**Academic Journal of Science and Technology**
ISSN: 2771-3032 | Vol. 12, No. 1, 2024

# The Application and Prospects of Electric Ships in the Maritime Industry

**Baolong Peng, Rui Sun and Yufan Chen**

School of Shipping, Shandong Jiaotong University, Weihai 264200, China

**Abstract:** With the escalation of global climate change and environmental pollution, the shipping industry urgently needs to undergo transformation. Electric ships, leveraging advantages such as zero emissions, low noise, and high energy efficiency, demonstrate significant potential and market prospects. This paper reviews the current research status of electric ships, discussing the latest advancements and challenges in battery technology and electric propulsion systems. While lithium-ion batteries remain mainstream, issues regarding range and charging speed persist, prompting exploration into new technologies such as solid-state batteries, fuel cells, and sodium-ion batteries. The Battery Management System (BMS) plays a crucial role in enhancing battery safety and reliability. Optimized design and intelligent control strategies have notably improved the efficiency and reliability of electric propulsion systems. The paper summarizes the technological advancements in electric ships, identifies current challenges, and outlines future development directions.

**Keywords:** Electric Power Ships; Battery Technology; Electric Propulsion System; Battery Management System.

## 1. Introduction

As a crucial pillar of the global economy, the shipping industry is responsible for about 90% of international trade transport[1], but it is also one of the main sources of energy consumption and emissions. Traditional ships primarily rely on fuel power, generating large amounts of pollutants such as carbon dioxide[2], sulfur oxides, and nitrogen oxides, which pose serious threats to the atmospheric environment and human health. Therefore, achieving green transformation and sustainable development in the shipping industry has become an urgent issue. In this context, electric ships, as an emerging green and low-carbon transportation mode, have gradually gained widespread attention from the international community.

The research on electric ships began in the late 20th century. With the continuous development of battery technology and electric propulsion technology[3], the depth and breadth of research have gradually expanded. Currently, the research on electric ships mainly focuses on battery technology and electric propulsion systems. At the same time, electric propulsion systems provide power through battery packs or generators, driving motors to rotate propellers[4]. They have advantages such as good maneuverability, strong reliability, high space utilization, and excellent environmental performance. Researchers are dedicated to optimizing the design and control strategies of electric propulsion systems to improve their efficiency and reliability.

**Figure 1.** Electric-powered ship

## 2. Battery Technology

Battery technology is one of the core technologies of electric-powered ships[5], playing a crucial role in their performance, efficiency, and economic viability. Currently, lithium-ion batteries have become the mainstream battery technology for electric-powered ships due to their advantages such as high energy density, long lifespan, and low cost. Lithium-ion batteries possess high charging and discharging efficiency, providing stable and reliable power output to meet the demands of electric-powered ships under different working conditions. However, lithium-ion batteries still face some pressing issues, including relatively slow charging speed, limited driving range, and safety concerns under extreme conditions.

To address these challenges, researchers are actively exploring and developing new battery technologies to enhance the overall performance and competitiveness of electric-powered ships [6].

### 2.1. Solid-state Batteries

Solid-state batteries are considered the representative of the next-generation battery technology, offering advantages such as high energy density, high safety, and long lifespan. Unlike traditional lithium-ion batteries, solid-state batteries employ solid electrolytes instead of liquid electrolytes, significantly reducing the risk of thermal runaway and enhancing battery safety. Additionally, solid-state batteries have a higher energy density, enabling them to store more electrical energy in the same volume, thus extending the driving range of electric-powered ships. While solid-state batteries are still in the research and development phase with initial applications, their potential advantages make them an important development direction for future battery technology in electric-powered ships.

