Brief Analysis on The Current Situation of LNG Fuel Powered Ship and The Challenge of LNG Fuel Bunkering

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Abstract-In order to realize the green, low-carbon and sustainable development of shipping, liquefied natural gas (LNG) fuel powered ships as an effective measure of energy saving and emission reduction in shipping, have been paid attention to by the shipping industry. Based on the statistical data of Det Norske Veritas, this paper studies the proportion of global LNG fuel powered ships in clean energy ships and the types of ships which used LNG as fuel through data comparison and analysis. At the same time, the paper further makes a comparative analysis of the bunkering mode of LNG fuel powered ships and the supply and demand status of LNG bunker vessels and puts forward constructive suggestions, with a view to providing reference for the development of bunkering of LNG fuel powered ships in China.

Keywords: LNG fuel powered ship, energy saving and emission reduction, comparative analysis, fuel bunkering, development suggestions

1. INTRODUCTION

In 2018, the 72nd meeting of IMO (the International Maritime Organization) MEPC (Marine Environmental Protection Committee) adopted the preliminary strategy for ship greenhouse gas emission reduction, which made an overall deployment for the shipping industry to respond to climate change [1]. The use of clean fuel for ships is an effective technical route to achieve green, low-carbon and sustainable development of shipping. According to Clarkson's statistical data, as of the beginning of November 2021, about 4.2% of the ships in the global fleet use clean fuel in terms of total tons, and 34% of the ships in the existing orders use clean fuel [2]. In addition, according to the data of DNV alternative fuel insight (DNV AFI), at present, ships using LNG (liquefied natural gas) as fuel account for 12.14% of all ships using alternative fuels and related emission reduction technologies. As an effective measure for shipping energy conservation and emission reduction, LNG fuel powered ships have attracted great attention from shipping enterprises in various countries. However, with the growth of the fleet of LNG fuel powered ships, the research and practice of LNG fuel bunkering, bunkering methods and the scale of bunker vessels are still in the preliminary stage. Minghan Luo [3] studied the current situation of LNG powered ships and marine LNG bunkering stations in various countries under the background of energy saving and emission reduction in shipping, analyzed the deep-seated reasons for the backward development of China's LNG powered ships, and explained that the number of LNG bunkering stations is insufficient and the distribution is unreasonable.

ICICA 2022, December 02-04, Chongqing, People's Republic of China

DOI 10.4108/eai.2-12-2022.2327980

Chenglong Yu [4] selected the current typical LNG powered ships for fuel calculation and calorific value analysis, determined the capacity of the bunker vessel, and proposed relevant LNG bunkering requirements by referring to the fuel oil bunkering experience. Shuhai Sun [5] analyzed and compared the common bunkering methods of LNG powered ships, and assessed that during the design and construction stage of LNG powered ships, bunkering design should be carried out according to the operation bunkering methods and characteristics, and the bunkering of LNG ship- to- ship bunkering is the trend. Haifeng Fang [6] analyzed the favorable and unfavorable factors for the development of LNG bunkering station through practical experience, and gave suggestions for the development of LNG bunkering industry. Wenda Zhu [7] elaborated the development status of global LNG fuel powered ships and port LNG bunkering industry through data analysis. Based on the prediction of marine LNG fuel bunkering market demand, he analyzed the existing problems of marine LNG bunkering industry and proposed corresponding solutions.

To sum up, although there are many studies on LNG fuel powered ships and LNG bunkering, the general defect is the lack of data support, which makes it difficult to explain the real supply and demand of Marine LNG fuel. This paper analyzes the application of global LNG fuel powered ships and bunker vessels from the data, studies the fuel supply status of LNG powered ship's major types, and gives guidance and suggestions on the insufficient bunkering matching of LNG fuel powered ships.

2. ANALYSIS OF CURRENT SITUATION OF LNG FUEL POWERED SHIP

2.1 Status quo of LNG powered ships and other clean fuels and technologies

There are two types of LNG fuel powered ships, one is to use LNG as the main engine fuel, and the other is to use LNG and fuel oil to provide dual fuel power for the engine [3].

