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Study on the Selection of New Energy Vessels in the Yangtze River Delta

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Abstract

In order to achieve the target of energy saving and emission reduction in 2030 and 2050, to achieve green shipping, the transformation of traditional fuel ships to new energy vessels is an inevitable trend, therefore, it is necessary to analyze the environmental and economic benefits of many new energy vessels and find out the optimal new energy ship type. In order to more objective, efficient and fair comparison of the performance of various types of new energy vessels, with traditional fuel ships as the benchmark, the use of power models to analyze the emission reduction effects of various new energy vessels, economics as an auxiliary reference, and finally found that: LNG container ships relative to traditional fuel container ships can reduce pollutant emissions by 80%, compared to other new energy ships earlier economic advantages, and not limited to technical problems difficult to promote, is currently the best choice to achieve green shipping.

Keywords

Environment; Energy Conservation and Emission Reduction; Economy; New Energy Ships; Yangtze River Delta Integration.

1. Introduction

The International Maritime Organization (hereinafter referred to as IMO) has adopted a series of carbon emission reduction strategies from 2008 to 2018 [1], which generally include:Based on 2008 years, at least a 40% reduction in carbon intensity by 2030, to 2050 will be shipping at least halving greenhouse gas emissions, and reduce the average 70% lower by the middle of the century, IMO's goal is to completely eliminate produce greenhouse gases in the century fuel, so IMO is speeding up the pace of building a green shipping,Reduce greenhouse gases and other pollutants from shipping.

China, like IMO, wants to achieve green shipping as soon as possible and complete the transition to environmentally friendly shipping.In order to build green shipping, it is necessary for ships to adopt new green energy.Studies have proved that new energy ships can effectively reduce the pollutant emissions generated by shipping, and even some new energy ships have zero pollution emissions [2,3].According to this estimate, the number of ships in China's 2030 market will need to be medium to medium in order to achieve the IMO2030 carbon reduction targetHowever, according to the hydrogen ship planning statistics of six cities including Wuhan, Hubei Province [4 ~ 9], there will only be 600 pure electric ships by 2025, which cannot meet this requirement. China's shipping transformation to environment-friendly requires the combined use of a variety of new energy ships:On the one hand, to accelerate the research and development of pure electric ships, on the other hand, to find out the ship type with the best emission reduction effect from other new energy ship types, and synchronously implement the reduction of pollutant emissions from ships.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202107_7(7).0028

2. Establish dynamic model based on AIS data to analyze environmental benefits

In this paper, four oil-fired container ships (Hantang Suzhou), pure electric container ships (Zhongtian Dianyun 001), LNG container ships (Lvd7012) and diesel-LNG hybrid container ships (Hongri 166, hereinafter referred to as "hybrid container ships") operating in the inland waterways of the Yangtze River are selected as the research objects.Based on the traditional fuel container ships, the environmental and economic benefits of the other three new energy ships are compared and analyzed.Since the annual mileage and standard container number of selected objects are different in this paper, in order to obtain results with reference value, this paper takes the emissions per container per nautical mile of transportation as the reference index of environmental benefits.The cost per container per nautical mile of transportation is taken as the economic benefit reference index, and the fixed number of years is 20 years.

2.1 Establish the model of ship pollution emission

according to the target ship AIS dynamic data[10] , analysis of the data information in different sailing conditions, using dynamic method for a sailing condition of pollutant emissions, the final summary of pollutant emissions target ship sailing on the various conditions, and as a standard to estimate emissions in the next decade, computing [11, 12] as follows:

$$E=B\times L\times F\times C \tag{1}$$

$$W=MCR\times P \tag{2}$$

$$M=W\times E\times T()\times 10^{-6} \tag{3}$$

In formula:

E: ship pollutant emission factor, g• kW •h^{-1};

B: Marine pollutant baseline emission factor, g• kW •h^{-1};

L: host low load correction factor;

F: Fuel correction factor (according to the requirements of China's emission control area, the Yangtze River Delta inland river ships need to use light diesel oil with sulfur content of no more than 0.1%);

C: Emission reduction control factor (no emission reduction measures are considered in this paper and C=1);

W: actual power of main engine, auxiliary engine or boiler of the ship, kW;

MCR: Rated power of ship main engine, kW;

