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Research on New Fuels for Marine Internal Combustion Engines Under the Low-Carbon Background

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Abstract. More than 80 percent of the global goods are transported by sea. Traditional ships use the heavy oil and diesel as the fuel, and cause environmental pollution. In order to deal with this problem, the International Maritime Organization has set the targets for the shipping emission reduction. China is also working towards the goals of carbon peaking and carbon neutrality. The marine power systems should turn to the green energy.This paper studies four new fuels for marine internal combustion engines: liquefied natural gas (LNG), methanol, hydrogen and ammonia. This paper explains the features, advantages and disadvantages of each fuel. And then, it makes a full comparison from five aspects: the environment protection, the technology, the storage and transportation, the safety and the commercial use.The research results indicate that LNG is a transitional fuel with mature technology and high safety. Methanol is easy to use and will be widely promoted in the near future. Hydrogen and ammonia can realize zero carbon emissions. Hydrogen fit inland and short-distance ship, and ammonia works better for ocean-going vessels. The marine new fuels will develop in diverse ways in the future.

Keywords: Low-carbon transformation, marine internal combustion engine, green shipping

1. Introduction

Sea transport plays an important role in global trade. Over 80% of international goods are transported by sea. Most of the traditional ships burn heavy oil and diesel. During the sailing, they give out a lot of carbon dioxide, sulfur oxides, nitrogen oxides and solid particles. These pollutants seriously damage the atmosphere and marine environment. Data shows that ships produce 8.1% of the world's sulfur oxide emissions and 15.2% of nitrogen oxide emissions [1]. The shipping industry has become one of the main sources of air pollution.

Faced with the global warming and the ecological damage, the International Maritime Organization put forward "Initial Strategy on Reduction of Greenhouse Gas Emissions from Ships" in 2018. The rule requires the shipping industry to cut the greenhouse gas emissions by at least 50% by 2050 compared with the level in 2008, and finally reach zero carbon emissions [2]. Besides, the European Union, China, Japan, South Korea and other countries and regions have also issued the strict environmental rules and low-carbon policies.

Green ships are a key part of the drive for carbon peaking and carbon neutrality in China. Traditional fossil fuel ships cannot meet the new requirements. At present, LNG, methanol,

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hydrogen and ammonia are the four most promising new fuels for marine engines. Most of the existing studies only focus on one or two of them. In this paper, the four fuels are given a full introduction and comparison, and their development trends are analyzed. It can offer useful references for the ship fuel selection.

2. Analysis of four main new marine fuels

2.1. Liquefied natural gas (LNG): mature transitional fuel

LNG is the most widely used clean fuel at present. The main component is methane. It almost produces no sulfur oxides or solid particles. Compared with diesel, its nitrogen oxide emissions drop by about 80%, and carbon dioxide emissions reduce by 20% to 25% [3]. Ships using LNG do not need big changes on their original engines. LNG dual-fuel engines can match existing marine power systems well. The technology to control methane leakage has been improved greatly. Many real ship tests have proved that LNG hybrid power systems have low energy use and little pollution [4]. Up to now, more than 950 ships around the world use LNG power. The large ship of China, called Xinhaixun, also use LNG dual-fuel technology and meet the strictest international emission standards. LNG is a reliable transitional fuel for the shipping industry in short time [4]. Now the researchers mainly work on the optimizing hybrid systems, the control of the leakage of methane and building more LNG refueling stations [5].

2.2. Methanol: main fuel for near-term promotion

Methanol is liquid at normal temperature. The method of storage and refueling is similar to the traditional fuel. The ships using methanol only need simple change. The overall cost is low and the fuel is good safety. Methanol burns clean. If it is made from biomass and green power, it can nearly reach zero carbon emissions [6]. The thermal efficiency of methanol dual-fuel engines can be over 40%. With direct injection technology, methanol can replace 92% of fossil fuel [7].

