Analysis of Impact Factors of Bulk Carrier Energy Efficiency Operation Index

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Abstract: According to the definition of the ship energy efficiency operation index (EEOI), mathematical statistics tests are used to analyze the impact of various impact factors on the actual ship carbon emissions (including fuel type, fuel consumption, cargo volume and shipping mileage), proposing effective measures to reduce carbon emissions from perspective of operational management.

1. Introduction

From a global perspective, the transportation industry accounts for more than 20% of the world's energy consumption and greenhouse gas emissions, and is still rising rapidly. Responsibility for energy conservation and emission reduction is significant, and countries around the world have made green and low-carbon transportation a strategic priority. Although the carbon emissions from maritime traffic are not as good as those on land, with the development of the shipping industry, the number of ships has increased significantly, the tonnage of ships has risen sharply, and the carbon emissions of ships are not to be underestimated. In addition, as a mobile carbon source, ships have a particularly serious environmental impact on ports and coastal cities. The research on ship carbon emission monitoring methods mainly involves the specific interests of the stakeholders such as ports, shipowners and other shipping related departments in terms of economy, health and environmental protection, and has positive significance in reducing the adverse effects of air pollution on the human body and the environment. It is related to the realization of the emission reduction targets of operating ships.

2. Definition of EEOI

EEOI is the ship energy efficiency operation index, which refers to the carbon dioxide emissions of the ship after completing the unit cargo turnover (shipload multiplied by the transport distance). Although EEOI does not stipulate enforcement, IMO is gradually advancing the requirements for the development of EEOI. Shipbuilding companies and other shipping industries should still pay sufficient attention to strengthen research to promote the continuous improvement of energy efficiency of operating ships. According to the relevant international marine conventions, the calculation formula for the ship energy efficiency operation index is as shown in formula (1):

$$EEOI = \frac{\sum_{j} FC_j \times CF_j}{m_{c\arg o} \times D} \tag{1}$$

Where FC_j means the actual consumption of fuel of class j, CF_j means the carbon dioxide emission factor, $m_{c\arg o}$ means the cargo transportation volume and D means the cargo transportation distance.

3. EEOI Calculation of Real Ship

Bulk carriers usually use a single voyage as the statistical range of fuel consumption: the cargo unloading completion time of the previous voyage is taken as the start time of the voyage, and the total unloading completion time of the voyage is the end time of the voyage. The fuel consumption of a ship refers to the total amount of fuel consumed by the ship's main engine, auxiliary machine, boiler, incinerator, etc. during the navigation and operation of the ship. Ships in the berthing process include loading and unloading at the port. Although no cargo transport turnover is generated, the fuel consumption of ships at port must also be included in the statistics. In addition, it should be noted that the voyage in the ship EEOI does not refer to the plot distance of the nautical chart during the voyage, nor does it refer to the shortest distance from the departure port to the destination port, but refers to the actual voyage distance of the ship recorded on the logbook. When the ship EEOI is applied, it can be calculated by one or more voyages of the ship or for a period of time. In the "Guidelines for Voluntary Application of Ship EEOI", it tends to compare the energy efficiency of ships with a single voyage, so that more real ship data can be obtained, and it is more convenient and reasonable to compare the energy efficiency of ships in various voyages and various operating states. In addition, the calculation of the average EEOI is not simply dividing the total fuel consumption by the flight segment or the annual fuel consumption by the product of the flight segment or the total annual cargo volume and the mileage. Instead, the total fuel consumption of the segment is divided by the voyage in the flight segment. The sum of the product of the volume and the mileage, the resulting data is consistent with the average of all single voyage EEOI values. The fuel consumption is also calculated as such, and the relationship between the fuel consumption and the EEOI is determined, and the value is referred to according to the carbon content of the fuel. When calculating the two, the fuel consumption should be calculated first. According to the shipping situation of a certain enterprise bulk carrier in 2015-2017, the fuel consumption of the EEOI of the ship is calculated as shown in Table 1.

Take the calculation of the 2017 068 voyage as an example: Calculate the fuel consumption formula according to the fuel consumption: fuel consumption per unit equals to fuel consumption of the voyage / freight volume multiply sailing distance. It is impossible to calculate the exact value of the fuel used in the voyage. In the calculation, the value of the voyage of the ship based on the carbon content of the fuel used by the ship is about 3.1144, then the EEOI of 068 voyage equals to $3.578*10^{-6}$t/(t.n mile). According to the above calculation results, the EEOI average value of the ship during the year of navigation can be obtained, and the indicators for 2015-2017 are counted, as shown in Table 2.

According to the analysis in Table 2, the fuel consumption in 2015 is larger than that in 2016 and 2017, the fuel consumption is relatively low, and the value of the ship EEOI is also low. The main reason for this result is the ship operation and carbon emission factors. influences.