P: load coefficient of ship main engine;

M: pollutant discharge from ships,t;

The emission factor in this paper refers to the 2012 Air Pollutant Emission List of the Port of Los Angeles, USA [12]. This emission factor is based on the heavy oil with 2.7% sulfur content. When the sulfur content of ship fuel is different from that of the heavy oil, the fuel correction factor is used to correct it [13].The excessively low load of ship main engine will cause the increase of pollutant emission, so the low load correction factor of ship main engine is used for correction [12,13].The emission factors of air pollutants from ships refer to the Technical Guide for the Preparation of Emission Inventory of Air Pollutants from Non-road Mobile Sources of the Ministry of Environmental Protection of the People's Republic of China (Trial) [14].

Table 1. Fuel container ship information

Ship	Main engine power (kw)	Main engine speed (r/min)	Low sulphur oil fuel type	Engine type	Maximum load (t)	Design speed (kn)	Year
Oil	360	1200	MGO	MCR	1989	10	2018
Hybrid	441	1350	MGO	HFO	1596	11	2004

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3. Case study of ship environmental benefit

3.1 AIS data and other basic information of the ship

(1) The basic information see table 1.

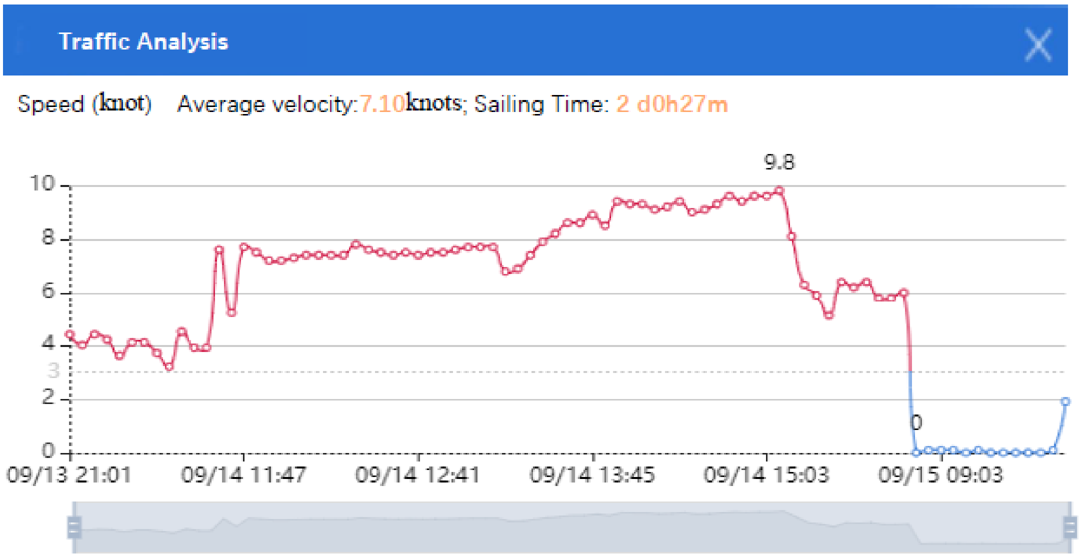

Fig 1. Speed analysis diagram of oil-fired container ship

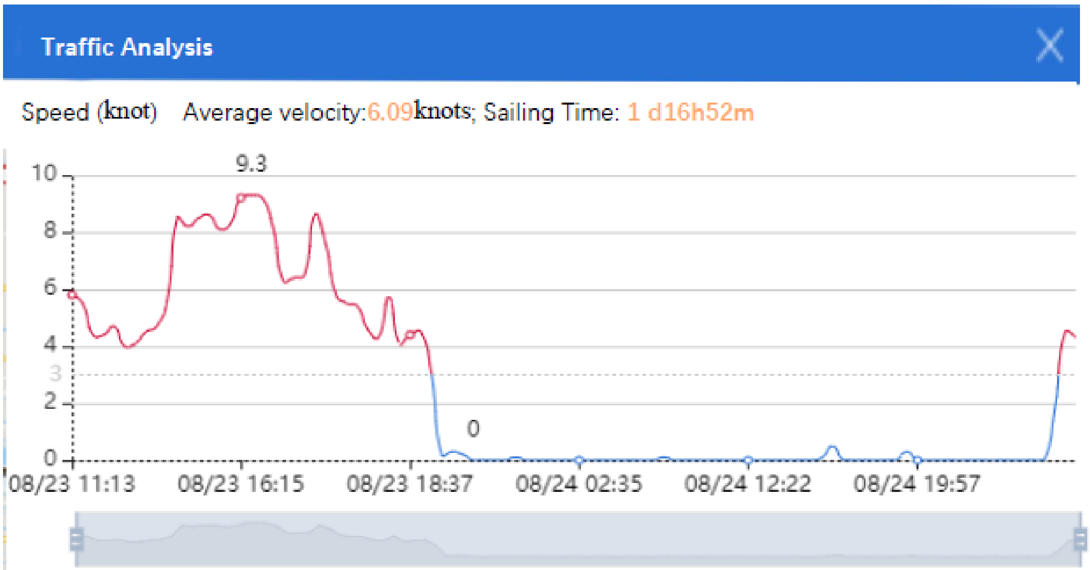

Fig 2. Speed analysis diagram of hybrid container ship

Figure 1 shows the activity levels of oil-fired container ships and hybrid container ships under different sailing conditions. The analysis results are shown in Table 2 and Table 3.

Table 2. Average activity level of oil-fired container ships under different sailing conditions

Project	Cruise (speed ≥12knots)	Low speed cruising (8knots≤speed <12knots)	Motor (3knots≤speed <8knots)	Anchoring (1knots≤speed <3knots)	Anchor (speed <1knots)
Length per cycle /h	0	3	27	1.5	17
10 years cumulative duration /h		5418.5567	48767.0103	2709.2784	30705.1546
Average speed per kN	-	8.5	5	2	0
Load of main machine /%	75	50	18	10	0

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Table 3. Average activity level of hybrid container ships under different sailing conditions

