Critical Technology of Energy Conservation and Environmental Protection of Shipboard Incinerator

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Abstract: At present, disadvantages regarding energy conservation and environmental protection of shipboard incinerator still exist. To tackle this problem, measures in terms of energy conservation such as waste-heat utilization and high-temperature dehydration, and of environmental protection such as thermostatic control and comprehensive combustion, along with a scientifically-designed working process of shipboard incinerator, are promoted to largely improve the performance of energy conservation and environmental protection of shipboard incinerator, which, given the background of global energy intensity and maritime environment deterioration, is of positive significance.

85% of the world’s total volume of trade are completed via ship transport. With the development of global economy, an increasing number of ships begin to undertake shipping tasks. As a consequence, the pollution caused by ships is getting worse day by day, accounting for 35% of the overall maritime environmental pollution, which has drawn the attention of governments of different countries[1]. The shipboard incinerator is one of the necessary anti-pollution equipment for ocean vessels stipulated by MARPOL73/78 (The International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978). Over 50 types of shipboard incinerators have been developed in several companies around the world, such as the Hamworthy in the U.K., the Attis in Denmark, Hitachi Zosen Corporation in Japan, In China, there are two companies, respectively, China State Shipbuilding Corporation (CSSC) 704 Institute, and CSSC Nanjing Lvzhou Machine Co., Ltd., which has applied the technologies developed by the Gora, Norway[2]. Most of the incinerators from these companies have a few common features, such as the auxiliary burner, high degree of automation and the capability of burning sump oil and solid waste. But they are to be improved regarding energy conservation and environmental protection. For example, gas heat emitted from the exhaust pipe of the shipboard incinerator is not utilized, the water ratio of the combustible sump oil is just about 50%, the performance of stable combustion and comprehensive combustion is poor, the working process is not scientific. With financial support provided by the Guangdong Government, our program team offers a number of new methods and measures to deal with problems regarding energy conservation and environmental protection of a

shipboard incinerator, which, given the background of global energy intensity and maritime environment deterioration, is of positive significance.

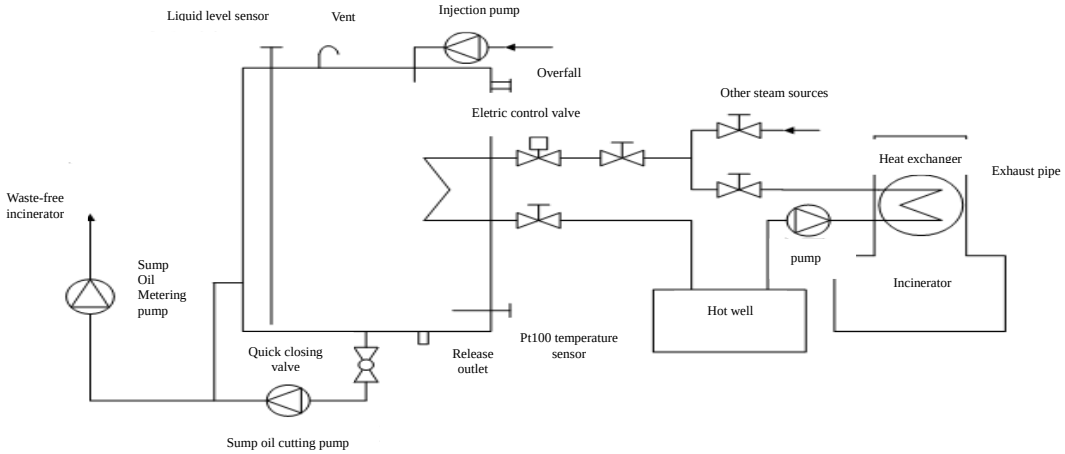
Principle of System Structure of Shipboard Incinerator

The system of shipboard incinerator mainly consists of the diesel system, sump oil system, air compression system, incinerator and electric control cabinet[3-4]. The sump oil system is responsible for storage, heating and pumping of the sump oil. The diesel system is responsible for the storage and pumping of the diesel. The air compression system is responsible for the atomization of the diesel or the sump oil, pipe cleaning before the sump oil combustor stops and promoting some actuators such as the gallery port. The electric control cabinet is responsible for the installation of some control devices such as PLC and frequency transformer. The incinerator mainly consists of the hearth, gallery port, ash door, diesel combustor, sump oil combustor, positive blower and throttle controller. The solid waste or sump oil is mainly burned inside the incinerator.