4. EEOI Impact Factor Analysis

According to the EEOI calculation formula, its value is closely related to the carbon dioxide emission factor and the actual consumption of fuel. The actual consumption of fuel is related to the ship's speed, draft, ship structure and other factors. The carbon dioxide emission factor is related to fuel type and carbon oxidation. The rate is closely related. In addition, EEOI is closely related to ship cargo capacity and sailing mileage, and is not a simple negative correlation.

4.1. Fuel Type

From the calculation formula of the ship energy efficiency operation index, it can be concluded that for the same ship and equipment, changing the fuel can change the EEOI of the ship. The non-dimensional conversion coefficients of carbon dioxide emissions of different fuels are different, as shown in Table 3.

Table 1. Carbon emissions data for a bulk carrier from 2015 to 2017

year	voyage	Fuel consumption/t	Cargo transportation volume/t	Cargo transportation distance/n mile	EEOI/（10^{-6}t/（t.n mile））
2015	051	3980.212	139229	22233	4.19
	052	1084.654	140392	7324	3.28
	053	1232.243	149203	7893	3.26
	054	1531.452	143939	13291	2.49
	055	1623.312	140392	8293	4.34
	056	1834.423	147093	8319	4.67
	057	2614.434	143912	16284	3.47
	058	2013.783	136131	11023	4.18
2016	059	1023.231	135932	4321	5.42
	060	1102.781	139013	5239	4.72
	061	1508.131	145031	4923	6.58
	062	1332.459	143911	5882	4.90
	063	1398.142	139321	6031	5.18
	064	1985.801	132321	7133	6.55
2017	065	1690.251	120012	9031	4.86
	066	1755.534	122231	9231	4.85
	067	1702.312	132241	10323	3.88
	068	1690.312	131311	11231	3.57

Table 2. EEOI distribution from 2015 to 2017

year	Fuel consumption/t	Fuel consumption per cargo turnover/（g/（t.n mile））	EEOI/（10^{-6}t/（t.n mile）
2015	13900.73	1.179	3.671
2016	10364.33	1.342	5.361
2017	6838.409	1.377	4.290

Table 3. Non-dimensional conversion coefficient table for CO2 emissions from different fuels

Fuel type	Reference	Carbon content /%	Emission factors
Diesel/Gas oil	ISO 8217, DMX-DMC	0.875	3.206
Light Fuel Oil	ISO 8217, RMA-RMD	0.86	3.15104
Heavy Fuel Oil	ISO 8217, RME-RMK	0.85	3.1144
Liquefied Petroleum Gas	Propane	0.819	3
	Butane	0.827	3.03
Liquefied Natural Gas	/	0.75	2.75

According to the analysis of Table 3, if the liquefied natural gas is used to replace the fuel mainly used by the current ship as the main fuel, the carbon emission can be reduced to some extent. Because the main component of liquefied natural gas is methane, it has a high calorific value and a low carbon content. The relevant data show that liquid natural gas can reduce carbon dioxide emissions by 25 to 30 percentage points compared with fuel oil. The market price of liquid natural gas is lower than that of ordinary fuel oil, and it has great economics advantage in reducing ship energy efficiency and improving ship operation.

