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# Economic Analysis of the Sulfur Limitation Program

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***ABSTRACT.*** *International trade is becoming more and more vigorous. In recent years, the shipping industry has gradually come out of the doldrums, continues to develop steadily, and the number of ships is also rising. Today, ship exhaust pollution has become one of the main causes of air pollution. According to the International Maritime Organization (IMO), from January 2020, the sulfur content of ship fuel in sulfur emission control zones is less than 0.1%, and the sulfur content of ship fuel in non-control zones is less than 0.5%. There are currently three mainstream countermeasures; 1. Low-sulfur fuel technology; 2. LNG replacement technology; 3. Exhaust gas treatment technology. This article analyzes the average annual cost of two of these options, and analyzes which one is more suitable for the development of the shipping industry.*

***KEYWORDS:*** *sulfur limitation order, low sulfur fuel*

## 1. Introduction

In October 2006, the international organization still discussed and passed the sulfur restriction order and introduced the amendments to the International Convention for the Prevention of Pollution by Ships. The Convention stipulates that the sulfur content of all marine fuels does not exceed 0.5%, and the sulfur content of ship fuels in the ECA-controlled areas of the four major emission control areas of the North Sea, North America, the Baltic and the Caribbean does not exceed 0.1%.

The Implementation Plan for Ship Emission Control Zones in the Pearl River Delta, Yangtze River Delta, and Bohai Rim (Beijing-Tianjin-Hebei) Waters, which was officially implemented in China on January 1, 2016 .It is stipulated that the ship uses sulfur fuel with a sulfur content not higher than 0.5% during docking at the core port of the emission control zone. In October 2019, the Maritime Safety Administration issued the "2020 Global Fuel Oil Sulfur Limitation Order Implementation Plan", which stipulates that international navigation vessels entering the domestic air pollution control emission areas of river vessels should use fuels with sulfur content not exceeding 0.1%.

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## 2. Analysis of three main measures

At present, there are three mainstream measures to deal with the sulfur restriction order: low-sulfur fuel technology, LNG replacement technology, and exhaust device treatment technology.

### *2.1 Low sulfur fuel technology*

Low sulfur fuel technology refers to the use of low sulfur fuel. This scheme does not require modification of the ship, and it is relatively convenient to deal with sulfur restriction orders. However, the price difference between low-sulfur fuel and high-sulfur fuel fluctuates greatly, currently it is about 230 USD / t. Ships need to use low-sulfur fuel in the ECA in the sulfur-restricted area, and they can continue to use heavy oil in the non-controlled area.

*Table 1 The fuel price of world's major ports in 2019.11*

| port | HFO Average price($/t) | MGO Average price($/t) |
|---|---|---|
| Singapore | 361 | 587 |
| Panama | 360 | 618 |
| Rotterdam | 296 | 564 |

### *2.2 LNG replacement technology*

Alternative fuel technologies refer to technologies that replace clean energy with traditional marine fuels such as biofuels, methanol and liquefied natural gas (LNG). The reason why LNG replacement technology is currently the most widely used alternative fuel technology for ships is that the sulfur content of LNG fuel is extremely small and negligible, it can reach 100%, and it also reduces emissions of other pollutants. And control the production of harmful products within a certain range.

However, the use of LNG as an alternative fuel also has the following problems: The first is to retrofit the ship 's power plant to make it suitable for LNG as a fuel, which requires a large amount of investment in the early stage to increase costs; second, LNG gas fuel is used during the operation of the ship Exist in liquid form. It is not stored. It needs to be equipped with special equipment and LNG storage rooms, which can take up space available on the ship, and may lead to reduced cargo transportation and lower profits. Third, LNG alternative fuel storage and equipment installation and operation are more complex, which brings offshore workers A lot of work and high work difficulty. The fourth is that liquefied natural gas alternative fuels are usually transported and stored in liquid form, because liquefied natural gas is volatile and explosive, and the safety requirements of equipment for ship transportation are relatively high. Fifth, most ports are not suitable for the infrastructure for loading LNG, and the ship has poor durability. All these

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shortcomings have limited the development of LNG ship power, and LNG takes a long time to be widely used as fuel on board

### *2.3 Exhaust gas treatment device technology*

Exhaust gas treatment device technology is to install an exhaust gas washing device at the stern of the ship, and the ship needs a certain installation space. There are three main types of washing devices, open, closed and composite. The open type is mainly used to wash the sulfur content in the tail gas by seawater, and the operation is relatively simple, although the sulfide does not enter the atmosphere, it enters the seawater. In the closed type, the corresponding chemical reagent is mainly added to achieve the purpose of desulfurization, but the waste liquid needs to be recovered on the ship, and the operation is relatively complicated. The composite type can be switched between open and closed. With the IMO's emphasis on environmental protection, waste liquid may not be allowed to be poured into seawater in the future, so this article does not analyze this solution.

