Proceedings of 15th International Marine Design Conference (IMDC-2024)
June 2-6, 2024
Amsterdam, the Netherlands

Overall scheme design of green typical demonstration ship types under the background of Double Carbon Policy

ZhengChen Lian[1,*] and LiZheng Wang[2]

ABSTRACT

In order to explore the overall design and research issues of green typical demonstration ship types, this article takes Hunan Province's green typical demonstration ship types as an example. Using a combination of policy interpretation, research analysis, theoretical analysis, and overall design, with the Double Carbon Policy as the background, the overall positioning analysis of the ship type is conducted first. Then, the key technical features and application solutions of the ship type will be introduced to ultimately achieve the goal of matching the design ship type with the waterway conditions.

KEY WORDS

Green ship type scheme, ship type positioning, power mode selection, ship adaptability

INTRODUCTION

Inland waterway shipping has important strategic significance for the development of the national economy. With the completion of cascade development and a series of shipping construction projects, the conditions of China's inland waterways have greatly improved. However, it is also noted (Lian Zhengchen, Wang lizheng 2023) that the seasonal changes in the navigation conditions of China's inland waterways after channelization are significant, resulting in low load capacity, poor navigation performance, insufficient navigation safety, and potential safety hazards for ships navigating in such key sections. The comparative advantages of large transportation capacity, low cost, low energy consumption, and light pollution in inland waterway shipping have not been fully utilized. At the same time, in combination with the current implementation of the national strategy of "carbon peak and carbon neutrality" and the need for green and high-quality development of inland ships, there is an urgent need to promote the emission reduction and green upgrading of green standard ship types in the new era. This puts forward higher requirements for the overall plan research of ship types and is also an important prerequisite for the economic and efficient operation of ships. Therefore, it is crucial to explore the overall design and research issues of green typical demonstration ship types.

This article takes the green typical demonstration freight ship types in Hunan Province as the research object, with "carbon peak and carbon neutrality" as the policy background. At the same time, it strengthens the research on the "one river, one lake, and four water" ship types, especially the "four water" ship types, clean and environmentally friendly ship types, and new energy ship types in Hunan Province, and matches them with the Three Gorges ship type to achieve the urgent goal of connecting the river and the sea. Therefore, this article proposes an overall plan for Hunan Province's green typical standard demonstration ship type from the perspectives of market demand and navigation environment characteristics, overall positioning analysis, key technical characteristics analysis, and overall design scheme application. Through the above research, it points out the direction for the application and engineering demonstration of emission reduction technology for standard ship types in inland rivers in Hunan Province, and provides strong support for promoting the transformation and upgrading of the shipbuilding industry and green and high-quality development.

[1] Affiliation (Ship Engineering Department of Wuhan University of Technology, Wuhan University of Technology, Wuhan, China);

[2] Affiliation (Ship Engineering Department of Wuhan University of Technology, Wuhan University of Technology, Wuhan, China);

* Corresponding Author: email: zhengchen.lian@qq.com

Submitted: 15 February 2024, Revised: 1 May 2024, Accepted: 3 May 2024, Published: 23 May 2024

Conference paper, DOI: https://doi.org/10.59490/imdc.2024.885 e-ISSN: 3050-486

ANALYSIS OF THE OVERALL FRAMEWORK POSITIONING OF THE GREEN FREIGHT STANDARD DEMONSTRATION SHIP TYPE

Ship type positioning analysis

In terms of policy orientation, in order to achieve the strategic goals of "dual carbon", becoming a strong transportation country, and developing inland waterway shipping, and promoting high-quality development of inland waterway shipping, the selection of green standard demonstration ship types for waterway freight transportation in Hunan should meet the following three policy requirements (*Implementation Opinions of the Ministry of Industry and Information Technology and Five Other Ministries on Accelerating the Green and Intelligent Development of Inland River Ships*, 2022).

i. Guided by the goals of carbon peak and carbon neutrality, guided by promoting the green and standardized development of inland river ships in Hunan, and focusing on the development of new energy and clean energy powered ships, the typical scenarios of Hunan waterway freight transportation are selected to carry out demonstration applications according to local conditions, so as to accelerate the transformation and high-quality development of green energy applications of inland river ships in Hunan, implement the "14th Five-Year Plan" water operation and operation development plan in Hunan, and promote the green upgrading of inland river standard ship types in Hunan Province in the new era.

ii. Adhere to policy guidance, strengthen the coordination and linkage of departments, localities and enterprises, develop green and energy-efficient ships and green shipping, and improve the level of safe and green development. Promote scientific and technological innovation, adhere to demonstration and promotion, support representative enterprises in the inland river basin of Hunan to take the lead in the trial, summarize typical experience and practices, and steadily promote the basic principles.

iii. Comprehensively consider the perspectives of economy, energy efficiency and design optimization to create a standardized green energy ship type that meets the needs of typical scenarios of Hunan waterway freight, realize the demonstration application of Hunan inland river operation routes, form an experience that can be implemented, replicated and promoted, and form a green model of Hunan freight ships.