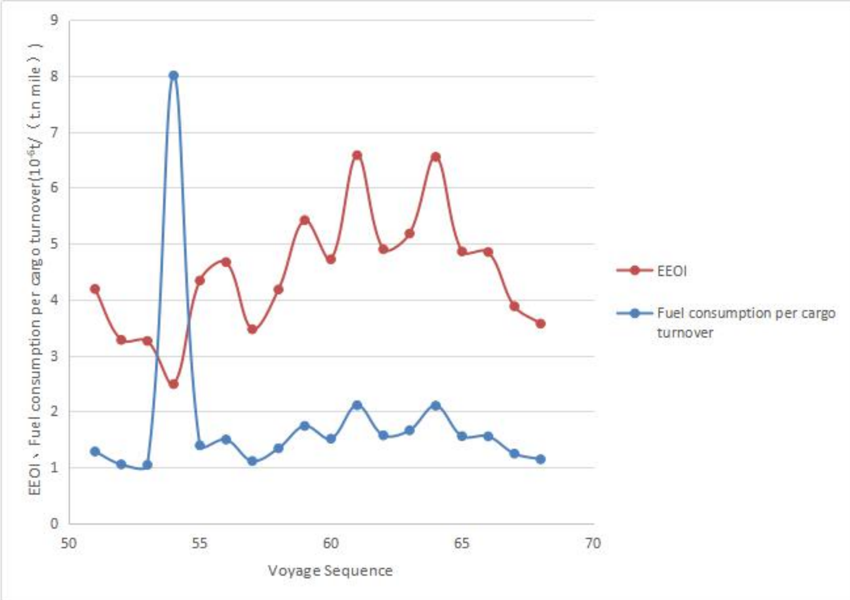


Figure 1. Distribution of EEOI and Fuel consumption per cargo turnover

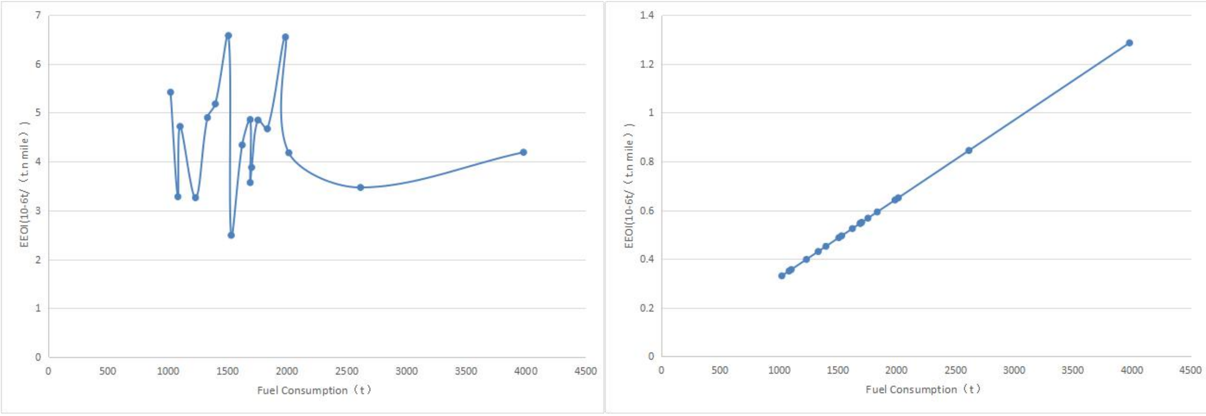
According to the voyage data of the bulk carriers in Table 1, combined with the calculation formula of the ship energy efficiency operation index, the fuel consumption and energy efficiency operation index of each voyage unit of the bulk carrier in 2015-2017 can be calculated, as shown in Figure 1.

In the figure, the ship energy efficiency operation index is basically consistent with the ship unit fuel consumption curve, reflecting that the fuel used by the ships in the above voyages is similar. However, the unit fuel consumption of the 054 voyage is inconsistent with the corresponding ship energy efficiency data, reflecting that the fuel used by the ship in the 054 voyage is different from the previous voyage, and the carbon emission factor of the fuel causes the two indicators in the curve to change inconsistencies!

4.2. Fuel Consumption

According to the EEOI calculation formula of a single voyage of a ship, it can be seen that the amount of carbon dioxide emitted by the completion of the unit cargo turnover is proportional to the amount of fuel consumed by the ship. This indicator takes into account emissions from the amount of fuel consumed by the ship during operation (including during sailing and berthing), equipment, auxiliary machinery and boilers. Therefore, from the perspective of reducing the amount of fuel consumed by equipment such as main engines, auxiliary machines and boilers, the overall system performance of the ship can be effectively improved, thereby reducing the value of the ship EEOI.

In the EEOI calculation formula, the ship energy efficiency operation index is positively correlated with the fuel consumption. However, in Figure 2(1), according to the fuel consumption of each voyage of the ship from low to high, the ship's energy efficiency operation index and oil consumption change are not consistent, indicating that the ship's fuel consumption can not directly reflect its carbon emission level!If the ship's cargo capacity and mileage are kept constant, EEOI is linearly and positively correlated with the ship's fuel consumption, as shown in Figure 2(2).



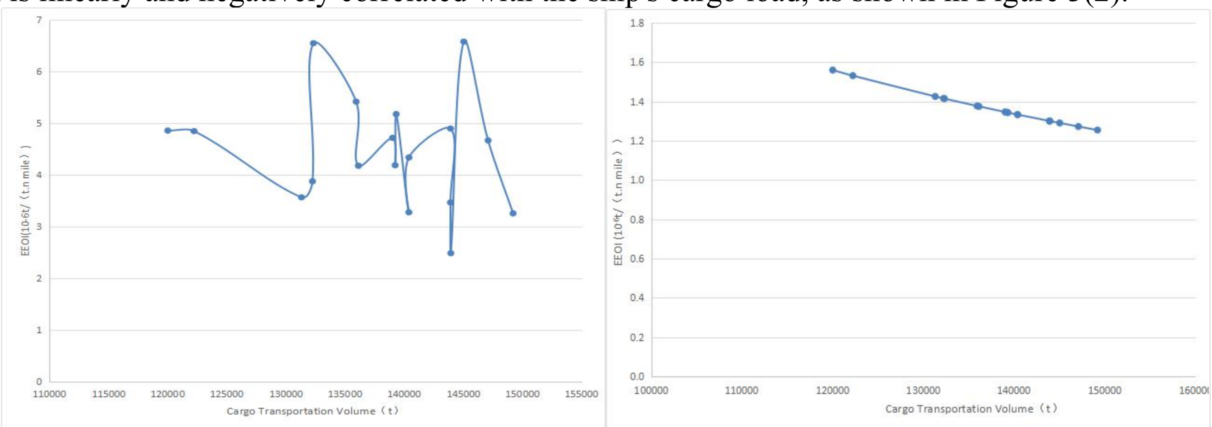
(1) (2)