Project	Cruise (speed ≥12knots)	Low speed cruising (8knots≤speed <12knots)	Motor (3knots≤speed <8knots)	Anchoring (1knots≤speed <3knots)	Anchor (speed <1knots)
Length per cycle /h	-	0.01382	6.5330	0.9	33.5532
10 years cumulative duration /h	-	29.5300	13958.3122	1922.9268	71689.2310
Average speed per kN	-	8.1	4.79	1.5	0
Load of main machine /%	75	50	18	10	0

3.2 Ship environmental benefit analysis process

It is easy to obtain from the above model of ship pollution discharge: M=W×E×T×10-6=MCR×P×B×L×F×C×T×10^{-6}, and the emissions of the same pollutant from the same ship under different sailing conditions are cumulative, so the calculation process is as follows:

Table 4. Calculation of pollutant emission from oil-fired container ships

Pollutants	Sailing conditions	Vr	Vd	P	MCR(kw)	B	L	F	C	T×10-6(h)	Missions
PM	cruise	8.5	10	0.85	360	1.59	1	0.17	1	5418.557	5.944t
	motor	5	10	0.5	360	1.59	1.04	0.17	1	48767.010	
	anchoring	2	10	0.2	360	1.59	1.38	0.17	1	2709.278	
	anchor	0	10	-	360	-	-	-	-	-	
NO_x	cruise	8.5	10	0.85	360	10.2	1	0.17	1	5418.557	3.053t
	motor	5	10	0.5	360	10.2	1.04	0.17	1	48767.010	
	anchoring	2	10	0.2	360	10.2	1.38	0.17	1	2709.278	
	anchor	0	10	-	360	-	-	-	-		
SO_2	cruise	8.5	10	0.85	360	2.1	1	0.17	1	5418.557	2.246t
	motor	5	10	0.5	360	2.1	1.04	0.17	1	48767.010	
	anchoring	2	10	0.2	360	2.1	1.38	0.17	1	2709.278	
	anchor	0	10	-	360	-	-	-	-		
CO	cruise	8.5	10	0.85	360	5.1	1	0.17	1	5418.557	3.028t
	motor	5	10	0.5	360	5.1	1.04	0.17	1	48767.010	
	anchoring	2	10	0.2	360	5.1	1.38	0.17	1	2709.278	
	anchor	0	10	-	360	-	-	-	-		

Annotation: Benchmark emission factors of host pollutants in The table are taken from The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2012 [12]. Fuel Fuel Modification Factor Modification Based on Port of Los Angeles Air Emissions Inventory 2009 [13];The low load correction factor of ship main engine is obtained from "Xiamen Ship Control Area Air Pollutant Emission Inventory and Pollution Characteristics" [11] and "Port of Los Angeles Air Emissions Inventory -2009, ADP #050520-525" [13]. The emission factors of air pollutants from ships refer to the Technical Guide for the Preparation of Emission Inventory of Air Pollutants from Non-road Mobile Sources of the Ministry of Environmental Protection of the People's Republic of China (Trial) [14].