According to the data of DNV, as of July 27, 2022, a total of 6716 ships (including those in operation and ordered) in the world have respectively used clean fuels such as LNG, methanol, LPG and hydrogen and emission reduction technologies such as scrubber to achieve energy conservation and emission reduction, including 815 LNG powered ships and 229 LNG ready ships, accounting for 12.14% and 3.41% respectively. The specific application of alternative fuels and emission reduction technologies is shown in Figure 1.

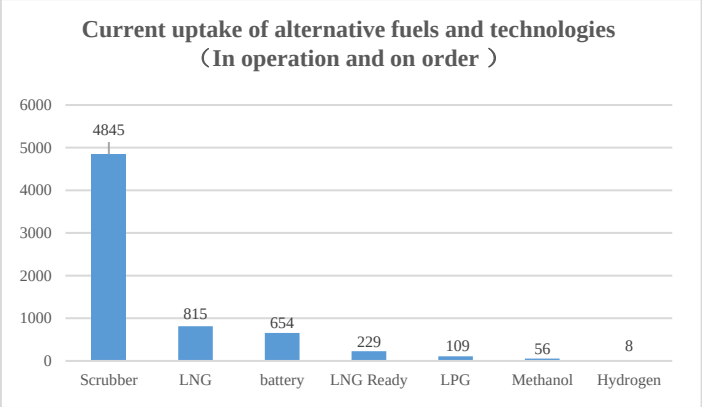

Figure 1. Application status of alternative fuels and technologies

It can be seen that compared with the number of ships installing scrubber, LNG powered ship as a new clean energy ship has better application and development prospects.

2.2 Global LNG fuel powered ship operation status

According to the data of DNV, there are 304 LNG fuel powered ships in operation in the world, including 289 newbuild ships and 15 retrofitted ships. As is shown in Figure 2.

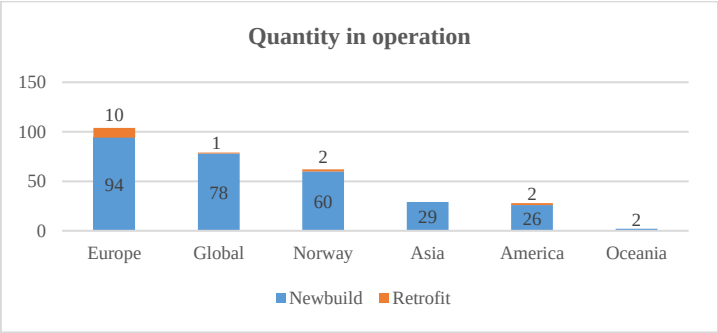

Figure 2. Operation status of LNG powered ships

It can be seen from Figure 2 that there are 180 newbuild ships which are operated in Europe, America and Norway, accounting for 62.28% of all newbuild LNG powered ships, and only 29 ships in Asia, accounting for 10.03%. It can be seen that Europe and America have taken the lead in ship energy conservation and emission reduction.

2.3 LNG fuel application status of different ship types

According to the data of DNV, LNG fuel has been widely applied in 16 types of ships, including container ships, crude oil ships, dangerous chemical carriers, car carriers and bulk carriers. Among them, the number of container ships is the largest, including 37 ships in operation and 172 ships on order.