Many shipping companies such as Maersk and COSCO SHIPPING have put methanol powered ships into use. A number of large methanol oil tankers have been delivered in China [6]. Many think that methanol will be the core fuel for shipping's low-carbon development in the near future. Current research mainly focuses on methanol-electric hybrid systems, efficient combustion technology and low-cost production of green methanol [4].

2.3. Hydrogen: ideal fuel for inland and short-distance ships

Hydrogen is a real zero-carbon fuel. It has high heat value and fast response. It only produces water after burning and create no polluters. It can be used for both internal combustion engines and fuel cells [2]. Hydrogen engines may have backfire and knocking problems. But people can solve these problems by improving engine structure and adding explosion-proof devices [7]. The hybrid system of fuel cells and internal combustion engines can make full use of energy. The total efficiency is above 55%. Ships using hydrogen can realize zero carbon during inland short-distance trips [7].

Many countries are also testing hydrogen powered ships [4]. The "Sea Change" hydrogen fuel cell ferry in the United States has been put into service. Hydrogen is hard to store and easy to burn and explode. Related research now focuses on stable combustion and safety protection. Hydrogen powered ships are gradually moving from tests to real use [8].

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2.4. Ammonia: key fuel for ocean-going ships

Ammonia contains no carbon. It will not produce carbon dioxide after burning. Its energy density is higher than liquid hydrogen. Its storage and transportation technology is mature. It can be supplied through existing chemical industry chains, so it is very suitable for large ocean-going ships [1]. Ammonia is hard to ignite and burns unstably. It also tends to produce nitrogen oxides. To solve these problems, some researchers mix ammonia with hydrogen to help combustion, and install denitrification equipment. After improvement, ammonia engines can achieve the secondary emission standards. Wärtsilä launched commercial ammonia-fueled engines in 2022, and some ammonia powered ships designed in China have passed international certification. Ammonia is seen as a key zero-carbon fuel for future ocean shipping [9]. Now some researchers are working on better combustion and safety control technology.

In summary, what can be said is that new marine fuels will develop in different stages. In the short run, LNG and methanol will be in the leading position. In the medium and long run, hydrogen and ammonia will be the core zero-carbon fuels [6].

3. Comprehensive comparison of four new fuels

3.1. Environmental performance

LNG is a kind of fossil fuel. It can cut pollution greatly but cannot reach zero carbon. It also has the risk of methane leakage [10, 11]. Methanol is a low-carbon fuel with very few pollutants [12]. Green methanol can nearly realize zero carbon. Hydrogen has the best environment performance and causes no pollution at all [13]. Ammonia will produce nitrogen oxides during burning, so ships need extra exhaust treatment equipment [14].

3.2. Technical maturity

The most complete LNG engine technology is the most widely used. Methanol engine technology is also mature and has been used in commercial service. Hydrogen engines still have the technical problem such as backfire and knocking [13]. Ammonia has the highest technical difficulty because it is hard to ignite and burns unstably [14].

3.3. Storage and transportation

Methanol is liquid at room temperature. People can use existing storage and refueling facilities directly [12]. Ammonia can turn into liquid under normal pressure and can rely on existing chemical supply chains [14]. LNG needs to be stored at ultra-low temperature, and its storage tanks take up a lot of space [9]. Hydrogen has strict storage rules and high costs [13].

3.4. Safety performance

Because hydrogen is easy to burn and explode, it has the highest safety risks [13] . Ammonia is toxic and corrosive, but it has a special smell to give early warnings. Methanol is slightly toxic and corrosive, and its flame is hard to find [12]. LNG has complete safety rules, and the lowest risks for large scale use.

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3.5. Commercial development

LNG has been used in commercial shipping [11]. Methanol is in the rapid growth period [12]. And, hydrogen and ammonia are in the demonstration and trial stage, and they will be put into large-scale use in step in the future.