Table 5. Calculation of pollutant emission from electric container ships

Pollutants	Missions
PM	0t
NOx	0t
SO2	0t
CO	0t

Table 6. Calculation of pollutant emission from LNG container ships

Pollutants	LNG	Missions/10000m3LNG	Missions
PM	1800t	2.4kg	0.779t
NOx	1800t	1.89kg	0.681t
SO_2	1800t	1kg	0.324t
CO	1800t	2.3kg	0.746t

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Annotation: The pollutant emission coefficient per unit volume of LNG in the table is taken from the Technical Guide for the Preparation of Air Pollutant Emission Inventory of Non-road Mobile Sources of the Ministry of Environmental Protection, PRC (Trial) [14].

Table 7. Calculation of pollutant emission from hybrid container ships

Pollutants	Sailing conditions	Vr	Vd	P	MCR (kw)	B	L	F	C	$T\times10^{-6}$(h)	LNG	Emissions /m3LNG	Emissions
PM	cruise	8.1	11	0.736	441	1.59	1	0.17	1	29.530	1260t	2.4kg	0.878t
	motor	4.8	11	0.435	441	1.59	1.04	0.17	1	13958.312			
	anchoring	1.5	11	0.136	441	1.59	1.38	0.17	1	1922.927			
	anchor	0.0	11	0.0	441	-	-	-	-	-			
NO_x	cruise	8.1	11	0.736	441	10.2	1	0.17	1	29.530	1260t	1.89kg	0.709t
	motor	4.8	11	0.435	441	10.2	1.04	0.17	1	13958.312			
	anchoring	1.5	11	0.136	441	10.2	1.38	0.17	1	1922.927			
	anchor	0.0	11	0.0	441	-	-	-	-	-			
SO_2	cruise	8.1	11	0.736	441	2.1	1	0.17	1	29.530	1260t	1kg	0.384t
	motor	4.8	11	0.435	441	2.1	1.04	0.17	1	13958.312			
	anchoring	1.5	11	0.136	441	2.1	1.38	0.17	1	1922.927			
	anchor	0.0	11	0.0	441	-	-	-	-	-			
CO	cruise	8.1	11	0.736	441	5.1	1	0.17	1	29.530	1260t	2.3kg	0.762t
	motor	4.8	11	0.435	441	5.1	1.04	0.17	1	13958.312			
	anchoring	1.5	11	0.136	441	5.1	1.38	0.17	1	1922.927			
	anchor	0.0	11	0.0	441	-	-	-	-	-			

Annotation: Benchmark emission factors of host pollutants in The table are taken from The Port of Los Angeles Inventory of Air Emissions for Calendar Year 2012 [12]. Fuel Fuel Modification Factor Modification Based on Port of Los Angeles Air Emissions Inventory 2009 [13]; The low load correction factor of ship main engine is obtained from "Xiamen Ship Control Area Air Pollutant Emission Inventory and Pollution Characteristics" [11] and "Port of Los Angeles Air Emissions Inventory -2009, ADP #050520-525" [13]. The emission factors of air pollutants from ships refer to the Technical Guide for the Preparation of Emission Inventory of Air Pollutants from Non-road Mobile Sources of the Ministry of Environmental Protection of the People's Republic of China (Trial) [14].

3.3 Ship environmental benefit analysis results

According to the data information of each ship, the total pollutant emission of each ship (10 years) and the pollutant emission results per container per nautical mile are obtained, as shown in Table 8.

