Analysis on Waste Heat Recovery Technology of Marine Diesel Engine

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Abstract: Since the oil crisis in 1973, the world's oil prices are rising, the operating costs of ships are rising year by year. In 2013, energy efficiency design index (Energy Efficiency Design Index, EEDI) formally entered into force, a hard indicator is set for the emission of the ship's CO2, a new round of technical competition has been brought to the construction of ships, and the application of waste heat utilization technology is very effective for improving the efficiency of diesel engine. Experts and scholars at home and abroad have conducted in-depth studies on the utilization of ship waste heat, which is fruitful. In this paper, the current utilization technology of residual heat of ships is combed and analyzed.

1. Introduction

As the energy crisis intensifies, As a non-renewable energy source, oil and other prices are rising, As a large fuel consumption ship, fuel costs are increasing. Especially with the international maritime organization (IMO) in The International Convention for the Prevention of Pollution from Ships (MARPOL) by bylaws VI EEDI in the amendment of effective implementation. The low energy efficiency of ships requires compensation for environmental damage in addition to high fuel costs. The efficiency of ship diesel engine, which is the main power output of ship, will affect the energy consumption of ship directly. The energy produced by burning fuel in a diesel engine is not fully utilized, and nearly half of the energy is lost to the atmosphere in the form of heat, which is often referred to as residual or waste heat.

2. Composition of Waste Heat

Marine diesel engine is a sailing ship operating, power source, its exhaust waste heat almost account for nearly 40% of the total quantity of heat, exhaust temperature in 350 °C to 420°C, if the heat directly into the atmosphere, not only cause energy waste but also bring harm to the atmospheric environment.

The total amount of diesel exhaust residual heat is:

$$Q=C_P^{T_2}\cdot M\cdot T_2-C_P^{T_1}\cdot M\cdot T_1 \tag{1}$$

Q——total exhaust residual heat of diesel engine

$C_P^{T_2}$,$C_P^{T_1}$——the specific heat at constant pressure when the exhaust temperature is T_1 and T_2 respectively

M——the exhaust quality

T_2——the output temperature of the turbocharger turbine end

T_1——the ambient temperature

Cooling is necessary in order to guarantee the normal work of the diesel engine, a link, but cooling can take away part of the heat, which reduces the thermal efficiency, cooling in the diesel engine main parts is the cylinder liner and piston, to improve the efficiency of this part of the cooling water to take away heat recycling.

The heat taken away by cooling water is:

$$Q_2=C_{P_1}\cdot m_1\cdot \Delta T_1+C_{P_2}\cdot m_2\cdot \Delta T_2 \tag{2}$$

C_{P_1},C_{P_2}——The specific heat capacity of piston and cylinder cooling fluid is determined by pressure

m_1,m_2——Are respectively the mass flow of piston and cylinder cooling fluid

ΔT_1,ΔT_2——Irespectively the temperature difference of the inlet and outlet of the piston and cylinder cooling fluid

In addition, in the process of diesel engine operation, its own, air cooler, lubricating oil cooler, pressurized air, etc. will also lose a part of the heat, which is difficult to collect, generally not considered.

3. Introduction of Waste Heat Utilization Technology

Through consulting the data and reading the literature, it is known that the utilization of diesel engine residual heat mainly comes from two aspects: kinetic energy and thermal energy.

It is the use of the indoor turbine exhaust inertia force to drive the turbine, turbine and drive the coaxial impeller, the impeller to the fresh air compressed air filter, make the air into the cylinder pressure increases. Into the air in the cylinder pressure increases, then the corresponding amount of air into the cylinder is increased, thus can support more fuel combustion, so increasing fuel injection quantity and adjust speed, can realize the increase of the output power of diesel engine, the fuel consumption. How it works is shown in figure 1.

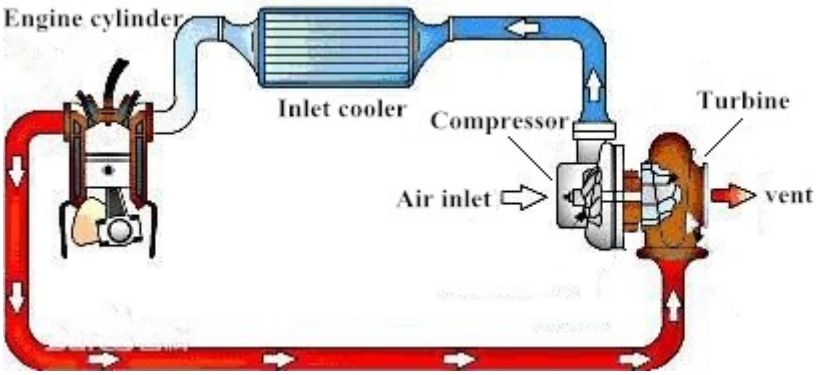

Fig. 1 working principle of exhaust gas turbocharger

A power turbine is a turbomachinery which converts the energy of gas into mechanical energy to drive the external load. Diesel engines operate at high loads by directing excess exhaust to drive power turbines that generate electricity from generators that are connected to the grid.

4. Energy Utilization Technology of Waste Heat

Pressurization technology application in ship of Marine diesel exhaust temperature about 400 °C, through the pipe to the introduction of the high temperature flue gas waste heat boiler, steam or hot water. Steam can be used to drive the steam turbine to generate electricity or to drive the steam auxiliary engine to work. It can also be used for heating the oil tank and daily water use of the crew on board.

