Research on Solution of Ship Low Sulphur Fuel based on IMO Sulphur Limitation Regulation

Zihui Wang, Honggang Zhang and Xuezhen Gan

Zhejiang Ocean University, No. 1 Haida South Road, Lincheng Street, Dinghai District, Zhoushan City, Zhejiang Province, China

2315455636@qq.com

Abstract. In recent years, the density of both domestic and international routes is generally at a high level. Intensive ship navigation frequency and ship number operations have brought many sulfur oxides, nitrogen oxides and other particulate matter to the port, resulting in increasingly serious port pollution, which has become one of the main sources of air pollution, and ship exhaust emissions are causing environmental pollution in coastal areas. As well as the main sources of port pollution, the pollution problem should not be underestimated. "Air pollution from maritime transport causes about 1450 to 37500 premature deaths each year and brings short-term and long-term changes to the climate system," the IMO reiterated in response to the seriousness of the problem that all ship fuels should meet sulfur content below 0.5% starting from January 1, 2020[1]. In view of this regulation, this paper systematically analyses three low-sulfur fuel solutions at present, and summarizes the optimal solution from the aspects of economy, feasibility and sustainability, and the comparative study of three different types of the optimal solution is carried out, that is, to refine the optimal solution again, and put forward the applicable technology in the optimal solution.

1. Pollution and harms of ship exhaust emission

Due to the rapid development of economic globalization, trade between countries has become more frequent. The large volume of ocean transportation and low freight have accelerated the large-scale manufacture of ocean-going ships and put them into use. The exhaust of ship contains a large amount of NOX and SOx. SOx not only smells bad, but also forms acid rain in the atmosphere when its concentration is too high. The formation of acid rain will greatly reduce the survival rate of various plants, and also affect the normally grow of crops, as well as people's food health[2]. NOx mainly causes respiratory disorders and carcinogenic hazards to humans[2]. Nox and SOx have become an increasingly serious global problem, and the elimination of NOx and SOx has become the hottest and urgent problem in the field of air pollution control.

2. Situation of solution to low sulphur emission from ships

2.1. Use low sulphur oil

The sulfides in the ship exhaust come from the combustion of the marine fuel, and it is only related to the sulfur content of the fuel, but independent of the structure of the marine engine and so on. From this point of view, the use of low-sulfur oil is a simple and effective method, but this method is not too mature from the economic point, reasons are as followed:
Firstly, at present, the price difference between traditional heavy oil and low sulphur fuel oil is about $200 per ton[3], and if a normal ship goes into operation, it will consume huge amount of fuel a day[4], which is no doubt a huge cost investment, putting enormous pressure on shipping companies or shipowners and even the entire shipping industry. Secondly, the market is short of supply. If this scheme is adopted, manufacturers will have to increase production, and the production of low sulfur fuel will last a long time, in the short term, the overall trend of the market is still in short supply. Thirdly, it is not compatible with engine equipment. Low sulfur fuel with lower sulfur content than 0.5m/m has lower lubricity and viscosity than traditional heavy sulfur fuel because sulfur can improve the lubricity of fuel. Poor lubricity and low viscosity will cause some problems such as parts wear, generator tripping and so on[5]. The long-term use of low sulfur oil should strengthen the inspection and maintenance of engine and other equipment. From the above three points of analysis, the idea of using low-sulphur oil is not mature at present.

2.2. LNG power boat

LNG, liquefied natural gas (LNG), is mainly composed of methane, which can almost achieve zero emissions of nitrogen and sulfur and reduce emissions of carbon dioxide by about 27%[6]. The super-large Maersk fleet is considering transforming some of its ships into LNG-powered ships by 2020 and has reached agreements with other fuel-supply companies such as Kadar LNG. The 9 super-large container ships and 12 container ships aboard the Dafei steamship all use LNG alternative fuel. Nevertheless, many of the drawbacks of LNG alternative fuels are still unavoidable. First, the construction of LNG injection station is not ideal. Put into operation of LNG power ships, we must build more LNG filling stations to meet, and from the current point of view, due to the pressure from investment costs, the enthusiasm of shipowners is not high[7]. If it is ocean-going ship, the route is long, the sailing time is long, from the long-term point of view, the ship needs more international filling stations[8]. Although Singapore, South Korea and other countries are very concerned about the construction of LNG filling station, however, its construction process is still not ideal, which is the most urgent problem to be solved. Second, the ship still needs to be reformed. The use of LNG alternative fuels still requires retrofitting of existing ships, including a series of equipment such as LNG fuel tanks, engines, gas supply lines, and so on. Among them, the LNG fuel tank occupies quite a large ship space, about consuming about the ship 500TEU cargo space, this is no doubt another form of cost input. On the other hand, it is necessary to analyze the physical properties of natural gas itself. The natural gas after gasification is flammable and explosive, and the temperature of natural gas at room temperature is -162°C. Once a leak occurs on the ship, it will do great harm to the ship and its crew[9]. Therefore, LNG power ships require very high fuel systems such as ship gas supply lines, engines and so on. At present, it is too early to develop LNG alternative fuel.