It was noted ("*Analysis Report on the Capacity Structure of Waterway Freight Ships in the Province"*, 2022) that, from the perspective of water transportation demand in Hunan Province in 2021, the province completed a freight volume of 212.72 million tons, an increase of 7.20% compared to the previous year, and a freight turnover of 45 billion ton-kilometer, an increase of 13.75% compared to the previous year. Among them, inland waterway transportation completed a freight volume of 211.31 million tons and a cargo turnover of 36.1 billion ton-kilometer; Ocean transportation has completed a freight volume of 1.41 million tons and a cargo turnover of 8.9 billion ton-kilometer. Although the water freight volume in the province has declined to a certain extent since 2014 due to the ban on sand and gravel mining in Dongting Lake and the significant decrease in water transportation volume, the development of container "water shuttle buses" has been actively guided to optimize and adjust the water freight structure, serving foreign trade transportation, and continuously optimizing the water freight transportation structure in recent years. The water transportation volume and proportion of bulk goods such as metal ores, coal, grains, and oil products in the province have significantly increased. In the long run, with the development of the economy and correct guidance, the structure of waterway freight transportation in Hunan will gradually transform and develop towards energy, steel, grain, equipment manufacturing, and more, serving the industrial development of Hunan Province. At the same time, considering further adjustment and optimization of the comprehensive transportation structure, with the adjustment of freight transportation from public transportation to water and from public transportation to rail, the medium and long-term water transportation volume will still show a gradual growth trend.

Subsequently, the Hunan Provincial Department of Transportation proposed key tasks for green transportation in the 2022 plan. Among them, in the key task of "optimizing transportation structure and innovating organizational methods," it was pointed out to deepen the promotion of the transportation of bulk goods and medium and long-distance goods from rail to rail and from water ("*Analysis Report on the Capacity Structure of Waterway Freight Ships in the Province"*, 2022). Focus on developing direct transportation between the Xiang River trunk line and the Dongting Lake area, consolidating the routes from Chenglingji Port to Yichang Port, Jingzhou Port in Hubei Province, and various ports in the upper reaches of the Yangtze River; In the key task of promoting resource conservation and intensive utilization, it is pointed out to promote the use of new and clean energy in highway service areas, ordinary national and provincial trunk highway service areas or overload control stations, CNG refueling stations and port shore power facilities, LNG refueling stations, and promote the use of new and clean energy in vehicles, ships, and other transportation equipment.

From an overall development perspective, from 2016 to 2020, the number of container arrivals and departures in Hunan Province has shown a continuous upward trend. In the first half of 2020, due to the impact of the epidemic, container transportation suffered a significant impact and demand declined. In the second half of 2020, with the gradual recovery of global trade, the demand for container waterway transportation increased, and the scale of transportation capacity quickly recovered. From 2016 to 2020, container waterway transportation ports in Hunan Province were mainly distributed in Changsha, Yueyang, Hengyang, and Changde cities. More than 60% of the export containers are shipped from Changsha New Port. Due to the limitations of the Xiangjiang River waterway, export containers from Hengyang Port, Changde Port, and Changsha Port need to transfer to Yueyang Chenglingji Port. In 2020, the total volume of container arrivals and departures in Hunan Province was 653693 TEUs, of which 327745 TEUs were inbound and 325948 TEUs were outbound ("*Analysis Report on the Capacity Structure of Waterway Freight Ships in the Province"*, 2022).Therefore, there is little possibility of a significant increase in the capacity of inland dry ship bulk cargo in Hunan Province in the future, and the development prospects of container transportation are promising. Therefore, this study chooses container waterway transportation as the demonstration object.

From the perspective of navigation environment, there are mainly two types of container transportation modes in Hunan Province: container "waterbus" transportation mode and river sea direct transportation mode. In the long run, with the development of the economy and correct guidance, the structure of waterway freight transportation in Hunan will gradually transform and develop towards multi-industry transportation such as energy, steel, grain, and equipment manufacturing, serving more industrial development, and the proportion of sand and gravel transportation will decrease. At the same time, considering further adjustment and optimization of the comprehensive transportation structure, with the adjustment of freight transportation from public transportation to water and from public transportation to rail, the water transportation volume in Hunan Province will continue to gradually increase in the medium and long term. Therefore, for the water container transportation mode in Hunan Province, this study chooses the inland river of Hunan as the research water area.

Determination of demonstration ship types

According to the current situation, development plan, and policy direction of water transportation in Hunan Province, the demand for typical demonstration ship types in Hunan Province has the following characteristics: firstly, the focus is on container cargo transportation; secondly, the development direction is based on the two transportation modes of inland river container "waterbus" (container liner shipping) and river sea direct transportation; thirdly, the development direction is driven by new energy and clean energy. Through market demand analysis, this article focuses on the transportation mode of container "waterbus" (container liner shipping) in Hunan's inland rivers, combined with transportation demand and typical scenarios of green energy application. From the perspective of adaptability, environmental protection, technological maturity, and economy of green technology application, short-term routes will be oriented towards electrification. At the same time, drawing on the development path of gasification and electrification of the Yangtze River, the demonstration ship selection is guided by building a green, low/zero carbon container benchmark ship for the Xiangjiang trunk line.

Based on the above analysis, in line with the national "dual carbon" strategy, meeting the urgent market demand, considering the navigable environment, the representativeness of transportation vessels, and scientifically positioning demonstration ship types. After market research, based on factors such as logistics environment, navigation environment, market environment, technology environment, and policy environment, a demonstration ship type suitable for the "waterbus" container transportation mode in inland rivers of Hunan has been determined as follows: considering adapting to the market's demand for multi cargo transportation, it is planned to use Lingji Port in Yueyang City as the hub port, and ports in Hunan Province such as Changsha Xianing Port, Changde Yanguan Port, Hengyang Songmu Port, etc Jinshi Port is a multi-purpose green container ship type fed to the port. The initial consideration of the deadweight of this ship type is 200 TEU container level, which is driven by electric motors.