Technology of Energy Conservation

Scientific Utilization of Waste-Heat

The gas heat emitted from the common shipboard incinerator is hardly utilized. In terms of energy conservation, this gas heat, which hits 1,100℃, can be developed and utilized. Take the TeamtecGS500c Shipboard Incinerator as an example. This incinerator's heat capacity is 335KJ/h, and can be predicted to produce 1t steam (1Mpa), which reflects that it has a high value for energy utilization. The measure is, to install a heat exchanger in the exhaust pipe of the incinerator to take in the waste-heat so that the temperature of the gas heat will fall below 300℃ and the level of pollutants such as dioxin will reduce. The steam generated from the exchanger is used to heat the sump oil in the cabinet so that other types of energy can be saved and the performance of the equipment can be improved.



Picture 1 Schematic Diagram of System of Sump Oil Cabinet of Shipboard Incinerator

Application of Frequency Conversion Technology

One of the advanced indicators of the shipboard incinerator is that in the premise of qualified indicator of control emission, the unit amount of diesel consumed can burn as much waste and sump oil as possible. If it is a constant pump and the amount of injected sump oil can not be adjusted when the temperature of hearth is either too high or too low, causing a waste of fuel oil, then the frequency conversion technology can solve this problem. It is suggested to apply the MM440 frequency converterr[5-6]. When the temperature of the hearth reaches 650℃, a starting signal will be sent to the frequency converter so that the sump pump will begin to pump the oil. In other words, the temperature of the hearth is set as the given signal, according to which the frequency converter outputs the frequency so that the speed and flow of the sump pump can be adjusted. The higher the temperature of the hearth, the higher the output of frequency as well as the speed and flow of the sump pump. In this way, the cost-effectiveness of the combustion can be improved.

Application of High-temperature Dehydration

At present, over 50 types of shipboard incinerators have been developed in several countries around the world. However, the water ratio of the sump oil is limited to about 50%[7] and is not combustible if it is too high. After being stirred by the cutting pump, the oil-water becomes emulsion. When the emulsion is burned, every drop contains water, and when the temperature of the surface of the drop increases above the boiling point, the pressure of the steam exceeds the surface tension of the the oil and the pressure of the environment. As a result, the steam overflows, leading to the explosion of the drop, and the drop is split into smaller particles. That is to say, a certain level of water content is helpful for atomization and combustion. However, if the level is too high, then the water will take in a large amount of heat by vaporization and the amount of oil will reduce, both of which is against combustion. Experiments indicate that when the water ratio of the sump oil ranges from 10% to 30%, the sump oil can be burned the fullest. This sump oil cabinet applies the technology of high-temperature (100℃) dehydration. In this circumstance, most of the water in the sump oil will vapor and nearly all the injected material is the combustible sump oil. It also enables the water ratio of the sump oil to exceed 80%. The application of the technology of high-temperature dehydration helps reduce the water in the sump oil and the heat loss due to water vaporization, which improves the stability of the incinerator and reduces the energy consumption.

Environmental Protection Technology

Constant Temperature Control

Apply the technology of constant temperature control in the sump oil cabinet of the shipboard incinerator. Specific principles are as follows: apply the Pt100 Temperature Sensor to detect the

signal of the temperature of sump oil in the cabinet. The Pt100 Temperature Sensor, whose platinum resistor is made from a thin platinum wire surrounding a mica holder, is a world-recognized high-precision standard temperature sensor. The detected signal of the temperature of sump oil in the cabinet is sent to EM235 module (in this module, this signal of current is more stable than that of voltage with better anti-interference performance) in the form of current signal. Then, the PLC makes comparison between the detected and the set temperature signal, and after being calculated by the PID, it sends a current signal to adjust the opening of the electric control valve of the steam heating and changes the amount of steam which is responsible for sump oil heating, so as to adjust the temperature of the sump oil. The opening of the electric control valve is under closed-loop control and gives feedback in the form of current signal, so that the sump oil in the cabinet keeps a constant temperature.

Because the types of ships and navigation conditions are different, and the content of the sump oil changes, this will probably make the combustion unstable and pollutants increase. Because the burned materials are uncertain and their calorific value varies, it is suggested to apply the technology of constant temperature control. The temperature is constant before the sump oil is injected into the incinerator. As a consequence, the period of unstable combustion is shortened, the consumption of fuel is reduced, the combustion is more stable, the emitted pollutants are decreased and the product is more environment-friendly.

Complete Combustion

Because of incomplete combustion of wastes, carbon monoxide and dioxin are very much possible to be released, which will lead to pollutant emissions and fuel wastage. To prevent pollution resulted from incomplete combustion, standards approved by the International Maritime Organization (IMO) on operating limits for shipboard incinerators (which are shown in Table 1) shall be followed.