4. Research on ammonia-hybrid power ships

4.1. Working principles

It is hard to ignite for ammonia, and hydrogen is difficult to store. Therefore, combining the two into ammonia-hydrogen hybrid fuel can make up for their weaknesses. It will be a major development direction for future ocean-going ships. There are three main application forms: 1. On-board hydrogen production: Store liquid ammonia on ships. When working, split part of ammonia into hydrogen. Use hydrogen to ignite the rest of the ammonia. The whole process realizes zero carbon. 2. Mixed combustion: Hydrogen can speed up ammonia combustion. First, mix ammonia and hydrogen in a certain ratio, then send the mixed gas into engines. 3. Fuel cell and engine hybrid system: Make hydrogen from ammonia to supply fuel cells. For making full use of energy, the waste gas from fuel cells will be reused by internal combustion engines. Ammonia-hydrogen hybrid technology solves the two biggest problems of single hydrogen or ammonia fuel. The overall performance is better [1].

4.2. Features of emission, refit and operation

The features of emission, refit and operation are described as below:

(1) Emission performance: It produces no carbon dioxide, sulfur oxides or solid particles. The content of nitrogen oxides is lower than pure ammonia fuel. With exhaust treatment devices, it can meet emission standards easily. Unburned ammonia can be reduced by proper mixing.

(2) Ship refit: The refit work is the most complex. The ships need to install ammonia storage, hydrogen production and gas mixing systems. Two sets of safety devices for explosion prevention and poison protection are needed. Pipes and equipment should resist hydrogen leakage and ammonia corrosion. The refit cost is higher than that of single-fuel ships.

(3) Daily operation and maintenance: The work becomes more difficult. Crews need to master the operation and emergency skills of both hydrogen and ammonia. More regular inspections are needed. Workers must have higher professional ability [1].

4.3. Comparison of hydrogen, ammonia and ammonia-hybrid ships

Table 1 presents the key technical indicators for three zero-carbon ships. They differ in pollution, fuel storage, refit cost, operation risks and suitable ship types.

Table 1. Key technical indicators for zero-carbon fuel ships powered by hydrogen, ammonia and ammonia-hydrogen blend

Comparison Items	Hydrogen-powered Ship	Ammonia-powered Ship	Ammonia-hydrogen Hybrid Ship
Carbon Emission	Zero emission	Zero emission	Zero emission
Main Pollutants	A small amount of nitrogen oxides	Nitrogen oxides, unburned ammonia, nitrous oxide	Low content of nitrogen oxides

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Table 1. (continued)

Storage Difficulty	High (high pressure / low temperature)	Low (liquefied at normal pressure)	Medium (mainly store ammonia)
Refit Cost	Relatively high	High	The highest
Main Operation Risks	Hydrogen brittleness, explosion	Corrosion, ammonia poisoning	Explosion, poisoning and corrosion
Suitable Ship Types	Inland ships, short-distance ferries	Large ocean-going ships	All types of ships

4.4. Industry development status

Hydrogen fuel cell technology is relatively mature. At present, hydrogen-powered inland cruise ships and short-distance ferries have been put into small-scale use [13]. But limited by refueling stations and storage technology, it cannot be used on ocean-going ships for now. Ammonia powered ships are still in design and prototype stage. There are no large commercial ammonia engines in use in the world. Enterprises mainly study ammonia combustion and exhaust treatment technology [14]. Ammonia-hydrogen hybrid technology is still in laboratory and ship test stage. It is also a key research field for many countries. According to the plan in the industry, related ships will start trial operation around 2030, and achieve large scale commercial use after 2035 [1].

5. Conclusion

Using new fuels for marine internal combustion engines is an inevitable trend for the green and low-carbon development of the shipping industry. With the strictly international emission rules and China's dual-carbon goals, traditional fossil fuel ship will be replaced step by step. The four new fuels all have their own advantages. LNG has mature technology and high safety, and serves as a good transitional fuel. Methanol is easy to store and refit, so it will be widely used in the near future. Hydrogen can reach complete zero carbon and suits inland short-distance ships. Ammonia has high energy density and is fit for ocean-going vessels. A single fuel cannot meet all shipping needs, so diverse new fuels will develop together in the future.

