas bypass module on the basis of standard main engine model, and to reduce fuel consumption rate and maximum combustion pressure of WHR engine by adjusting fuel injection timing and exhaust timing. When the steady-state and dynamic performance of the WHR engine are simulated, the simulation results show that the model is accurate and reliable except that the fuel consumption rate increases slightly. The exhaust temperature of the WHR main engine has reached 298°C, and the energy quality of waste gas entering the waste heat boiler has been improved to meet the requirements of the waste heat recovery system.

5. Conclusion

Based on the detailed analysis of the working process in the cylinder of the diesel engine, the 6S50ME-C8.2 volume method model was established based on Matlab/Simulink simulation platform, and the propulsion characteristics of the model were verified and calculated according to the test data of 6S50ME-C8.2 diesel engine. The simulation value was very close to the test value. Thus, the accuracy of the simulation model is verified. In order to improve the thermal efficiency of the marine waste heat utilization system, the

simulation model of the standard main engine was improved and the exhaust gas bypass module was added under the condition of ensuring the dynamic performance of the Marine diesel engine. The main engine model of the ship waste heat utilization system was established by adjusting the timing of fuel injection, exhaust timing, and exhaust gas flux, and the steady-state operation and transient working conditions were simulated. The results show that the model can well simulate the actual operation of the diesel engine, the exhaust temperature has reached 298°C, and the energy quality of waste gas at the inlet of the waste heat boiler has been improved, which meets the requirements of waste heat recovery system.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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