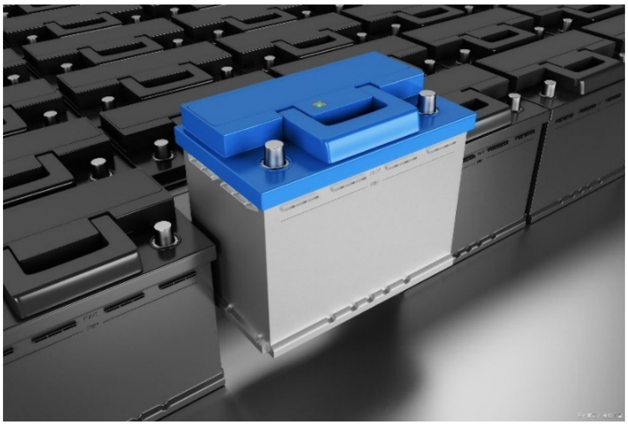
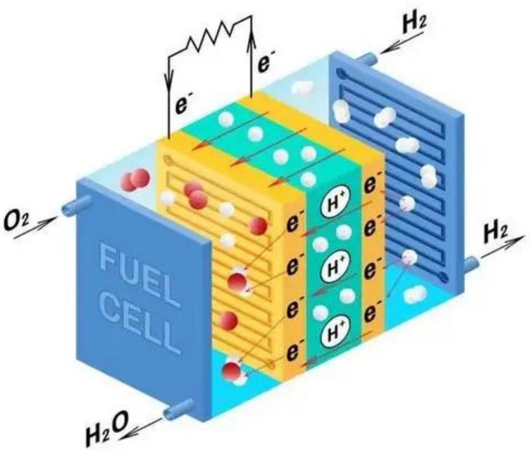


**Figure 2.** Solid-state batteries

### 2.2. Fuel Cells

Fuel cells are devices that directly convert chemical energy from a fuel (such as hydrogen) into electrical energy through an electrochemical reaction[7]. Fuel cells possess high energy conversion efficiency and zero emissions, making them highly suitable for electric-powered ships[8]. Hydrogen fuel cells only produce water during the power generation process, without emitting harmful gases, making them environmentally friendly. However, the main challenges facing fuel cell technology include the maturity and cost of hydrogen production, storage, and transportation technologies. Furthermore, the complexity and high cost of fuel cell systems limit their large-scale application in electric-powered ships. Nevertheless, with continuous technological advancements and the promotion of large-scale production, the application prospects of fuel cells in electric-powered ships remain promising.




"

**Figure 3.** Hydrogen Fuel Cell

### 2.3. Sodium-ion batteries

Sodium-ion batteries, as an alternative technology to lithium-ion batteries, have gradually garnered attention due to their abundant raw materials, low cost, and environmental friendliness. Sodium-ion batteries operate similarly to lithium-ion batteries but use sodium ions as the primary charge carriers. Although sodium-ion batteries have a lower energy density compared to lithium-ion batteries, they possess certain advantages in terms of cycle life and safety, particularly suitable for applications sensitive to cost and resource dependence.

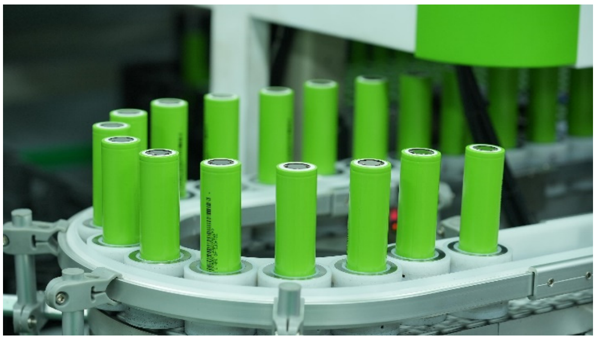


**Figure 4.** Sodium-ion batteries A

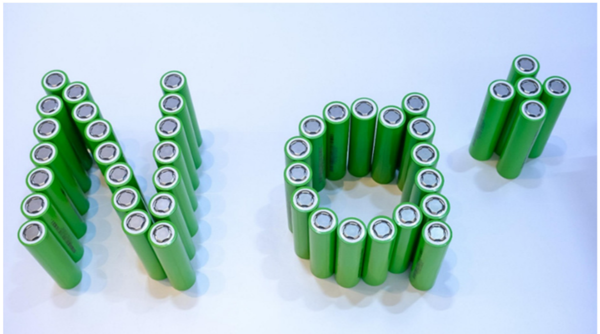


**Figure 5.** Sodium-ion batteries B

### 2.4. Battery Management System (BMS)

Battery Management Systems (BMS) are crucial for electric ships, monitoring battery status in real-time to ensure safety and reliability. They prevent faults like overcharging and overheating while optimizing energy use and extending battery life. Modern BMS integrates big data and AI for efficient battery management, enhancing ship operational efficiency. Ongoing battery tech innovation is key for electric ships, boosting performance and sustainability in the shipping industry.