For the determination of ship size, there has been a certain increase in the past two years for bulk carriers with a length exceeding 88m and a width exceeding 15.5m, as well as container ships with a length exceeding 85m and a width exceeding 15m. At the same time, a "shuttle bus" mode for containerized water transportation from various container ports in Hunan Province to Yueyang Chenglingji Port has been opened, and a 200TEU container level inland river container ship has been selected as the research object. This article is based on the limitation of ship size by the channel conditions of the Changsha Yueyang section, and calculated under the provided unified ship type demonstration platform to obtain the accuracy index results of each feasible ship type scheme. The trend chart of accuracy index changes with the main scale of the ship type is drawn, and the impact of variable changes in ship type schemes on the technical and economic performance of ship operation is analyzed. At the same time, the operation of the Changsha Yueyang route needs to pass through the Changsha hub, so the ship size needs to meet the requirements of the container ship series for the Yangtze River branch line lock transportation ships in the national mandatory standard GB38030.1. The preferred ship type size is CZ-J6 (with a length of 88m and a width of 15m), which is relatively close to the scale series. At the same time, considering that appropriately increasing the ship

width is beneficial for container stability, and combining the analysis of the changes in the above indicators with the ship size, it is advisable to choose the ship type with a length of 88m and a width of 15.00m. As mentioned above, the specific ship type parameters are obtained as shown in Table 1.

Table 1: Optimal ship type scheme for container ship

Project	Numerical Value
Length (m)	~88.00
Width (m)	~15.00
Draft (m)	~2.80
Container load capacity (TEU)	~200 container level

RESEARCH AND DEVELOPMENT OF DEMONSTRATION SHIP TYPES FOR ELECTRIC CONTAINERS IN HUNAN INLAND RIVERS

Based on factors such as logistics environment, navigation environment, market environment, technology environment, and policy environment, and considering adapting to the needs of multi cargo field transportation in the market, this demonstration ship type is planned to use Yueyang Chenglingji Port as the hub port, and Changsha Xianing Port, Changde Yanguan Port, Hengyang Songmu Port, and Jinshi Port as feeding ports to achieve a container "shuttle bus" water transportation mode, realizing Changsha Port, Hengyang Port, and Changde Port All containers entering and exiting Tianjin Port are transshipped at Yueyang Port. Develop a new generation of inland green container multi-purpose transport vessel that can sail on the ports and routes of Yueyang in Hunan Province, integrating safety, green, and economy. By optimizing the overall layout and line design, as well as applying advanced integrated power systems, we aim to reduce the carbon emissions of ships, improve the safety level of ship navigation, and create a "Hunan sample" of electric freight ships.

According to the previous analysis, the overall positioning of the demonstration ship type for inland electric containers in Hunan Province consists of the following parts. Firstly, from the perspective of transportation cargo types, the main focus is on loading containers and dry bulk cargo. Secondly, from the perspective of transportation routes, the transportation route of this demonstration ship type is from Changsha to Yueyang. Specifically, the container "shuttle bus" water transportation model is adopted, with Yueyang Chenglingji Port as the hub port and Changsha Xianing Port, Changde Yanguan Port, Hengyang Songmu Port, and Jinshi Port as the feeding ports. All containers entering and exiting Changsha Port, Hengyang Port, Changde Port, and Jinshi Port are transshipped at Yueyang Port. Finally, in terms of fuel power selection, in order to implement the national "dual carbon" strategy, starting from promoting green and low/zero carbonization of water transportation in Hunan, combined with the cargo demand and navigation environment conditions of Changsha Yueyang, considering various green energy energy density ratios, dynamic responsiveness of ships, container scheduling arrangements (*Green ship regulations*, 2020), distance and other factors, this ship adopts electric propulsion mode.

Next, this article introduces the overall overview of developing ship types. Firstly, for the main scale elements, the basic parameters of the ship are determined according to the applicable specifications based on its purpose and route (*Technical rules for statutory inspection of inland vessels*, 2019), as shown in Table 2.

Table 2: Basic parameters for developing ship types

Project	Numerical Value
Total length	88.00m
Length between perpendicular lines	85.36m
Molded breadth	15.00m
Molded depth	5.30m
Full load draft	3.52m
Load capacity	~3000t
Container capacity	208 TEU
Block coefficient	0.85
Maximum speed	18km/h
Rated power of propulsion motor	500kW×2

According to the Freund's number range and according to the speed requirements and characteristics of electric boats, this boat is a low-speed boat. It is also noted (Sheng Zhenbang et al, 2010) that educing shape resistance and improving propulsion efficiency are the main means to improve the speed of ships. In order to improve the flow of the tail propeller, improve the propeller propulsion efficiency, and adapt to the navigation environment of the inland river, the stern of the ship

adopts a double tail line type, which effectively reduces the deflow angle, and at the same time, the propeller of the ship is equipped with an energy-saving attachment with a vortex elimination fin, which is used to reduce the energy consumption loss of the propeller circulation and increase the auxiliary thrust. The schematic diagram and overall layout of the demonstration ship are shown in Figure 1 and Figure 2 respectively.