The development of new marine fuels will be a very important period for the next ten years. In the short term, the dual-fuel engines of LNG and methanol will take the leading place. More and more refueling station will be built, and the use cost will go down. In the medium and long run, with the progress of green hydrogen and green ammonia technology, hydrogen and ammonia will enter the commercial stage. The shipping industry will really step into the zero-carbon era.

In terms of technology, researchers will keep making breakthroughs in efficient combustion, safe storage and intelligent energy management; in terms of policies, unified global safety rules and supporting policies will be improved; in terms of industry, shipyards, energy companies and ports will work together to build a complete industrial chain.

The development of new marine fuels can improve the inland water environment and strengthen the shipping competitiveness of China. The development of cleaner and smarter green ships will be the mainstream in the future, and also will push the whole shipping industry to move forward steadily.

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References

[1] Hu, Y. Z., Wang, M., Li, L. D., Men, Z., Zhao, X. T., Zhu, Y. Q., & Liu, L. (2023). Innovative development of ammonia–hydrogen powered marine ships in China. *Strategic Study of CAE, 25*(2), 133-146.
[2] Hao, F., Lin, S., Fang, D., & Wen, S. (2026). A review of development of hybrid power driven ships integrated with green energy. *Marine Electric & Electronic Engineering, 46*(1), 1-7.
[3] Liu, J. H., Xiao, J. C., Wei, S. X., & Feng, D. Y. (2016). The status quo and development tendency analysis of green ship. *Ship Engineering, 38*(S2), 33-37.
[4] Huang, C. Y. (2025). Research on the integrated design method of ship hybrid power systems (Master's thesis, Harbin Engineering University).
[5] Ruan, Y. (2025). Combustion efficiency and emission control of ships with liquefied natural gas internal combustion engines. In *E3S Web of Conferences* (Vol. 606, p. 01009). EDP Sciences.
[6] Ma, C. H., An, Y. H., Dou, Q. L., & Sun, K. (2025). Analysis of carbon neutrality routes and policies for global maritime emission. *Ship Engineering, 47*(11), 63-75.
[7] Li, C. J. (2025). Research on performance of hydrogen-based fuel cell and internal combustion engine hybrid system for ship (Doctoral thesis, Harbin Institute of Technology).
[8] Alfatarizqi, A., Semin, S., Ariana, I. M., & Kadirgama, K. (2025). Hydrogen application as a renewable fuel in the internal combustion engine and fuel cell towards zero carbon emission: A technical review. *Journal of Advanced Research in Experimental Fluid Mechanics and Heat Transfer, 21*(1), 96-125.
[9] Ma, D., Jing, J. H., & Han, Z. T. (2025). Research on sustainable marine fuels. *China Water Transport*, (23), 1-4.
[10] Zhou, X. H., Ni, M., Li, J. Y., Hu, Q. Q., & Tian, X. L. (2025). Research on application of LNG-diesel hybrid power in waterway service ships. *China Water Transport*, (09), 69-71.
[11] Wang, A. Q., Sha, Z. R., Wang, H. Y., & Lian, Q. X. (2025). Development trend of LNG-powered ships under dual-carbon goals. *Navigation,* (6), 5-7.
[12] Bing, S. W., Tan, H., Wang, X. N., Qin, S. J., Ji, P., Cheng, H., & Xu, T. (2025). Development status and prospects of methanol-powered ships technology. *Traffic Energy Conservation and Environmental Protection, 21*(4), 159-164.
[13] Wang, H. (2025). *Analysis and prevention of causes of ship hydrogen fuel cell leakage and explosion accidents* (Master's thesis, Beijing Institute of Petrochemical Technology).
[14] Li, X. X., Cheng, H., Luo, T. T., Zhang, Y., & Li, F. Q. (2024). Technological development and challenges of ammonia as alternative fuel for ships. *Ship & Ocean Engineering, 53*(5), 11-15.