The discovery of the seebeck effect made possible the direct conversion of heat energy to electricity. Connect one end of the two different semiconductors together and heated, make its in high temperature condition, on the other side does not make processing under low temperature condition, will form the open circuit voltage on the low temperature end Δ V, this effect called the seebeck effect. See figure 2. At the ends of the seebeck voltage Δ V with hot cold Δ T is proportional to the temperature difference, namely:

$$\Delta V = \alpha_s \Delta T = \alpha_s \Delta \ (T_2 - T_1) \tag{3}$$

α_s——Seebeck coefficient

T_2——High temperature end temperature

T_1——Cold end temperature

And because the installation is almost complete without maintenance and the service life is long, the application of temperature difference generation technology in ships has a broad prospect. As its power supply unit, the temperature difference generator unit in the waste heat temperature difference generator unit can generate electricity and recover some energy by placing it on the outside wall of the exhaust pipe.

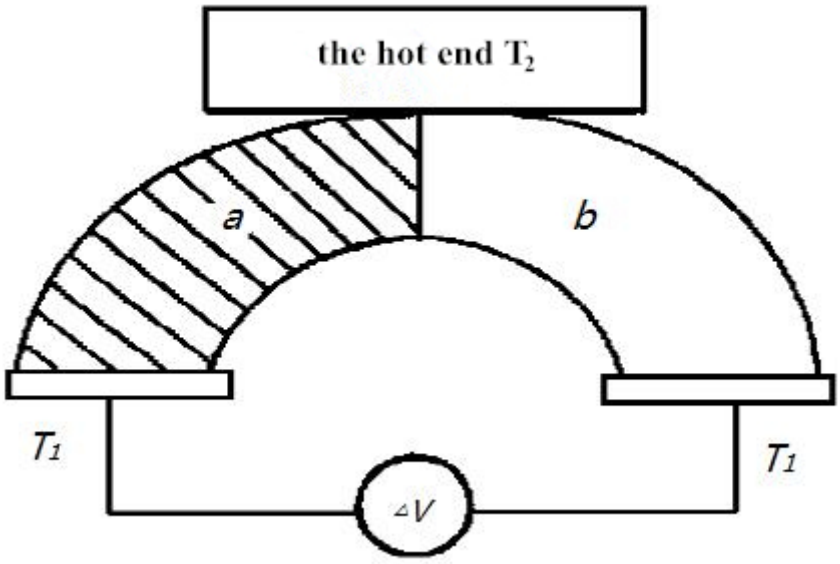

Fig 2. Siebel effect

Ballast is a necessary condition in normal operation of a ship. However, the biological invasion caused by the transportation of ballast water has been listed as one of the four major Marine hazards. Since 2009 the IMO has required all new ships to dispose of ballast water before discharging it. Currently, there are many methods for ballast water treatment, but there are not many universally recognized methods for ballast water treatment. There are mainly chemical, physical and mechanical methods, among which heating method is one of the effective means of ballast water treatment. Major measures is to ballast water is heated to kill the pest, usually need to heating temperature 45 °C to 35 °C - between, and the need to heat preservation 4 to 6 hours to have a good result for destroy harmful microorganisms. The high temperature cooling water of cylinder sleeve, piston and other parts of Marine diesel engine can be introduced into ballast tank to heat ballast water.

Fresh water is normal navigation, ship personnel daily necessities of life and Marine freshwater reserves is limited, and can bring adverse effect to the ship loading capacity can also affect the ship sailing cycle, so on general oceangoing ships need to be equipped with seawater desalination equipment. The boiling desalination device is widely used in ships. Its working principle is that the seawater is heated to boiling and evaporation at a certain vacuum degree, and the steam is cooled and condensed into fresh water. The evaporation temperature is low under vacuum condition, so the cooling water at low temperature can be used as the heat source of desalination device, which reduces the cost and improves the efficiency of ship diesel engine. In addition, at present, the waste heat of flue gas is used to heat the seawater desalination evaporator, and the steam is cooled in the condenser to obtain fresh water.

Using the diesel engine's waste heat to ship's air conditioning system for heating or cooling, to achieve the effective recovery of waste heat, increase the efficiency of diesel engine. In winter, diesel engine waste heat can be heated by heat exchanger. In summer, it can be used as the heat source for heating air conditioning and refrigeration. There are mainly: lithium bromide absorption refrigeration, adsorption refrigeration, wheel dehumidification refrigeration, liquid dehumidification

refrigeration and so on.

5. Conclusion

Diesel engine as a ship's host the status quo in the short term will not change, and serious environmental problems, especially the energy efficiency design index (EEDI) took effect, the green technology, saving energy and reducing consumption has been a theme of today. Since the beginning of this century, the price of petroleum, as a major energy source, has been rising steadily. The increase of oil price directly causes the operating price of ships to increase year by year, and the operating cost of ships rises, which makes the shipping industry suffer a great impact. In this paper, the existing technology of Marine diesel engine waste heat utilization is summarized, and the recovery and utilization of waste heat mainly focus on heat energy and kinetic energy. In terms of thermal energy utilization, there are mainly waste heat boilers, temperature difference power generation technology, waste heat heating ballast water, desalination of seawater and heat source of air conditioning, etc. The utilization of kinetic energy mainly focuses on two aspects: exhaust gas turbocharger and power turbine. Future ship host requirements must be development towards high efficiency, low emissions, environmental protection and energy saving aspects, the application of waste heat utilization technology has significant effect to improve the efficiency of ship diesel engine, with broad prospects for development.

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