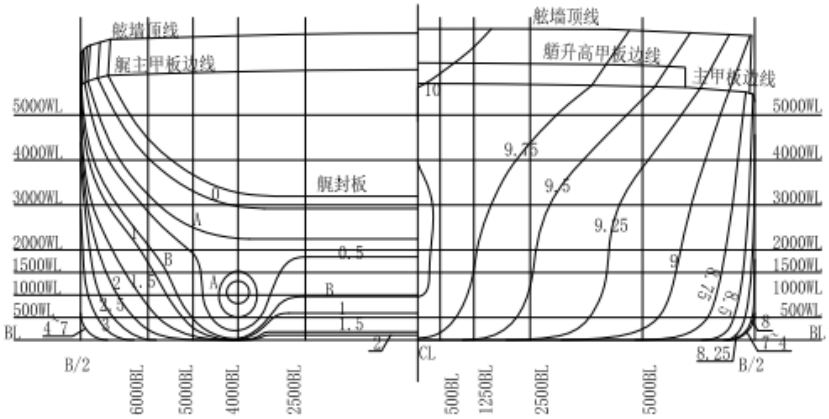

Figure 1: Schematic diagram of demonstration ship type line

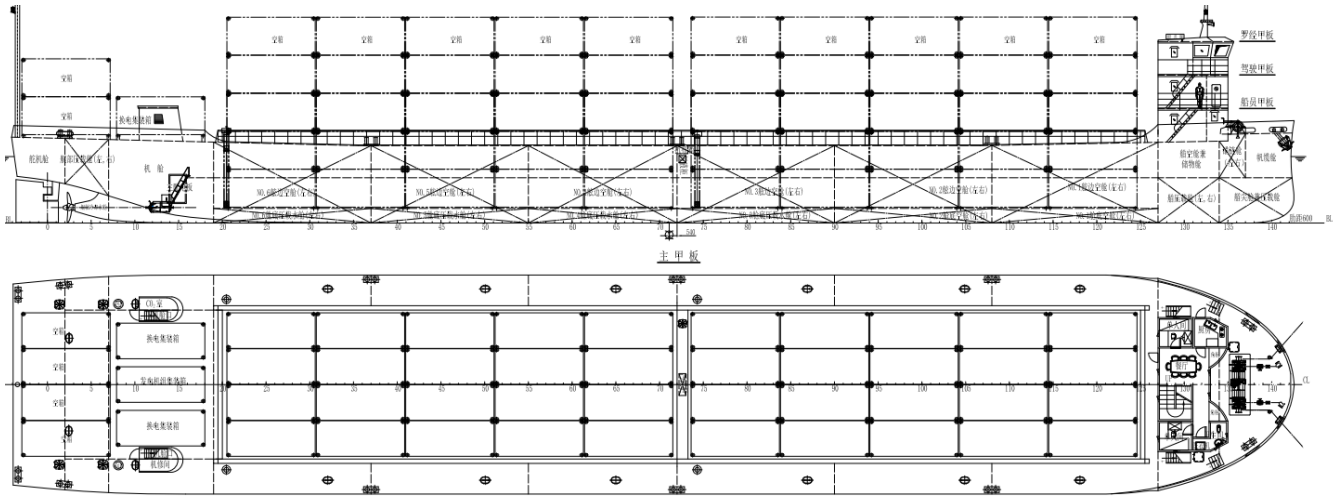

Figure 2: Schematic diagram of the overall layout of the demonstration ship

Regarding the adaptability of the overall demonstration scheme of inland electric container ship in Hunan Province, firstly, the modified Ayre method is used to evaluate the effective power of the ship to obtain the effective power curve of the ship, and the MAU spectrum propeller is used to design the propeller. In terms of ship accessibility, the adaptability of the main scale is judged from the perspectives of channel water depth, dock berthing and loading and unloading capacity, and clearance height. At the same time, with the goal of maximizing the length of the cargo hold, the principle of intensive layout is adopted to design the general layout of the ship to achieve the goal of maximizing the loading of the ship. In particular, the maximum height of the ship after lowering the mast does not exceed 12m, which is suitable for navigation in the Xiangjiang River and the Yangtze River waterway. If there are more special requirements, the ballast water can be adjusted to further reduce the height of the entire water surface of the ship and ensure the loading capacity of the container.

POWER MODE SELECTION

Technical analysis and battery capacity selection

There are various forms of electric propulsion. Such as pure electric ships, diesel powered electric propulsion, hybrid power, and extended range engines. Among them, hybrid vessels can be further divided into series hybrid, parallel hybrid, series parallel hybrid, and shaft generator modes(*Guidelines for Inspection of Hybrid Electric Ships*, 2019).

Series extended range hybrid mode refers to the configuration of a certain amount of chemical energy storage batteries and diesel or other internal combustion engine generator sets on board the ship. When the batteries are charged, pure electric propulsion is used, and when the batteries are depleted, the generator sets are used to generate electricity and charge the batteries to increase endurance. It is also noted (Tang Tianhao, Han Chaozhen 2015) that its biggest feature is that the batteries and generator sets can be placed in a fixed position inside the cabin, or can be placed in a container form and can be moved or suspended externally.

The container ships for inland water transportation in Hunan Province have a large tonnage and a long voyage. The biggest advantage of this method is that it solves the problem of navigation endurance and does not conflict with battery swapping and charging. In other words, in terminals with replaceable battery conditions, the battery can be directly swapped, and in terminals with charging piles, it can also be charged. If sailing in navigation areas where battery swapping and charging are not possible for a long time, the mode of generator range extension is adopted for continuous navigation. The use of series extended range in the transportation of bulk cargo can better solve the problem of endurance, improve the charging process and operational efficiency. In different situations, pure electric navigation, charging navigation, and charging or battery swapping can be flexibly selected. Its application can also meet the current policy implementation for new energy subsidies and development. Therefore, for the distance between Changsha and Yueyang, considering that the shore support is not yet sound and the route is not a short distance fixed point-to-point route, it can be seen from a technical perspective that the series extended range hybrid mode is more suitable for this demonstration ship.