## 3. Electric Propulsion System

The electric propulsion system is another key technology for electric ships[9]. Its role is to convert electrical energy into mechanical energy to drive the ship forward. This system typically supplies electricity through battery packs or generators, driving motors to rotate the propeller, thus achieving the propulsion of the ship. Compared with traditional internal combustion engine propulsion systems, the electric propulsion system has significant advantages in many aspects[10], making it increasingly popular in modern ship design and applications.

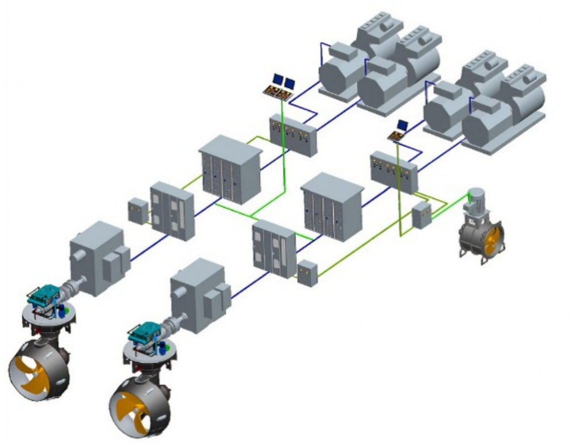


**Figure 6.** Electric Propulsion System

### 3.1. Advantages of Electric Propulsion Systems

**1.Electric propulsion systems boast excellent maneuverability [11].**

Since electric motors can provide instantaneous and precise torque control, electric propulsion systems can achieve more sensitive maneuvering responses. This is particularly crucial for ships requiring frequent speed changes and steering operations, such as harbor tugboats and offshore vessels. The quick response capability of electric motors ensures good maneuvering performance in various complex navigation environments.

**2.Electric propulsion systems are highly reliable.**

Compared to internal combustion engines, electric motors have fewer moving parts, reducing wear and failure. They require less maintenance and have a longer lifespan. Electric propulsion systems use redundancy with multiple motors and battery packs, ensuring continued operation even if one component fails, thus enhancing overall ship reliability.

**3.High space utilization is another significant advantage of electric propulsion systems**.

Traditional internal combustion engine systems use complex mechanical transmission systems that occupy significant space. In contrast, electric propulsion systems optimize ship interior space by flexible arrangement of motors and battery packs. This increases cargo or passenger capacity and allows for more innovative ship designs.

**4.Electric propulsion systems excel in environmental performance [12].**

They do not emit pollutants during operation, significantly reducing the environmental impact of ships. When powered by renewable energy sources, they can achieve true zero emissions. This is crucial for inland river navigation, port operations, and sailing in environmentally sensitive areas, effectively reducing air and water pollution and protecting the ecological environment.

### 3.2. Development Trends in Electric Propulsion Systems

Currently, researchers are working to optimize the design and control strategies of electric propulsion systems to enhance their efficiency and reliability.

**1.High-efficiency motor design**

High-efficiency motor design is key to improving electric propulsion systems [13]. Researchers are developing smaller, lighter, and more efficient motors by optimizing materials and manufacturing processes. These motors provide higher power and efficient operation, reducing energy loss and enhancing ships' economic and environmental performance.

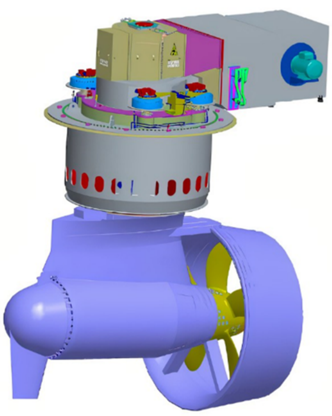


**Figure 7.** Ship Electric Propulsion Unit

**2.Intelligent control strategies**

Intelligent control strategies optimize electric propulsion systems using advanced algorithms like fuzzy control, neural networks, and adaptive control. These strategies enable precise power distribution and real-time adjustment of motors and battery packs based on operating status and environmental conditions, enhancing dynamic response and energy efficiency.

**3.Integrated system design**

Integrated system design enhances the reliability and maintainability of electric propulsion systems [14]. By combining motors, inverters, BMS, and control systems into a single unit, researchers reduce complexity and failure rates. This approach simplifies installation and maintenance, cuts operating costs, and boosts overall system reliability.