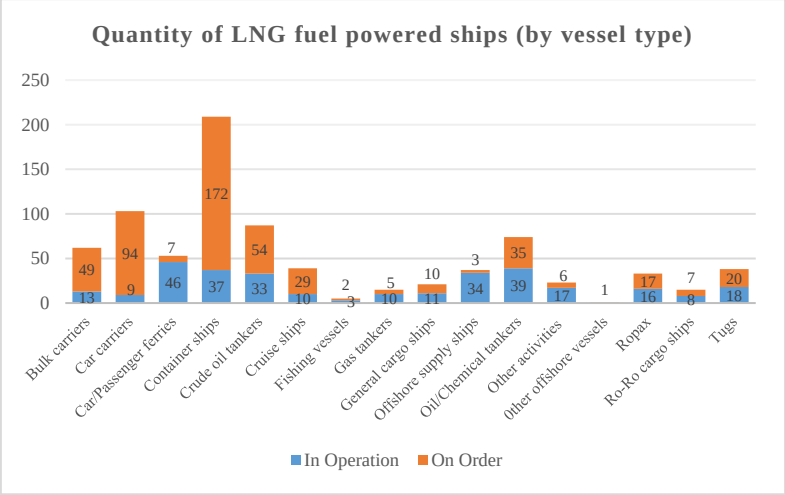

Figure 3. Number of LNG powered ships of different ship types

In comparison, offshore ships, fishing vessels and gas tankers use less LNG fuel. From the perspective of the order quantity, the scale of the container LNG powered ships is the largest, and the application of LNG in car carriers and bulk carriers has also increased significantly. As is shown in Figure 3.

3. BUNKERING MODE OF LNG FUEL POWERED SHIPS

At present, there are three main bunkering methods for LNG fuel powered ships: tank truck-to-ship bunkering (TTS), LNG intermediary terminal to ship via pipeline bunkering (TPS)and ship to ship bunkering (STS). The most widely used method is tank truck to ship bunkering. The bunkering method of TPS has been widely applied in Norway. The application of bunkering with bunker vessels is developing slowly. In 2013, the world's first LNG bunker vessel built by Cryo AB company in Sweden was put into operation in Viking line [4].

3.1 Tank truck to ship bunkering

Tank truck to ship bunkering is to provide LNG fuel bunkering service for the LNG fuel powered ship berthed at the port through the liquid tank of the tank truck. The liquid tank of one LNG tanker is usually loaded with about 49m³ LNG fuel. The bunkering time is about 1 hour [5]. TTS bunkering has great advantages over small tank capacity LNG ships.

3.2 LNG intermediary terminal to ship via pipeline bunkering

Terminal to ship via pipeline bunkering refers to the LNG bunkering service provided by the ship bunkering station at the shore terminal for the LNG fuel powered ship. Small LNG storage tanks are arranged at the wharf and hoses are used for bunkering. The TPS bunkering has high bunkering efficiency and is applicable to coastal ports and inland river wharfs with stable water level, and can also be used with LNG pontoons. According to relevant specifications, the maximum tank capacity that can be arranged at the shore station is 600 m^3, therefore, TPS

bunkering is only applicable to the bunkering of small capacity LNG fuel powered ships [5].

3.3 Ship to ship bunkering

Ship to ship bunkering means that special LNG bunker vessels are used to provide LNG fuel bunkering services for LNG fuel powered ships at the wharf or anchorage. The LNG bunker vessel has large single bunkering volume, high bunkering efficiency, good mobility and flexible operation. It is applicable to the bunkering of large LNG fuel powered ships. In addition, the LNG bunker vessel can also conduct LNG fuel replenishment for the onshore LNG terminal [6].

4. RESEARCH ON SUPPLY AND DEMAND OF LNG BUNKER VESSELS

4.1 Operation status of LNG bunker vessel

According to DNV data, there are 38 LNG bunker vessels in operation in the world, which can provide refueling services for 304 LNG fuel powered ships in operation worldwide. The number of LNG fuel powered ships in Europe is the largest, and there are 18 currently, followed by 6 in Asia and America. Among the recent orders, 8 ships from Asia are in the leading position, followed by 5 ships from Europe and America. On the whole, Europe, America and Asia are accelerating their investment in bunker vessels. The number of bunker vessels in different regions is shown in Figure 4.