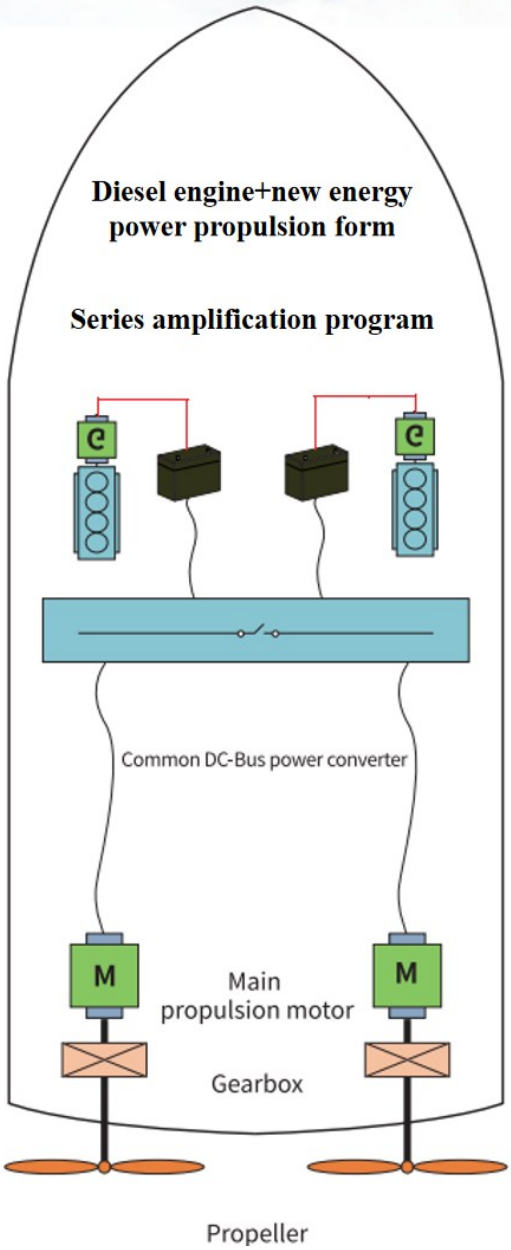

Figure 3: Series extended range hybrid mode

The selection of ship battery capacity should consider the following three factors: firstly, the main propulsion energy consumption of the ship mainly depends on the operating power and operating time of the ship; The second is the electricity consumption for crew members, which mainly depends on the power distribution and usage time of the ship's daily life; The third is the attenuation of the battery, taking 85% of the maximum capacity of the battery pack. Among them, the selection of energy consumption and the calculation of battery capacity adaptability are shown in Table 3.

Table 3: Battery Capacity Adaptability Analysis Table

Electricity consumption type	Project	Numerical Value
Main propulsion energy consumption	Route range	Approximately 150km
	Design Speed	18km/h
	Operational speed	12km/h
	Rated propulsion power	1000kW
	Operating propulsion power (12km/h)	Converted to approximately 297kW
	Single voyage time	12.5h
	Energy consumption for single voyage main propulsion	3713kWh
hotel load	Power of household distribution system	Approximately 30kW
	Waiting time for loading and unloading	1.5d
	hotel load and energy consumption	45kWh

According to Table 3, the ship is equipped with two box type power supplies. Due to the design specifications requiring that the capacity of each box type power supply should not exceed 2000kWh (*Battery Power Specification for Ship Applications*, 2023), two box type power supplies from 712 Institute were selected, each with a battery capacity of 1998kWh. The total battery capacity of this ship is 3996kWh. Calculated based on 85% effective capacity, it is 3397kWh, which cannot meet the energy demand of a single voyage of the ship, so diesel fuel range extension is still required.

Economic and Environmental Analysis

From the perspective of technological adaptability, container ships for trunk and branch transportation in Hunan Province have a smaller tonnage and shorter voyage. Diesel powered ships, extended range electric ships, pure battery powered ships, and LNG powered ships all have no endurance issues and are technically feasible. Among them, pure battery powered ships require more electricity per journey than the maximum carrying capacity of the ship itself, requiring one battery exchange midway.

By selecting the existing operating ship types in Hunan as the object, the comparison of cost, carbon emission and payback period under different power schemes was calculated according to the parameters given by the shipowner. The specific calculation results are shown in Figure 4. From the perspective of environmental benefit analysis, compared with pure diesel ships, the carbon emissions of extended-range electric ships are reduced by about 40% to 70%, while pure battery-powered ships can achieve zero emissions, and the carbon emissions of LNG-powered ships are reduced by about 10-15%.

Similarly, through the technical and economic calculation and analysis of different power schemes of sample ships, the relationship between ship cost subsidy and payback period in Hunan inland river transportation and trunk branch transportation container scenarios is obtained. Compared with pure diesel ships, the necessary freight rates for pure battery-powered ships have increased by about 15%, and the necessary freight rates for LNG-powered ships have decreased by about 10%. The economic analysis mainly focuses on the cost comparison of electric propulsion vessels with conventional diesel-powered vessels. When the ship cost subsidy is 10% to 20%, the payback period of extended-range electric ships can reach the level of pure diesel ships, while the payback period of pure battery-powered ships is difficult to reach the level of pure diesel ships through subsidies.