Figure 2. Correlation chart between EEOI and fuel consumption

4.3. Cargo Transportation Volume

The cargo capacity of a ship is the total tonnage of the cargo loaded on a single voyage. The size of the cargo load directly affects the size of the ship's energy efficiency operating index. There is a certain inverse relationship between the cargo load and the EEOI. The general trend is that the larger the cargo load, the smaller the EEOI value, but when the cargo load is small, the EEOI does not show a clear regular curve. Therefore, special attention should be paid to the maximum cargo capacity of the ship during the operation of the ship. The amount of cargo will directly affect the economics of the ship's operation and the carbon dioxide emissions.

In the EEOI calculation formula, the ship energy efficiency operation index is negatively correlated with the cargo load. However, in Figure 3(1), according to the order of the cargo capacity of each voyage of the ship from low to high, the energy efficiency index of the ship is not consistent with the change of the cargo capacity, indicating that the cargo capacity of the ship cannot directly reflect the carbon emission level! If the ship's fuel consumption and mileage are kept constant, the EEOI is linearly and negatively correlated with the ship's cargo load, as shown in Figure 3(2).

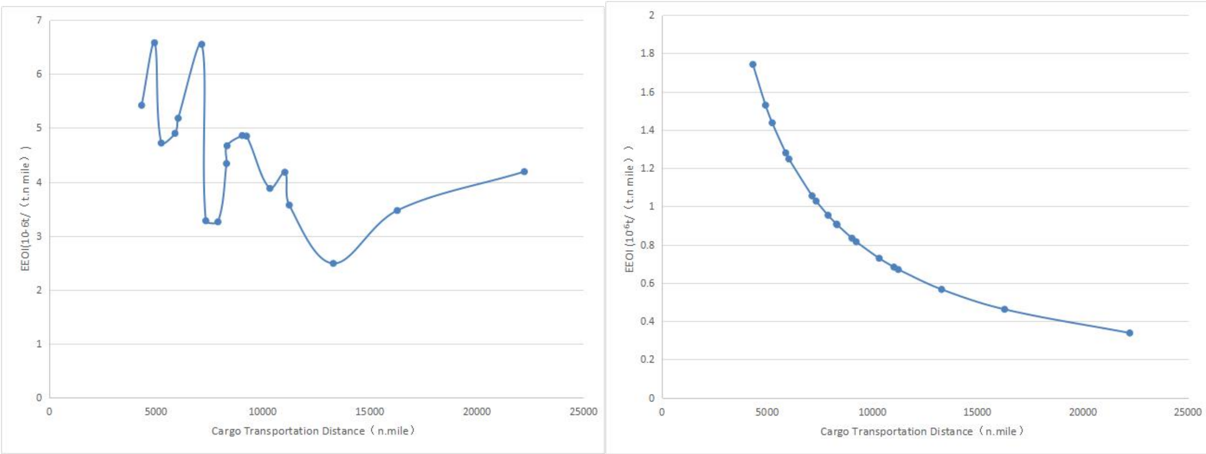


(1) (2)

Figure 3. Correlation chart between EEOI and Cargo transportation volume

4.4. Cargo Transportation Distance

In the EEOI calculation formula, the ship energy efficiency operation index is negatively correlated with the voyage. However, in Figure 4(1), according to the voyage of each voyage of the ship from low to high, the ship's energy efficiency operation index and the voyage change are not consistent, indicating that the ship's voyage cannot directly reflect the carbon emission level! If the ship's fuel consumption and cargo capacity are kept constant, the EEOI is non-linearly and negatively correlated with the ship's sailing mileage, as shown in Figure 4(2).



(1) (2)

Figure 4. Correlation chart between EEOI and Cargo transportation distance

5. Conclusions

This paper focuses on the fuel consumption of the ship's main engine, and mainly analyzes the factors affecting the ship's carbon emissions. It is found that under the same operating conditions, that is, the voyage, speed, cargo volume, and voyage time are certain, the large-scale ship is conducive to improving the efficiency of the ship. In addition, it is also possible to reduce carbon emissions by changing the type of fuel, the amount of fuel, and the carbon oxidation rate, and ultimately achieve the purpose of improving the energy efficiency of the ship.

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