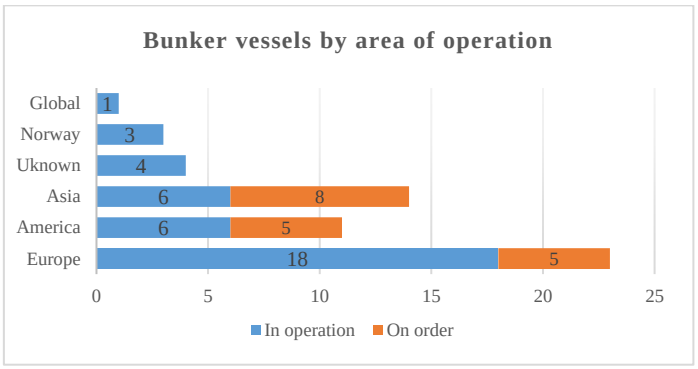

Figure 4. Number of bunker vessels in different regions

According to the comparative study of existing data, the ratio of LNG fuel powered ships in operation and LNG bunker vessels in operation in the world is 8:1. In Europe, there are 18 LNG bunker vessels in operation, while there are 104 LNG fuel powered ships in the region. The ratio of LNG fuel powered ships to LNG bunker vessels is about 5.8:1. In Asia, there are 6 LNG bunker vessels in operation and 29 LNG fuel powered ships in the region. The ratio of LNG fuel powered ships to LNG bunker vessels is about 4.8:1. It can be seen that there is little difference in the proportion of LNG powered ships to LNG bunker vessels between Europe and Asia.

4.2 Supply and demand matching analysis of single ship LNG fuel

In order to deeply analyze the LNG fuel supply and demand of large-scale LNG fuel powered

ships, the storage tank volume of existing LNG bunker vessels is first studied. At present, there are mainly four types of storage tank volume of LNG bunker vessels which are respectively less than 1000m³, 1000 m³ to 5000 m³, 5000 m³ to 10000 m³ and above 10000 m³ . Among them, the number of bunker vessels in operation that its storage tank volume is between 5000 m³ and 10000 m³ is the largest, with a total of 19. There are 8 LNG bunker vessels in operation with storage tanker volume between 1000 m³ to 5000 m³. There are 7 LNG fuel bunker vessels with storage tank volume more than 10000 m³. The volume statistics of the fuel tank of the LNG bunker vessel is shown in Figure 5.

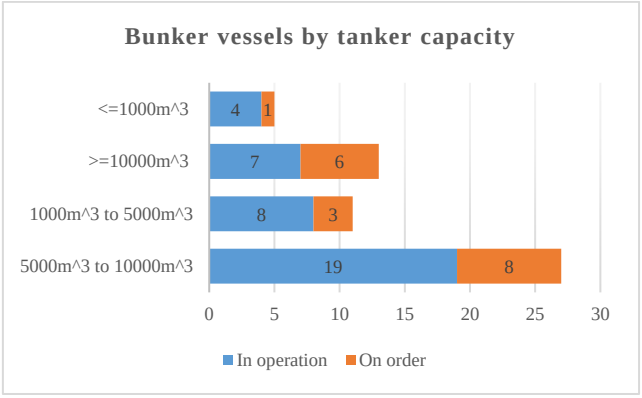

Figure 5. Capacity of fuel tank of LNG bunker vessel

According to Clarkson's statistics, by the end of March 2022, there were 686 LNG powered ships in operation worldwide, including 296 LNG container powered ships and LNG powered crude oil ships, accounting for 36.32%. In addition, according to the order data of 26 LNG fuel powered ships of Korea Daewoo shipbuilding in the last 12 months, the LNG fuel tank volume of the ship has different designs according to the ship type, as shown in Table 1.

Table 1. Orders of LNG fuel powered ships of Daewoo shipbuilding in recent year

Ship Type	Number of ships	Shipowner/charterers	Ship size	Number and size of fuel tanks
VLCC	10	AET and International Seaways/ Royal Dutch	300000DWT	2*3000cbm
Container ship	12	Herbert	23660TEU	1*185000cbm
VLCC	4	Adnoc	300000DWT	2*3000cbm

It can be seen from table 1 that the tank capacity of VLCC (Very large crude carrier) fuel tank is 2*3000cbm (cubic meter) and that of LNG container ship fuel tank is 1*18500cbm.

4.3 Comparative study on tank capacity of LNG bunker vessels and fuel tank capacity of the above two main ship types

Matching scheme 1: consider filling one super large LNG dual fuel container ship with LNG

fuel. In order to ensure efficient filling, two 10000cbm fuel bunker vessels are required. However, at present, there are only 7 LNG fuel bunker vessels with more than 10000cbm tank capacity in the world, and they are distributed in different regions. And there are 37 LNG container powered ships in operation in the world.