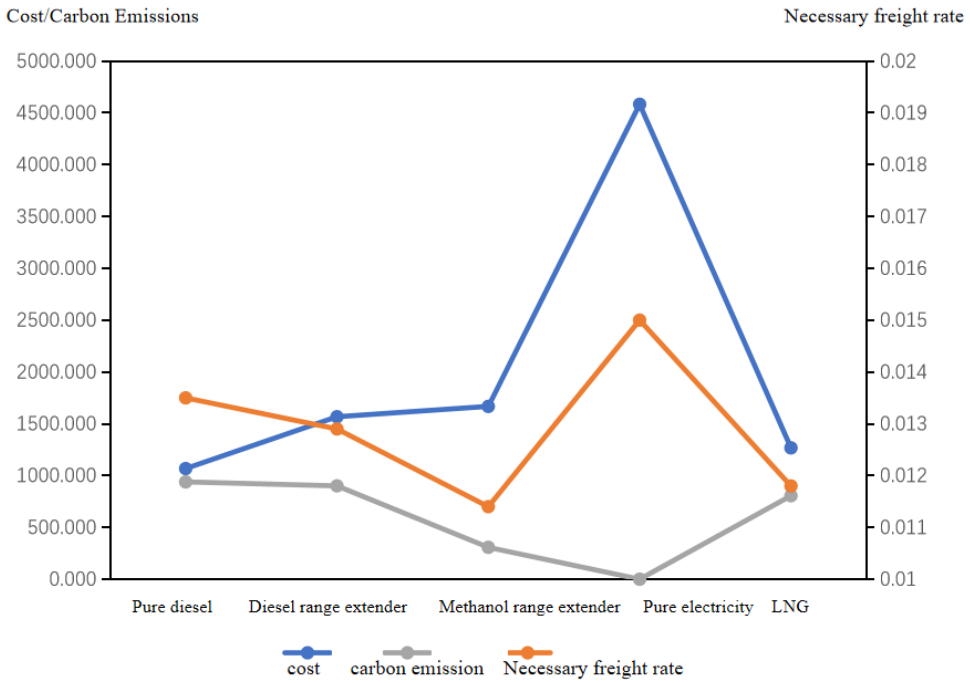

Figure 4: Calculation of cost, carbon emission and payback period of different power schemes in Hunan inland river transportation and trunk branch transportation container scenarios

Table 4: Comparison of prices between pure diesel and electric ship power systems

Serial Number	Cargo capacity (ton)	Pure diesel power (Ten thousand yuan)	Pure battery power (Ten thousand yuan)	Extended range electric boat (10000 yuan)		
				Pure electric range 120km	Pure electric range 100km	Pure electric range 80km
1	1000	~80	~530	~420	~382	~344
2	2000	~99	~730	~553	~494	~435
3	3000	~119	~984	~717	~642	~566
4	4000	~148	~1500	~910	~821	~732
5	5000	~179	~1976	~1068	~966	~865
6	6000	~203	~2452	~1232	~1120	~1008
7	7000	~238	~2938	~1394	~1272	~1151
8	8000	~260	~3014	~1535	~1405	~1275

According to Table 4, the main source of cost increase for electric powered ships is energy storage batteries. It can be seen that due to the increase in initial investment, the economic performance of electric powered ships is worse than that of traditional diesel powered ships without government subsidies. However, the environmental advantages of electric propulsion for ships are significant. Starting from achieving the "dual talk" goal of water transportation in Hunan, we should vigorously promote the electrification of medium and short distance freight ships. Before the design and construction of this vessel, the shipowner and relevant parties have conducted in-depth investigations and economic calculations, and even without any policy subsidies, the profitability of its operation is predictable.

In addition, the ultimate goal of the design, construction, and operation of this ship is to achieve complete pure electricity and zero emissions. Not only does it have zero emissions in terms of power, but it also includes zero emissions of dirty oil, sewage, and domestic sewage. The ship is equipped with oil and sewage collection tanks and domestic sewage collection tanks, which are used to collect and store all oil and sewage generated on board. Except for receiving at the shore or anchorage, the entire life cycle of the ship will not discharge any oily or domestic sewage outward.

Based on the analysis of the adaptability and economy of battery powered ship technology, and considering the adaptability, environmental friendliness, technological maturity, and economy of battery powered technology application, it is recommended to use diesel extended range hybrid power scheme at this stage. At present, the use of series extended range hybrid mode can better adapt to the current conditions of the Changsha Yueyang route where the shore based support for electricity supply is not yet sound and is not a short distance fixed point-to-point route. Therefore, it is feasible for this demonstration ship to adopt series extended range hybrid mode.

Overall Plan Description of 208TEU Inland River Electric Container Demonstration Ship Type

Based on the research and development concept mentioned earlier, and through the analysis of ship type positioning and ship power mode of the demonstration ship, modern design methods are adopted to meet the requirements of the latest applicable standards, conventions, and rules. Drawing on the research and development achievements of domestic and foreign inland river green ship types, the overall scheme design of the Changsha Yueyang 208TEU inland river pure electric distribution dual-use demonstration ship type is carried out. And introduce the plan from four aspects: cost estimation and construction progress of the hull, engine, electrical, and demonstration ship type.

Hull design

This ship is a dual engine, dual propeller, lithium battery + diesel generator hybrid electric propulsion, all steel structure, open hatch type container and distribution dual-purpose cargo ship. It mainly carries containers or containers containing some dangerous goods, and can also load dry and miscellaneous cargo such as sand, cement, stones, coal, grains, metal ores, etc. It mainly navigates within the A and B level navigation areas of inland rivers. A container capable of loading dangerous goods in packaging such as 1.3G, 1.4G, 1.4S, 2.2, 8, 9, 3, 4.1, 4.2, 5.1, 6.1, etc. (*Code for construction of steel inland vessels*, 2016)

For the selection of ship type, this ship is a multi-purpose cargo ship with a straight aft leaning slightly curved bow, square stern, twin engine, twin propeller, and stern electric drive. The entire ship is of steel fully welded structural type. The overall layout is as follows: below the main deck, from the front to the tail, there are bow peak tanks (ballast tanks), bow ballast tanks, cargo tanks, engine rooms, stern shaft tanks, stern ballast tanks, and rudder rooms. The head position on the main deck consists of three decks: crew deck, pilot deck, and compass deck. Set up battery swapping containers on both sides of the stern deck, with battery swapping generator containers placed in the center. Machine repair rooms, CO2 rooms, and lower engine stairwells are set up along the walkways on both sides of the stern deck. The front end of the upper structure at the bow is a raised deck, with wing bridges on both sides of the cab, and a full window in front. Since the ship is in the stage of actual ship construction and application, this paper models and displays an overview of the 208TEU inland river pure power distribution demonstration ship based on the software modeling and simulation platform based on the above overall layout, as shown in Figure 5.