Table 8. Detailed table of pollutant emission from various ships

Project	Oil	Electric	LNG	Hybrid
TEU	124	124	120	128
Distance(n mile)	19425.8580	19425.858	23423.4	13340.75
CO(t)/proportion(%)	3.0267/100.00%	0/0.00%	0.7787/25.73%	0.887/29.31%
NOx(t)/proportion(%)	6.0534/100.00%	0/0.00%	0.681/11.25%	1.042/17.21%
PM(t)/proportion(%)	3.9436/100.00%	0/0.00%	0.3244/8.23%	0.384/9.74%
SO2(t)/proportion(%)	2.2463/100.00%	0/0.00%	0.7462/33.22%	0.762/33.92%
CO discharge per container per nautical mile(g)/proportion(%)	1.256514/100.00%	0/0.00%	0.277038/22.05%	0.519438/41.34%
NOx discharge per container per nautical mile(g)/proportion(%)	2.513029/100.00%	0/0.00%	0.242279/9.64%	0.610207/24.28%
PMdischarge per container per nautical mile(g)/proportion(%)	1.637159/100.00%	0/0.00%	0.115412/7.05%	0.224875/13.74%
SO_2discharge per container per nautical mile(g)/proportion(%)	0.932537/100.00%	0/0.00%	0.265475/28.47%	0.446236/47.85%

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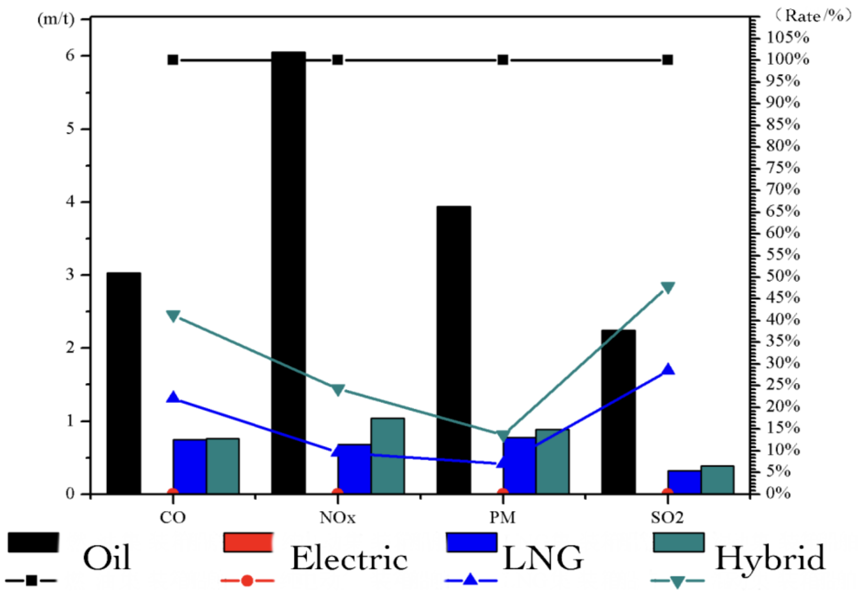

Fig 3. Analysis diagram of total pollutant emission of various ships (10 years) and pollutant proportion per container per nautical mile

There is an important premise in this paper: fuel container ships and hybrid ships operate in the emission control area of the Yangtze River Delta all the year round, so they need to use fuel with sulfur content less than or equal to 0.5%mm in accordance with the requirements of the emission control area of the Yangtze River Delta to reduce pollutant emissions. Analysis of figure 3 shows that:

(1) In terms of pollutant emission reduction, three kinds of new-energy container ships are obviously superior to oil-fired container ships. In particular, without considering the pollutants generated in the production, construction and scrapping process, the fuel cell technology used by pure electric container ships basically achieves zero transportation emission and has the best environmental benefits.Without considering economic cost and promotion difficulty, pure electric container ships are the best choice to build green shipping.

(2) Fuel container ships and hybrid container ships have the highest total NOx emissions, because the main engine NOx benchmark emission factor (B=10.2) in the fuel process is significantly higher than that of other main engine pollutants, and the calculated total pollutant emission is a multiplier formula, which has a magnifying effect on the calculated results.Finally, the NOx emission of the two pollutants is significantly higher than that of other pollutants.

(3) The emissions of CO and SO2 from LNG container ships are relatively high, which is caused by the different coefficient of pollutants produced by LNG per unit volume. In actual transportation, the coefficient of pollutants produced by LNG per unit volume will change due to the different composition of natural gas from different gas suppliers, and the calculation results will also change accordingly.