## 3. Cost comparison between using low sulfur fuel technology and LNG alternative fuel technology

The following is an analysis of investment costs, voyage costs, and route operations. The ship selected in this section is a certain China-Europe route (Shanghai-Singapore-Antwerp). The specific parameters of the ship are as follows

*Table 2 General Ship particular*

| General Ship particular | | | |
|---|---|---|---|
| monitor rate | 5000KW | Maximum design speed | 14 knots |
| Host speed | 700RPM | Economic speed | 12 knots |
| Total load | 7500TEU | Days / cycle | 36.8 days / 9 |

*Table 3 General ship voyages information and fuel consumptions*

| Voyages | Route | Total distance | SECA | Non-SECA | MGO | HFO |
|---|---|---|---|---|---|---|
| 1 | Shanghai to Singapore | 2199 | 1515 | 684 | 70.07 | 32.18 |
| 2 | Singapore to Antwerp | 8398.8 | 5351 | 3047.8 | 250.24 | 143.42 |

The ship will refuel in Singapore. The fuel price will be Singapore price, of which HFO is 361 $ / t and MGO is 587 $ / t.

### *3.1 Cost analysis of low sulfur fuel technology*

Low sulfur fuel technology uses MGO with a sulfur content of 0.1% instead of HFO, and sulfur content of 3.5% as a marine fuel. Because low-sulfur fuel

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technology does not add additional equipment, the cost of retrofitting old ships and operating and maintenance equipment costs are almost zero; because the price of low-sulfur fuel is much higher than the price of low-quality heavy oil, the use of low-sulfur fuel technology is mainly due to fuel Due to price. Increase fuel consumption costs. Due to the high price of low-sulfur fuel oil with a sulfur content of 0.1%, in order to reduce fuel costs, ships use low-sulfur fuel with a sulfur content of 0.1% as ship fuel, except for sailing in the SECA area and stopping at the port, and for the rest use it. Heavy oil with a sulfur content of 3.5% is used as ship fuel.

The annual cost of low-sulfur fuel technology fuel is as follows:

$$C_d = T\sum(C_{HFO} + C_{MGO})$$

$C_d$ is the annual cost of low sulfur fuel, T is sailing cycle, $C_{HFO}$ is fuel cost for HFO, $C_{MGO}$(\$). Is fuel cost for MGO

$C_d$=(143.42+32.18)*361*9+(250.24+70.07)*587*9= 2262722.13

### *3.2 Cost analysis of LNG alternative fuels*

Ships using LNG instead of fuel technology are different from traditional ships. Therefore, if an old ship is retrofitting an LNG-fueled ship, it will need to add equipment to the original engine, which will increase costs. For storage purposes, LNG fuel is usually stored on board as a liquid, so a special LNG storage room needs to be built. The storage and use of LNG alternative fuels are relatively complicated, and strict requirements are imposed on the staff on duty. Before they can work normally, relevant personnel must be trained in operation and safety, which increases personnel costs. Due to the volatility and explosive nature of LNG, the safety requirements of shipping methods and equipment are relatively high. At present, due to transportation difficulties, the price of LNG is also high. In order to reduce fuel costs, ships use LNG as fuel for ships in the SECA area and use it when calling at ports. The rest of the time uses low-quality heavy oil as fuel,

LNG replacement fuel conversion cost and fuel cost two parts, which is calculated as

$$C_{LNG} = \frac{Q_{GZ}}{k} + \sum_i (Q_{HFO}^i \times P_{HFO} + Q_{MGO}^i \times P_{MGO} + Q_{LNG}^i \times P_{LNG})$$

$C_{LNG}$ is annual cost of ships using LNG alternative fuel technology; i is number of voyages a ship operates in a year; k is years of ship operation; $Q_{GZ}$ is ship modification costs; $Q_{HFO}^i, Q_{MGO}^i$ and $Q_{LNG}^i$is MGO consumption, HFO consumption and LNG consumption for a voyage; $P_{HFO}, P_{MGO}, P_{LNG}$ are the price of MGO, the price of HFO, and the price of LNG.