Matching scheme II: considering that a dual fuel VLCC powered ship is filled with LNG fuel, a fuel bunker vessel with a tank capacity of more than 6000cbm is required. However, there are only 19 LNG bunker vessels with a capacity of 5000cbm to 10000cbm in the world. At present, there are 33 LNG crude oil tankers that need to be bunkered in the world.

Therefore, with the increasing number of large-scale container LNG powered ships, crude oil ships and other LNG fuel powered ships, it can be predicted that large-scale LNG bunker vessels will not be able to meet the demand of various regions and ports for LNG fuel refueling. Each country needs to reasonably increase large-scale LNG fuel bunker vessels according to ship routes and refueling needs.

5. CHALLENGES AND OPPORTUNITIES FACED BY LNG FUEL BUNKERING INDUSTRY

With the promotion of energy saving and emission reduction in shipping, LNG fuel as a power fuel for ships will be paid more and more attention by the shipping industry. Therefore, the construction of LNG fuel bunkering ships and the improvement of the maritime service capacity of clean fuels will also meet new opportunities and challenges.

5.1 Build an international LNG fuel bunkering Center

Keeping the LNG price stable is an effective way to promote the development of LNG fuel bunkering center. The relevant government departments of the country should establish the oil and gas price binding mechanism, prepare the price index of LNG fuel for ships, ensure that the LNG fuel has certain price advantages compared with the traditional marine fuel, give the shipowners a relatively stable price expectation of LNG resources, improve the enthusiasm of the shipowners to use LNG, and promote the sustainable development of the LNG ship bunkering industry [7].

5.2 Improve the service capacity of LNG bunker vessel

Among the three main LNG fuel bunkering methods, the LNG fuel bunker ship can provide bunkering services with different geographical locations, large filling volume and high bunkering efficiency for various types of ships [8]. Therefore, it is necessary to strengthen cooperation with shipping enterprises to build fuel bunker ships suitable for different ship types, select safe bunkering berths and anchorages, formulate standard operating procedures, and provide convenient and preferential LNG fuel refueling services for ship owners.

5.3 Speed up the layout of LNG bunker vessel to ensure the matching between LNG powered ship and LNG terminals

In recent years, the major ports of the main shipping lines in the world have deployed the LNG bunkering business, with Singapore port and Rotterdam port as the representatives, which have

realized the rapid growth of LNG bunkering business. From March 14 to 15, 2022, the world's largest LNG bunker vessel "Harbor future" filled about 7000 cubic meters of LNG for the large container dual fuel ship "CMA CGM SYMI" docked at Yangshan Port, Shanghai [9], creating the first bunkering business for large LNG dual fuel power container ships in Chinese ports. However, it also reflects the slow development of LNG bunkering business in China [10]. Therefore, China should speed up the expansion of the LNG fuel bunker vessel business market.

5.4 Suggestions

First, adhere to the principle of matching of the supply and demand of ships operating in the port and bunker vessels, and ensure that the bunkering demand of LNG fuel powered ships and the LNG bunkering business develop synchronously.

Second, strengthen cooperation with large-scale energy enterprises, work together to build a LNG powered ship bunkering network covering major coastal and inland ports, and build an international LNG bunkering center.

Third, focus on accelerating the layout of ship-to-ship LNG bunkering, and compete for the status of the international ship fuel bunkering center in the current wave of decarbonization of the shipping industry.

6. CONCLUSION

By analyzing the market application status of global LNG fuel powered ships and the challenges encountered in the development of the marine LNG fuel bunkering industry, this paper puts forward three suggestions to ensure that the LNG fuel supply matches the bunkering demand of ships arriving at the port, build an international LNG bunkering center and speed up the layout of ship-to-ship LNG bunkering, which have certain practical significance for solving the problem of high efficient bunkering of LNG fuel powered ships. The next research direction will be to use the mathematical model of operational research to build the optimal quantity ratio of the main ship types of LNG VLCC and large-scale LNG container power ships to LNG bunker vessels, which will provide a theoretical basis for the practice of LNG bunkering industry.

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