For the performance analysis related to the demonstration ship type, this ship has two engines and two propellers, with a full load speed of 18km/h. Set up two streamlined balance helmets and equip them with a 160kN. m hydraulic servo. To effectively control vibration and noise, important compartments should be arranged away from noise sources; Optimize the shaft alignment and propeller design. Try to increase the gap between the propeller blade tip and the hull plate as much as possible, and design the propeller specifically to adapt to the uneven wake at the tail, delay the occurrence of cavitation or reduce the cavitation area, and reduce vibration; Properly strengthen the ship structure and ensure the reasonable strengthening and continuity of the entire ship structure. Strengthen the structure above the propeller and below the base. There is a good transition between bone materials and plates or between bone materials and bone materials.

Figure 5: Overview of 208TEU Inland River Pure Electric Distribution Demonstration Ship

Marine Engineering

This ship adopts a dual motor propulsion and dual fixed pitch propeller linear transmission method. The power device consists of a propulsion motor, high elasticity coupling, reduction gearbox, propeller and propeller shaft, control and monitoring system, etc. Two TYC500-6 propulsion motors from Xiangdian Corporation are selected as the main engine, with fixed pitch propellers. Each motor, shaft system, and its corresponding power system form an independent system, and the two propulsion motors can operate independently. The propulsion motor and gearbox are remotely controlled in the cab, monitored in the monitoring room, and controlled locally at the machine side. The main propulsion device consists of a propulsion motor, a high elastic coupling, a marine directional reduction gearbox (with clutch), a control and monitoring system, a shaft system and its accessories, and a fixed pitch propeller. The basic parameters of the selected propulsion motor and gearbox are shown in Table 5.

Table 5: Main propulsion device parameters

Propulsion device type	Project	Numerical Value
propulsion motor	Model	Xiangdian Corporation TYC500-6
	Rated power	500kW
	Speed	1450r/min
	Number of units	2
Gearbox	Model	HCD800
	Reduction ratio	5.889:1

Ship Electrical Design

It is recommended to use a range extender (diesel generator set) to meet the range extender requirements in the selection process of power mode for electric propulsion on this ship. This is mainly due to considerations of the operating scenario conditions being applied. At present, diesel power generation with extended range can be replaced with methanol power generation with extended range, hydrogen fuel cell with extended range, or other forms of power generation with extended range, which can increase the adaptability of new energy development to different new energy applications. In the design of this ship, sufficient design margin, interfaces, and equipment have been reserved to ensure charging, battery swapping, range extension, etc. Various modes can be freely switched, especially the range extension method. The system does not require any changes and can be directly connected for use.

In terms of power supply configuration, this ship is equipped with two containerized mobile power supplies and one generator set container on the main deck at the stern. Each containerized power supply is equipped with approximately 2000kWh of lithium iron phosphate battery packs and their supporting system equipment. Each generator set container is equipped with one 400kW marine diesel generator set and its supporting system equipment. The electrical protection level of the box type power supply shall not be lower than IP56, meeting the requirements for layout in outdoor deck spaces. There are emergency shutdown devices for each battery system on the driver's console and outside the box power supply, which can emit both visual and auditory signals during operation.

In addition, the box type power supply continuously provides power to the ship by replacing the fully charged box type power supply at the dock power station. The entire box type power supply includes a battery system, fire extinguishing system, plugging and unplugging system, fire protection design, air conditioning system, and seismic protection system. The battery system mainly consists of battery packs, high-voltage boxes, main control boxes, etc. The plug-in system mainly consists of plugs, sockets, and in place sensors. The fire protection system mainly consists of detectors, HFC-ea fire extinguishing, water sprinkler fire extinguishing, and monitoring. The fire protection design mainly consists of A60 compartments and A60 fire doors on both sides. The air conditioning system is mainly composed of air conditioning and air ducts, and the vibration isolation system uses steel wire isolators. The box type power supply is equipped with a BMS battery management system. The system has remote data monitoring function, which can be monitored and displayed in the cab.

This ship is a hybrid electric propulsion system consisting of lithium batteries, diesel generators, and dual engine propulsion. The propulsion motor is controlled by frequency conversion and commutation through a frequency converter to control the harmonic components of the ship's power grid. And there is an integrated transformer and distribution device in the engine room, which is the center of the ship's power system. The integrated transformer and distribution device distributes and converts the direct current output from lithium batteries and diesel generators into variable frequency and voltage alternating current required for propulsion motors and constant frequency and voltage alternating current required for daily electrical equipment, directly supplying power to the entire ship's propulsion motors and daily electrical equipment. The specific selection of the main propulsion motor is provided by Xiangdian Group with relevant technical information. The

specific parameters are shown in Table 5. The propulsion control system includes: 1 set of main propulsion driver control panel, 2 sets of machine side control boxes, 1 set of dual path propulsion motor tachometer, and 1 set of dual machine control handle. The main propulsion control box is located in the engine compartment. There is a remote control handle on the driver's console. In speed control mode, the speed signal can be sent to the distribution cabinet through the remote control handle, and the speed of the propulsion motor can be adjusted to achieve speed regulation.

This ship adopts a hybrid power scheme, and the propulsion control adopts an integrated design, collectively referred to as the integrated control system. It integrates the generation, use, and scheduling of energy in control functions and strategies, and is integrated into the integrated transformer and distribution device. This is mainly to reserve space for subsequent device upgrades. In addition, it is equipped with an intelligent ship system, which has functions such as remote transmission of information and data, real-time online detection of ship energy consumption parameters, and backend analysis and optimization. Many related interfaces are reserved for future upgrades and renovations of the intelligent system.

Cost estimation and construction application situation

The estimated cost of the Changsha Yueyang 208TEU inland pure electric distribution demonstration ship is about 13 million yuan, as shown in Table 6.

