Research on Filling of Large Coastal LNG Fuel Powered Ships

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Abstract. With the implementation of MARPOL convention and related environmental protection policies, LNG as fuel power has become an important technical means to promote the green development of shipping. The construction and operation of large ocean-going ships in the world put forward an urgent demand for LNG filling. This paper points out that there is an urgent need to issue the design and technical standards of shore-based filling stations, the approval and operation of filling stations, the regulations on ship navigation management, and the related research on safety and emergency, etc., which puts forward the work direction for the future coastal LNG filling work.

Keywords. MARPOL Convention, LNG filling, Navigation management.

1. Introduction

In the International Convention for the prevention of pollution from ships (MARPOL), the International Maritime Organization (IMO) has formulated a sulfur restriction order in 2020, which stipulates that the sulfur content standard in marine fuel oil should be reduced from 3.5% to 0.5% from January 1, 2020, so as to achieve the goal of reducing 80% of sulfide emissions [1]. Ship owners and carriers can meet the requirements of the Convention by installing desulfurizing tower, using low sulfur oil or modifying ships to use new fuel (LNG or LPG). The maritime administration of the Ministry of transport of China issued the implementation plan of the global marine fuel sulfur restriction order 2020, which for the first time explicitly declared that China would not encourage the use of desulfurization tower, which means that Chinese ships and other ships may choose marine LNG or low sulfur fuel as the main fuel [2].

The Ministry of transport issued the implementation plan for the ship emission control zone in the Pearl River Delta, Yangtze River Delta and Bohai Sea Rim (Beijing Tianjin Hebei) waters, and the implementation plan of special action for ship and port pollution prevention and control (2015-2020), which require ship energy conservation and emission reduction and green development of shipping. LNG has become a powerful alternative to marine fuel [3-4].

In 2018, the Ministry of transport issued the document on further promoting the application of LNG in the water transportation industry (Draft for comments), which requires the optimization of the regulatory detailed planning and layout of LNG filling stations in the port area to enhance coastal filling service capacity, and promote the construction of international LNG filling centers around Bohai Sea, Yangtze River Delta and Pearl River Delt [5-6]. In 2020, the State Council issued the "Reply of the State Council on several measures to support the opening up and development of the whole oil and gas industry chain in China (Zhejiang) pilot free trade zone", supporting the formulation of management measures and operation specifications for marine LNG filling in Zhejiang pilot Free
Trade Zone, and pilot development of marine LNG filling business. It is imperative to develop LNG filling business [7].

2. Foreign LNG Filling
Norway, French and other European countries and Singapore have carried out LNG filling relatively early. LNG powered ships are mainly used for passenger ships shuttling across the Straits. The filling forms are mainly tank cars and small shore-based filling.

2.1. LNG Fuel Powered Ships
Around 2000, northern Europe began to be promoted LNG as ship fuel, mainly on passenger ferries, platform supply ships and freight ships. As of March 2018, there were about 248 LNG powered ships in operation and under construction abroad, and 182 orders were planned to be built or signed contracts. New LNG powered ships tend to be larger-scale and ship routes are globalized. Carnival group's 4 LNG powered luxury cruise ships, French CMA CGM 922,000 TEU super large LNG powered container ships are also the world's largest container ships at present, have 18600m³ fuel tank volume for round-trip journey.

2.2. Filling Mode
In early 2013, the world's first LNG tanker was put into operation at vikingline, one of Finland's major cruise lines. The ship was built by cryoab company in Sweden. The storage tank is vacuum insulated tank with a capacity of 180m3. In addition, FKAB of Sweden (see table 1), Kawasaki of Japan, TGE of Germany, Rolls Royce of the UK, Wartsila of Finland, STX of South Korea, bodewes of the Netherlands and GTT of France are also working on the design and construction of LNG bunkering vessels or LNG filling / transportation dual-purpose ships.

2.2.1. Ship to Ship (STS). According to the international transportation needs of Japan, Australia and other countries, the British and French spent fuel sea transportation enterprises (PNTL) make regular transportation plans and use special ships for transportation. From Japan to the British port of barrow and the French port of Thurburg, three routes have been planned respectively through the Panama Canal, around the Cape of good hope or cape horn. In terms of route selection, first, consider the security conditions of the channel, especially anti-piracy; second, the backup requirements of the channel. LNG bunkering ships to be delivered in 2019-2021 are as follows.

| Year | Ship owner | Operator / tenant | Home port | country | LNG tank capacity(m³) |
|------|------------|------------------|-----------|---------|----------------------|
| 2019 | Korea Line | Kogas            | Busan     | Korea   | 7500                 |
| 2019 | Titan LNG  | --               | Antwerp   | Belgium | 1680                 |
| 2019 | Titan LNG  | Shell            | Rotterdam | Netherlands | 3000               |
| 2019 | Titan LNG  | --               | Amsterdam | Netherlands | 1480               |
| 2019 | Central LNG Marine Fuel | -- | central section Japan | Japan | 3500 |
| 2020 | Japan Corporation | -- | | | 2500 |
| 2020 | Ecobunker Shipping | Harvey Gulf/ShellTBD | | | 4000 |
| 2020 | Q-LNG | Total | ARA | U.S.A | 4000 |
| 2020 | MOL | Total | the Baltic | Netherlands, Belgium | 18600 |
| 2020 | ShurmanKoshelev | Gazpromneft | the Baltic | Russia | 5800 |
| 2021 | EestiGaas | -- | the Baltic | Estonia | 6000 |
| 2021 | MOL | Total | Singapore | Singapore | 12000 |
| 2021 | Avenir LNG | -- | Oristano | Spain | 7500 |
| Year | Ship owner     | Operator / tenant | Home port  | country | LNG tank capacity(m³) |
|------|----------------|-------------------|------------|---------|----------------------|
| 2021 | Avenir LNG     | --                | Oristano   | Spain   | 7500                 |

2.2.2. *Pipe to Ship (PTS)*. At present, the main application is small passenger ships or cargo ships, so the existing filling gas stations are small. LNG filling time is generally 1 hour, 5 min preparation and berthing (excluding precooling time), 45 min filling, 10 min ending and disembarking. Its LNG tank capacity is 500~2000m³, and LNG is supplied by tank cars or adjacent LNG receiving stations.