Tab 1. IMO Approved Standards on Operating Limits for Shipboard Incinerators

Testing Items	Operating Limits
O2 in Combustion Chamber	6%~12% 6%~12%
CO in Flue Gas Maximum Average	200mg/MJ 200mg/MJ
Soot Number Maximum Average	Bacharach3 or Ringelman1 (20% opacity) (A higher soot number is acceptable only during very short periods such as starting up)
Unburned Components in Ash Residues	Maximum 10% by Weight
Combustion Chamber Flue Gas Outlet Temperature Range	850~1200℃ 850~1200℃

Whether the combustion of wastes and sludge oil in incinerator is complete or not depends on the oxygen content, namely, it will be relatively complete if it is oxygen-enriched combustion, and this is also why the average content of oxygen in combustion chamber (6%-12% as required) should

be tested as required in Table 1. The average CO content in flue gas, the weight of unburned components in ash residues and soot number are all measurements to test the completeness of waste combustion. Main decisive factors of incineration process include incineration temperature, flue gas temperature, pressure in combustion chamber, residence time of wastes and high temperature gas in incinerator, structure of inlet channel, air input, turbulivity, etc. In general terms, increasing the incineration temperature is good for the decomposition of the organic toxic components in wastes as well as the reduction of black smoke. However if the incineration temperature is too high, the quantity of auxiliary fuel consumption, nitrogen oxides and metal volatilization will be increased, which will result in secondary pollution. Besides, the high temperature will cause damage to the incinerator body. So the incineration temperature in the incinerator cannot just be increased without control. Similarly, if the temperature gets too low during the waste incineration process, it is not good for the complete combustion of the sludge oil and will make the incineration of solid waste even harder. Negative pressure in combustion chamber can help prevent the leak of the high temperature gas from the chamber so that the safety of the ship and its operators can be ensured, and a sufficient amount of gas for the waste incineration can be provided through a free flow of gas from the outside of incinerator into the inside. Because the residence time of the intake gas in incinerator exerts immediate impact on the completeness of waste incineration, it shall be controlled. Since the air input of fans is kept within a certain amount, the negative pressure in combustion chamber is mainly controlled by the opening of air damper, which means different opening positions can be taken to regulate the amount of gas flow so that the negative pressure is under control. According to the International Convention for the Prevention of Pollution from Ships, the outlet temperature of the incineration chamber shall not be higher than 1200℃ and the flue gas temperature shall not exceed 350℃. If the temperature of flue gas gets too high, most of the heat will be wasted, dioxin and other types of pollutants will be produced, and at the same time the equipment itself will suffer from damage.The air input amount depends on the size, position, number of the bores on the incinerator surface and the opening of the air damper. The pressure in chamber, which depends on the opening of the air damper, will affect the flow mix and the chamber temperature, and then the chamber temperature will exert direct influence on incineration efficiency and flue gas temperature (the opening of air damper can also influence flue gas temperature directly).

To tackle these problem, the structure of incinerator should be properly designed, and the opening of the damper should be controlled with a scientific approach to ensure an oxygen-enriched combustion.

Conclusions

Based on the above technical analysis and research, the following conclusions can be made:

1) By adopting technologies like waste-heat utilization, high-temperature dehydration, energy-saving standards of shipboard incinerator can be increased, benefiting the conservation of fuel oil and other energy resources.

2) By adopting technologies like thermostatic control and complete combustion, the environment protection standards of shipboard incinerator can be increased, benefiting the protection of marine environment.

References:

1. Sheng, W. Q. (2016). Analysis of Status of International and National Ship Anti-pollution Rules and Standards and Study of Countermeasures in China. *Ship Standardization Engineer,* (1): 6—11.

2. Cui, J. W., Han, X. B., & Xu, X. X. (2010). Three-dimensional Numerical Simulation of the Integral Structure of Marine Garbage Incinerator. *Ship & Ocean Engineering*, (2): 143—146.

3. Yin, P. H. (2000). *Ship Pollution Prevention Technology*. Dalian: Dalian Maritime University Press, 136—143.

4. Han, X. B. 3D Numerical Simulation of the Marine incinerator and Research of Fuzzy Control. *Shanghai Jiaotong University*, 2009.

5. Liao, C. C. (2008). *PLC Programming & Application*. Beijing: China Machine Press, 246—248.

6. Wu, Z. M., & Yang, S. F. (2009). *An Integrated Course of Siemens PLC, Frequency Converter and Touch Screen Application.* Beijing: China Electric Power Press, 250—252.

7. Zhong, W. H. (2012). Emission Numerical Simulation about Ship Waste Oil Incinerating and Research of Air Damper Control. *Ximen: JiMei University*, 9—11.

8. Huang, Y.J., & Luo, L. B. (2011). System Parameters & Control Strategies of Shipboard Incinerators. *Journal of Ship Design*, (1): 43—47.