2.3. Ship desulfurization equipment and technical analysis

The installation of ship desulfurization equipment is the best choice over the use of low sulphur oil and LNG alternative fuels. At present, Mediterranean shipping has taken action, adopting a different programme from Maersk shipping and Dafayette ships, namely, the installation of ship disused scrubbers. But some shipping companies have concerns such as price. In fact, even the installation costs of brands such as Wasserian, the international shipping industry giant, are only $5 million to $10 million per ship, while domestic installation costs are not as high, at about $2 million to $3 million. And a large container ship will be back in about a year. The advantage of waste scrubbers is that they can use the natural alkalinity of seawater or the artificial addition of lye to clean tail gas. It can be divided into three kinds of processing technologies: open desulfurization technology, closed-loop desulfurization technology and mixed desulfurization technology.
2.3.1. Open desulfurization technology. This technique is suitable for ships sailing in sea water areas, using the natural alkalinity of the sea water (PH7.8 to 8.5) to wash the flue gas to achieve the effect of desulfurization\[9\], the sea water after the reaction through the water treatment unit can be directly discharged to the sea, the desulfurization efficiency is high. The main reaction processes are as follows:

\[
\begin{align*}
\text{SO}_2(g) & \rightarrow \text{SO}_2(l) \\
\text{HSO}_3^- + \text{OH}^- & \rightarrow \text{H}_2\text{O} + \text{SO}_3^{2-} \\
\text{SO}_2 + \text{H}_2\text{O} & \rightarrow \text{H}^+ + \text{HSO}_3^- \\
\text{SO}_3^{2-} + \text{O}_2 & \rightarrow \text{SO}_4^{2-}
\end{align*}
\]

The flue gas flows from the bottom of the desulfurization tower, and the seawater pump sprinkles the seawater from the top of the desulfurization tower, which makes the flue gas fully mixed with the seawater and reacts so that the sulfides in the flue gas can be washed out\[10\]. There is also a mist remover at the top of the desulfurization tower, which is used to deal with sulfur oxides in the flue gas after atomization. After the reaction, the sea water can be discharged directly into the sea after treatment.

2.3.2. Closed-loop desulfurization technology. The closed-loop treatment technology is suitable for seawater or fresh water with low alkalinity. Unlike the open treatment technology, the artificial addition of alkaline solution (mostly sodium hydroxide) is needed to maintain the alkalinity of the reaction in the desulfurization tower. The main reaction process is as follows:

\[
\begin{align*}
\text{SO}_2 + 2\text{NaOH} & \rightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O} \\
\text{Na}_2\text{SO}_3 + \text{SO}_2 + \text{H}_2\text{O} & \rightarrow 2\text{NaHSO}_3 \\
2\text{NaSO}_3 + \text{O}_2 & \rightarrow 2\text{NaSO}_4
\end{align*}
\]

The flue gas enters at the top of the desulfurization tower, fresh water and lye enter from the top of the desulfurization tower and are fully mixed with the flue gas. To wash the sulfur oxides in the flue gas, except that most of the seawater or fresh water after the reaction is re-entered into the circulatory system to continue to participate in the reaction, and a small part is discharged after treatment\[10\]. As can be seen from the above reaction principle, acid ions such as HSO$_3^-$ continue to be produced in the reaction, so the PH used in circulating seawater or fresh water is constantly decreasing. In order to maintain alkalinity, fresh water as well as seawater, lye and other participating cycles are needed to achieve the desulphurization effect.

2.3.3. Mixed desulfurization technology. The hybrid desulfurization equipment combines the advantages of open desulfurization treatment technology and closed-loop desulfurization treatment technology, which enables ships to navigate not only in the ocean, but also in freshwater areas such as inland rivers and lakes. At present, it is the best economic and long-term scheme to solve the low sulfur emission from ships, and this treatment technology is the best desulfurization technology in the ship desulphurization equipment. Main principle of equipment. The figure is shown in Figure 1.
3. **Market prospect analysis of mixed desulfurization equipment**

We can understand that the ship exhaust gas desulfurization system is an effective measure for low sulfur emissions from ships. Through the above analysis, environmental protection has now risen to the level of national strategy, and green development has become the mainstream of the world today. At present, all countries in the world are actively seeking the most effective ship desulfurization technology, especially the mixed ship desulfurization equipment[11]. It has great economic and social benefits, which are manifested in the following aspects:

The hybrid ship desulfurization equipment can not only help shipping enterprises to reduce their operating costs, improve their international competitiveness, and increase their economic benefits. It can also set up the image of green environment protection of enterprises, help shipping enterprises to fulfill their obligations of energy saving and environmental protection, and assume the corresponding social responsibility. At the same time, some large shipping enterprises and ship equipment manufacturing enterprises to cooperate, increase the employment rate of personnel, help the development of related environmental protection manufacturing industry, and then improve the status of China in the world shipping, create a win-win situation.

4. **Epilogue**

In today's world, environmental protection is the requirement of the times, and it is normal for the IM0 to implement the "sulfur restriction order" on a regular basis, and it is impossible for it to postpone the implementation of the Global "sulfur restriction order" for ships, as is the case with the postponement of the Convention on the Management of Ballast Water. Therefore, shipowners and shipping enterprises should no longer maintain the attitude of onlookers, but to actively seek solutions. From the above series of comparative analysis, it can be seen that the installation of hybrid desulfurization
equipment is the best choice both in terms of cost and the effect of sulfur reduction achieved. It is just that at present, China's shipbuilding equipment manufacturing enterprises have not yet mastered complete technology, and some equipment parts are still dependent on imports, which has sounded a wake-up call for our country's equipment manufacturing enterprises, and in the fierce international market competition, Only innovation will not be eliminated by the market.

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