3. China's Current LNG Filling
In China, LNG powered ship engine filling is mainly used in inland river area.

3.1. *In Land River Ships*
The pilot work of LNG (LNG) powered ships in inland river basins such as Xijiang River and Beijing Hangzhou Grand Canal has been fully launched. Since the application of LNG powered ships in 2010, nearly 200 ships have completed the "oil to gas" project.

3.2. *In Land River Stations*
In late September 2014, the oil and gas Department of the State Energy Administration held a forum on "guiding opinions on the layout of LNG fuel powered ship filling stations", which will form "two horizontal, two vertical, two network and eighteen lines" (i.e., the Yangtze River trunk line, the Xijiang River trunk line, the Beijing Hangzhou canal, the national coastal waters, the Yangtze River Delta high-grade waterway network, the Pearl River Delta high-grade waterway network, Minjiang River and other 18 branch rivers) The distribution network of LNG filling for ships is proposed. As of December 2018, 19 inland river filling stations had been completed and 3 have been put into operation. Please see the following figure 1.

"Xijiang Xin'ao 01" is the first standardized bunkering barge built in China after the implementation of the "code for classification and construction of LNG fuel water filling barges". It is constructed in the mode of pontoon type filling station, which is composed of shore base and filling barge. The Bank Foundation covers an area of 334m², with a length of 78m, a width of 16m, a depth of 3.2m and a draft of 1.4m. It is equipped with two 100m³ LNG gas storage tanks, and the LNG / diesel dual fuel filling function can be filled at most 1.2t at a time, which takes 40-60min.

![Figure 1. Xijiang Xin'ao 01.](image-url)
3.3. Coastal LNG Filling
A small number of small LNG powered ships, such as offshore platform supply vessels (PSV), tugs, etc., are filled by tank trucks.

At present, there is an LNG carrier with mobile filling function in China, but it has not obtained CCS certification, so it is limited to be engaged in LNG transfer in some areas.

By the end of 2020, an 8500 m³ LNG fuel filling ship of Dachuan group will be the first largest C-type tank LNG filling ship in the world built by domestic shipyards. The total length is about 119.3 meters, the hull width is 19.8 meters, the depth is 11 meters, the design draft is 5.9 meters, and the structural draft is 6.2 meters. It is a semi pressure / full cooling LNG filling ship driven by single propeller and dual fuel main engine and suitable for navigation in unlimited navigation area.

3.4. Coastal LNG Filling Regulations

3.4.1. Standards. The Ministry of transport has promulgated the code for the classification and construction of LNG filling barges on water, the design standards for LNG filling stations for ships, and the design specifications for LNG bunkering terminals which are applied in inland river navigable waters, such as rivers and lakes, and the design of filling and berthing positions of LNG bunkering barges Design standard of coastal filling station.

3.4.2. Management Regulations. The ministry of transport promulgated the "safety supervision and management of LNG filling station on water", which is "applicable to the pontoon for LNG fueling on water by LNG fuel powered ships, and the combined construction of oil and gas barges." The technical requirements for tank car filling operation of natural gas fuel powered ships (Draft for comments) are applicable to tank car filling, while the safety regulations for LNG fuel filling on water (Draft) is applicable to STS filling on water, but there is no management regulation and operation guide for shore based filling.

4. Further Work

4.1. Construction of LNG Filling Facilities
The first is to formulate as soon as possible the layout plan of LNG filling facilities and the construction scheme of LNG fuel supply guarantee system which can meet the actual filling demand in China's coastal waters.

The second is to formulate the standards and specifications for the construction of LNG filling facilities for coastal ships (newly built, reconstructed terminal) and regulatory guidelines, further clarify the construction approval and operation supervision of LNG filling facilities, and accelerate the construction of LNG filling facilities for coastal ships.

4.2. Navigation Regulations
To study and promulgate safety supervision and management regulations for navigation of LNG powered seagoing vessels. According to the safety characteristics and operation requirements of LNG powered sea going vessels, this paper studies and defines the safety management methods for large ocean-going LNG powered ships entering and leaving the port.

4.3. Safety Technical Guides
To study and promulgate technical guidelines for direct filling of fuel powered vessels or filling vessels, and carry out safety risk assessment and emergency related research on shore-based filling and anchorage filling.
5. Conclusion
Through policy research, international and domestic information collection, this paper abstracts the LNG filling situation, finds out the shortage of LNG filling in China’s coastal areas, and points out that it is urgent to issue the design technical standards of shore based filling stations, the approval and operation of filling stations, the regulations on ship navigation management, and the related research on safety and emergency, so as to provide technical guidance for future planning, construction and management.

Acknowledgments
Thanks to the Ministry of transport for their strong support, providing technical materials and on-site investigation.

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