(4) 30% of the power of hybrid container ships comes from diesel, but NOx and PM emissions account for 17.21% and 9.74% of NOx and PM emissions of oil-fired container ships, which are lower than 30%. This is because new energy reduces NOx and PM emissions of hybrid container ships.It can be seen that the effect of new energy to help shipping to reduce nitrogen emissions and particulate emissions is very superior;

(5) The total SO2 emissions of hybrid container ships account for 33.92% of the corresponding pollutant emissions of fuel container ships, which is higher than 30%. This is because hybrid container ships spend the most time in berthing state and fuel container ships spend the most time in maneuvering operation.As a result, the main engine load coefficient of hybrid container ships (P=0.736) is higher than that of oil-fired container ships (P=0.5).

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(6) Since the number of standard containers (TEU) and the mileage of the research objects selected in this paper are different, the pollutant emission per container per nautical mile can be used as an environmental benefit indicator to more accurately represent the emission reduction results.The emission reduction effect of new energy ships is superior, especially the environmental benefit index of pure electric ships is obviously higher than that of other types of ships. Secondly, the environmental benefit index of LNG container ships and hybrid container ships is also very ideal, especially in the emission of particulate matter, which can be reduced by about 80%.

(7) The number of TEU transported by LNG container ships is almost the same as that of fuel container ships, but the mileage of the former is 1.2 times that of the latter, which greatly reduces the pollutant emission per container per nautical mile of LNG container ships.Therefore, the proportion of pollutant emissions per container per nautical mile of LNG container ships in the proportion of pollutant emissions per container per nautical mile of oil container ships is 1%-5%, relative to the proportion of total pollutant emissions of the two.

(8) The number of TEUs transported by hybrid container ships is similar to that of fuel container ships, but the mileage of the former is only 69% of that of the latter. The lower mileage also weaken the emission reduction advantage of hybrid container ships.Its pollutant emissions per container per nautical mile accounted for the pollutant emissions per container per nautical mile of fuel container ships, and the ratio of the total pollutant emissions of the two vessels increased by 4% ~ 14%.

4. Economic benefit analysis

This paper divides economic cost into construction cost, operation cost and voyage cost.Among them, the construction cost includes the cost of the ship or the rent and other expenses;Operating cost refers to the regular maintenance cost generated by the shipping company to ensure the normal navigation service of the ship;Voyage cost refers to a series of costs incurred by a ship during the voyage mission, mainly including electricity (fuel cost), port cost, canal and various commissions [16].In order to improve the reference of economic costs, 20 years of operation time is taken as the calculation period.

4.1 Cost data

The economic cost and annual voyage information of the object studied in this paper are shown in Table 9.

Table 9. List of ship economic costs

Ship	TEU	Construction cost (ten thousand Yuan)	Operation and maintenance cost (ten thousand Yuan/year)	Voyage cost (ten thousand yuan/year)	Sailing distance (n mile/ year)
Oil	124	600	166	197.37648	19425.858
Electric	124	1700	230.4	69.84	19425.858
LNG	120	710	176	43.02	23423.4
Hybrid	128	658	214.67	149.72412	13340.75

Note 1: According to the documents of the Ministry of Transport, ships are required to use Marine fuel with sulfur content of no more than 0.1%m/m when entering inland rivers [17-19].

Note 2: The amount of subsidy in the table is taken from the Administrative Measures for Standardized Subsidy Funds of Inland River Vessels [20];

Table 10. Annual fuel consumption and fuel prices of ships

Ship	Oil	Electric	LNG	Hybrid
Annual fuel consumption	720t	634900kw·h	180 t	420t(LNG)+18t(Oil)
The unit price	2741.34 Yuan/t	1.1Yuan/ kw·h	2390Yuan/t	Same as the previous data

4.2 Economic benefit analysis results

The cumulative total economic cost of each ship in 10 years is shown in Table 10, and the annual transport cost per container per nautical mile of each ship and its comparison with the cost of fuel container ships are shown in Figure 4:

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Table 11. Total economic cost of each ship in 10 years