**4.Advanced energy management system**

Advanced EMS optimizes energy efficiency in electric propulsion by managing battery packs, motors, and equipment in real-time [15]. Integration of big data and AI enhances performance. Electric propulsion systems boost efficiency, reliability, and environmental benefits, supporting sustainable shipping.

## 4. Conclusion

Electric propulsion in ships has great potential. Advances in motor design, intelligent control, integrated systems, and energy management boost efficiency, reliability, and environmental performance. New battery tech like lithium-ion, solid-state, fuel cells, and sodium-ion extend ship range, enhancing competitiveness. As green transport, electric propulsion reduces shipping's environmental impact, aiding a green transition. Future advancements will enhance performance, reliability, and eco-friendliness, making electric propulsion mainstream for green, efficient sustainability.

## References


[1] Yuan J. The Safety Transportation of Bulk Solid Cargoes[C]//Institute of Management Science and Industrial Engineering. Proceedings of 2017 4th International Conference on Machinery, Materials and Computer (MACMC 2017). Department of Navigational Technology, Tianjin Maritime College;, 2017:5. China National Standardization Management Committee. Specifications of Crane Design (China Standardization Press, China 2008), p. 16-19.

[2] Li Y, Jia P, Jiang S, et al. The climate impact of high seas shipping[J]. National Science Review,2023,10(03):102-116.

[3] Ren S, Gong Z, Wu Q, et al. Satellite breakup behaviors and model under the hypervelocity impact and explosion: A review[J]. Defence Technology,2023,27(09):284-307.

[4] Xin Yang W, Xing Bang Y, Jia Wei Z, et al. Aquatic unmanned aerial vehicles: Bionic prototypes, key technologies, analysis methods, and potential solutions[J].Science China (Technological Sciences), 2023,66(08):2308-2331.

[5] Xu X ,Weng K ,Lu X , et al. Functional thermal fluids and their applications in battery thermal management: A comprehensive review[J]. Journal of Energy Chemistry,2024,94(07):78-101.

[6] Yu Z, Wang L, Yu Z, et al. Demand Analysis and Application Discussion of Wireless Shore Power Technology for New Energy Ships[C]//Wuhan Zhi cheng Times Cultural Development Co., Ltd. Proceedings of 2nd International Conference on Artificial Intelligence and Communication Technology (AICT 2023).Shanghai Marine Equipment Research Institute;,2023:7.

[7] Qi Y, Liang Q, Song K, et al. Optimizing high-coordination shell of Co-based single-atom catalysts for efficient ORR and zinc-air batteries[J].Journal of Energy Chemistry,2024, 95(08): 306-314.

[8] Lei W. Research and exploration of direct current power supply and distribution systems for Antarctic research stations[J]. Advances in Polar Science,2024,35(02):228-237.

[9] [MENG X, XU Z, CHANG M, et al. Performance analysis and flow mechanism of channel wing considering propeller slipstream[J].Chinese Journal of Aeronautics, 2023,36 (11): 165-184.

[10] YUANYUAN X. Drivers of Change Chinese electric vehicles advance African countries' green mobility[J]. ChinAfrica, 2024,16 (06):18-21.

[11] Chang Lu. Numerical study of the grid erosion of field emission electric propulsion[J]. Plasma Science and Technology, 2021,23(10):5-12.

[12] Paul S, Chang J. Fast Model-based Design of High Performance Permanent Magnet Machine for Next Generation Electric Propulsion for Urban Aerial Vehicle Application[J]. CES Transactions on Electrical Machines and Systems, 2021,5 (02):143-151.

[13] Zhao zhi L, Mingzhu S, Ying juan S, et al. Supercritical CO_2 Cycles for Nuclear-Powered Marine Propulsion: Preliminary Conceptual Design and Off-Design Performance Assessment [J]. Journal of Thermal Science,2024,33(01):328-347.

[14] Xinwei Chen. Study of beam divergence and thrust vector eccentricity characteristics of the Hall thruster based on dual Faraday probe array planes and its applications[J]. Plasma Science and Technology,2023,25(05):120-31.

[15] Yi Z, Xiang C, Huaguang S, et al. Multi-Objective Coordinated Optimization for UAV Charging Scheduling in Intelligent Aerial-Ground Perception Networks[J]. Chinese Journal of Electronics, 2023, 32(06): 1203-1217.