Calculation of the amount of LNG is

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$$Q_{LNG}^{i} = \frac{Q_{MGO}^{i} \times q_{MGO} \times k}{q_{LNG}}$$

$q_{MGO}, q_{LNG}$ is calorific value of MGO and LNG respectively, k is comprehensive fuel replacement rate for LNG replacement fuel. Here the HFO calorific value is taken as 46MJ / Kg, The LNG calorific is taken as 38MJ/Kg. The comprehensive replacement rate of LNG alternative fuel is 50% to 70%, This article uses 65% calculation. The unit price of LNG is 226.6 $ / t. According to the shipping routes and fuel consumption data in the table, the annual cost of LNG alternative fuels is calculated as follows:

$C_{LNG} = \frac{6.76\times10^{6}}{15} + [320.31 \times 587 \times 9 \times 0.35 + 175.6 \times 361 \times 9 + 252.03 \times 226.6 \times 9]$=2127458

### *3.3 Analysis of operating costs*

Operating costs are recurring maintenance costs incurred by ships to maintain seaworthiness. It includes: crew costs, insurance costs, maintenance costs, materials costs, materials costs, supply costs, management costs, and other operating costs.

Material cost: Usually, the cost of materials and the cost of materials are the same, but for container ships, half of the cost of materials is taken because there is no need for materials such as stowage and separate tickets.

Insurance: According to the original value and use of the ship, the shipping company proposes a price guarantee. The value of the insured value varies with the age and technical status of the ship, but in the demonstration stage, it is assumed to be equal to the cost. The annual insurance premium rate also varies with various factors such as the old and new, size, voyage length, cargo type, navigation area conditions, etc., but it mainly increases with the age of the ship. According to the analysis of relevant research data, the relationship between the insurance rate of ocean-going ships and the age of the ship is obtained.

*Table 4 Ocean shipping insurance rates and age*

| Boat age | <=4 | 5-9 | 10-14 | 15-19 | 20-24 | >=25 |
|---|---|---|---|---|---|---|
| insurance rate | 0.6 | 0.68 | 0.8 | 0.99 | 1.2 | 1.3 |

Crew costs: There are two main criteria for estimating crew costs: one is the crew standard, which is the crew allocation standard for the type of ship being demonstrated. The other is the salary standard for ships. There is a large gap between the salary standards for ships in different countries, different regions and different periods.

Repair fee: The size of the repair cost of a ship depends on the size and type of the ship and its power plant, the operating conditions and technical status of the ship,

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including the cost of repairs to the shipyard, and the spare parts, tools, and materials required for the ship to repair itself during the voyage cost. In the years of the ship's service life, due to the great difference in the amount of repairs each year, the actual repair costs that occur each year are unequal. In the demonstration, in order to make the schemes comparable, it is generally based on the cost of the ship. To a certain ratio. The percentages of repair costs based on the ship price are 4.5% for Yangtze River ships, 3.5% for coastal ships, and 2.5% for ocean-going ships.

Querying relevant information shows the cost of the ship, and the service life of the ship we put into the ship is 15 years, and the total maintenance cost is distributed to each year, so the average annual repair cost is $ 126,200.

The total cost is as follows:

*Table 5 Cost Data Sheet for Two Technologies*

| | Low sulfur fuel | LNG |
|---|---|---|
| Initial investment | 5000000 | 540667 |
| Years of operation | 15 | 15 |
| Fuel cost | 2262722 | 1676791 |
| Material cost | 100000 | 100000 |
| Crew fee | 712000 | 750000 |
| insurance | 450000 | 600000 |
| Repair fee | 126200 | 126200 |

*Table 6 Total cost of both technologies*

| | Investment | Fuel c | Operating | Annual cost |
|---|---|---|---|---|
| Low sulfur fuel | 5000000 | 2262722 | 1388200 | 8650922 |
| LNG | 5450667 | 1676791 | 1576200 | 8703658 |

According to the data, low-sulfur fuel technology has the lowest initial investment cost; LNG alternative fuels require higher initial costs due to old ship retrofits, and fuel costs are lower than low-sulfur fuels. The average annual cost of low-sulfur fuel technology is lower than LNG replacement technology.

Starting from 2020, the route will restrict the sulfur content compulsorily, and the area using low sulfur oil will also increase. Due to the increase in demand for low-sulfur fuel, the price of low-sulfur fuel may rise, while the price of LNG is not volatile, and the cost of low-sulfur technical fuel will increase.

## 4. Conclusion

In terms of cost, low-sulfur fuel technology has the lowest cost investment; LNG alternative fuel technology has a higher initial investment cost. In daily maintenance, low-sulfur fuel technology requires more maintenance of the host. From the perspective of fuel prices, the price of LNG fuel will be relatively stable, while the

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price of low-sulfur fuel will fluctuate greatly. From the perspective of the ship's sailing time to the sulfur emission control area, if the ship sails to the emission control area for a long time and the operation period is long, it will be a better choice to use alternative LNG fuel technology.

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