Project	Oil accumulated economic cost (ten thousand Yuan)	Electric accumulated economic cost (ten thousand Yuan)	LNG accumulated economic cost (ten thousand Yuan)	Hybrid accumulated economic cost (ten thousand Yuan)
TEU	124	124	120	128
Mileage/n mile	19425.858	19425.858	23423.4	13340.75
0 year	600.000	1700.000	710.000	658.000
1 year	963.376	2000.240	929.020	957.642
2 years	1326.753	2300.480	1148.040	1187.284
3 years	1690.129	2600.720	1367.060	1416.9276
4 years	2053.506	2900.960	1586.080	1646.569
5 years	2416.882	3201.200	1805.100	1876.212
6 years	2780.259	3501.440	2024.120	2105.854
7 years	3143.635	3801.680	2243.140	2335.496
8 years	3507.012	4101.920	2462.160	2565.139
9 years	3870.388	4402.160	2681.180	2794.781
10 years	4233.765	4702.400	2900.200	3024.424
11 years	4597.141	5002.640	3119.220	3254.066
12 years	4960.518	5302.880	3338.240	3483.708
13 years	5323.894	5603.120	3557.260	3713.351
14 years	5687.271	5903.360	3776.280	3942.993
15 years	6050.647	6203.600	3995.300	4172.636
16 years	6414.024	6503.840	4214.320	4402.278
17 years	6777.400	6804.080	4433.340	4631.921
18 years	7140.777	7104.320	4652.360	4861.563
19 years	7504.153	7404.560	4871.380	5091.205
20 years	7867.530	7704.800	5090.400	5320.848

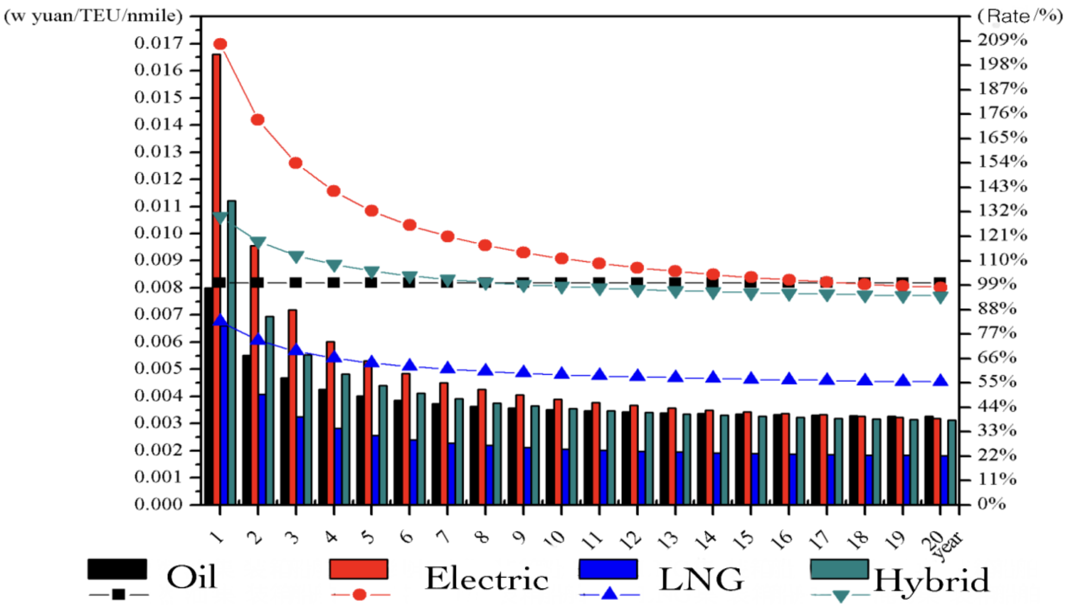

Fig. 4 The annual transport cost per container per nautical mile of each ship and the comparison with the unit transport cost of fuel container ships

The analysis of Figure 4 shows that:

(1) of pure electric fuel cell power equipment such as cost of container ship and operational cost is higher, the initial investment is about fuel container ship 2 times, in the first 18 years unit transportation cost is higher than the fuel container ship, only in the last two years and now the market aboard in fuel cell technology is not mature, the service life of the battery for 15 years or so commonly,This means that pure electric container ships need to replace batteries and increase

ISSN: 2414-1895 DOI: 10.6919/ICJE.202107_7(7).0028

operating costs before showing economic benefits in the 18th year. As a result, the weak economic advantages of pure electric container ships after the 18th year will be reduced or disappear, and may even be lower than the economic benefits of oil-fueled container ships.

(2) the LNG container ship 13 kinds of new energy container ship, the only reflect economic advantage in the early new energy container vessels, and good economic advantage in the expansion, the late 1 years occupied 83% of the fuel container shipping unit transportation cost, only 55% of 20 years, economic advantages to increase from 17% to 45%,An increase of 28%. If the two vessels are in continuous use,The economic benefits of the LNG container shipAdvantage has a tendency to continue to expand.

(3) hybrid container ship is due to the dual power system, so the initial construction cost is higher than the fuel container ships, so 1 year 130% of the fuel container shipping unit transportation cost, basic flat, 8 years from the beginning of 9 show the economic advantages of hybrid container ship, the late economic advantages to increase slightly,In the 20th year, it accounted for 94% of the unit transport cost of fuel container ships, which increased by 36% from -30% economic disadvantage to 6% economic advantage. The development potential of LNG container ships is greater than that of LNG container ships.

5. Conclusion

By comparing the environmental and economic benefits of four kinds of new-energy container ships, namely pure electric container ships, LNG container ships and hybrid container ships, with those of oil-fired container ships, this paper finds out the following problems and gives solutions.

(1) The emission reduction effect of pure electric container ships is the best, which is most in line with the purpose of green shipping. If such ships are promoted and used, the time to achieve the emission reduction target of 2030 and 2050 will be greatly accelerated. However, there are obstacles to the promotion and development of pure electric container ships in the domestic market: 1) The cost of power equipment such as fuel cells purchased at the initial stage and subsequent operation and maintenance costs of pure electric container ships are relatively high; 2) Due to technical limitations, the use time of fuel cells is earlier than the time to reflect its economic advantages; 3) Replace the battery on the ship will increase the operating cost of the ship, so it is not clear whether the economic benefits of pure electric ships are better than those of oil-fired ships.

This paper proposes the following solutions for the problems: 1) to solve the problem of electric ship larger initial investment, from the policy can give electric and hybrid container ship to encourage, for example, increase the intensity of subsidies, to realize the diesel and electric powered ships operating costs, you need to early subsidies cost 66.6%; Adjust the object of financial subsidy and directly subsidize shipowners; In terms of fiscal subsidies and various preferential policies, we should make reasonable planning and coordination to maximize the effectiveness of subsidies and policies.

2) Set technology research and development funds to promote the rapid maturity of pure electric technology, so as to promote the use of electric ships in China. I believe that with the improvement of technology, the battery purchase cost is expected to be further reduced in the future, so the development of electric ships has a very broad prospect in the future.

(2) Although the emission reduction effect of hybrid container ships is ideal, it also has the advantage of economic benefit in the later stage, and it has the advantage of convenient conversion from oil tanker to hybrid ship, but the initial investment cost is higher than that of oil-fired container ships, so that the economic benefit advantage of hybrid container ships is obvious at the beginning of the ninth year. Therefore, from the perspective of operation and maintenance costs, financial subsidies or policy support for hybrid container ships will promote the enthusiasm of changing existing oil-fired container ships into dual-powered ships, and effectively reduce pollutant emissions.

(3) There are still difficulties in the large-scale promotion of pure electric container ships, so the green shipping construction and the emission reduction targets set by the IMO can be achieved through

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LNG container ships and hybrid container ships, and the latter has ideal emission reduction effect and economic benefits, and is more suitable for the current domestic ship market environment. In particular, although 30% of the power of hybrid container ships comes from diesel, their NOx and PM emissions account for 17.21% and 9.74% of the NOx and PM emissions of oil-fired container ships.

6. Ending

With the gradual acceleration of green shipping construction, the emission reduction and economic advantages of new energy ships are becoming more and more obvious. Regarding the emission reduction and economic benefits of various new energy ship types, this paper chooses container ships in the same water area with similar number of containers and similar working nature as the research object, and takes traditional oil-fired container ships as the benchmark. The emission reduction effect and economy of the other three kinds of new energy ships are compared quantitatively to select the container ships with the best emission reduction effect suitable for the current shipping market. Based on the calculation results, this paper points out the problems existing in emission reduction and economy of new energy ships and gives corresponding solutions.

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