Table 6: Main propulsion device parameters

Serial Number	Project	Amount (Ten thousand yuan)
1	Hull materials	~350
2	Main equipment of the hull	~50
3	Marine equipment and materials	~120
4	Electrical equipment and materials	~540
5	labor cost	~200
6	Value added tax and surcharges	~110
7	Other Expenses	~30
8	Total cost of ship engineering	~1400

In terms of practical construction applications, the 208TEU inland pure electric distribution dual-purpose demonstration ship officially held a groundbreaking ceremony on June 12, 2023, and construction began in July at Xinyu Shipyard in Xiangtan County. The ship is expected to be completed and put into operation by the end of December. After the delivery of the vessel, it will become the largest 88m standard lock pure electric dual-purpose ship with container loading capacity in China, and also the first new energy pure electric dual-purpose ship in Hunan, serving the 160km container shuttle bus route from Lingji Port Area of Yueyang Port City to Xianing Port Area of Changsha Port in Hunan Ocean Shipping. The construction of a 208TEU inland pure electric distribution demonstration ship is shown in Figure 6.

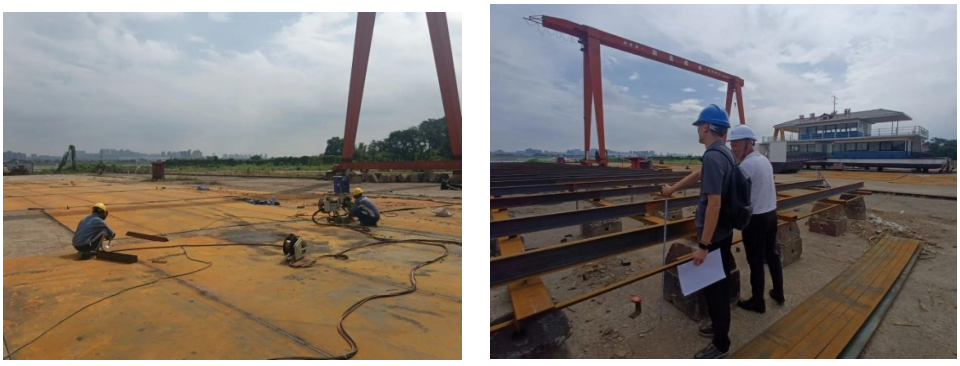

Figure 6: Construction status of a 208TEU inland pure electric distribution demonstration ship

With the construction and operation of the 208TEU inland pure electric dual-purpose demonstration ship, it is of milestone significance for promoting the green and low-carbon development of inland waterway navigation in Hunan Province's "one lake, four waters". In addition to the battery swapping function, in the future, ships will integrate digital and intelligent technology applications. After the formation of a large-scale network of ship charging and swapping stations, it is expected to achieve more than 10% of comprehensive energy-saving benefits.

CONCLUSIONS

This article aligns with national development strategies such as "dual carbon" to promote green, low-carbon, and high-quality development of shipping in Hunan. Adhering to the development concept of safe, applicable, green, efficient, economical, and low-carbon standard ship types, guided by the goal of "green, low-carbon/zero carbon", following relevant policies, regulations, standards, and technical requirements, adapting to the navigation environment of Hunan waterway freight ships, adapting to the "waterbus" transportation mode of Hunan inland river containers, and considering adapting to the market demand for multi cargo transportation. At the same time, combining green energy, power system technology and other applications, we will develop demonstration ship types for green, high-energy and direct river and sea transportation in Hunan Province, leading the development of green and standardized ships. Develop an overall plan for the demonstration ship type of pure electric distribution in the Changsha Yueyang inland river. This ship type has a load capacity of approximately 200TEU container level and is propelled by an electric motor. Its container capacity is 208TEU, with a total length of about 88.00m and a total width of about 15.00m. The designed draft is about 2.8m.

CONTRIBUTION STATEMENT

Zhengchen Lian[1]**:** Conceptualization; data curation, methodology; writing – original draft.
Lizheng Wang[2]**:** Conceptualization; supervision; writing – review and editing.

ACKNOWLEDGEMENTS

The authors are grateful for the Research on the Standard Ship Types for Green, High Energy Efficient Inland and River Sea Direct Transportation in Hunan Province.

REFERENCES

China Classification Society. (2016). Code for construction of steel inland vessels. Beijing: People's Transportation Publishing House.

China Classification Society. (2020). Green ship regulations. Beijing: People's Transportation Publishing House.

China Classification Society. (2023). Battery Power Specification for Ship Applications. Beijing: People's Transportation Publishing House.

China Classification Society. (2019). Guidelines for Inspection of Hybrid Electric Ships. Beijing: People's Transportation Publishing House.

China Maritime Safety Administration. (2019). Technical rules for statutory inspection of inland vessels. Beijing: People's Transportation Publishing House.

Department of Transportation of Hunan Province. (2022). Analysis Report on the Capacity Structure of Waterway Freight Ships in the Province. Retrieved from https://jtt.hunan.gov.cn/jtt/xxgk/jttj/202207/t20220715_27558285.html.

Hunan Provincial Department of Transportation. (2022). Hunan Province's 14th Five Year Plan for Transportation Development (Highway and Waterway). Retrieved from http://jtt.hunan.gov.cn/jtt/jjzdgz/jtghyj/ghyj/202203/t20220329_22724832.html.

Lian Zhengchen, Wang lizheng. (2023). SHIP PERFORMANCE EVALUATION AND GREEN SHIP TYPE SCHEME UNDER COMPLEX CHANNEL CONDITIONS. ASME Style Guide.

Ministry of Industry and Information Technology, Development and Reform Commission, Ministry of Finance, Ministry of Ecology and Environment, Ministry of Transport. (2022). Implementation Opinions of the Ministry of Industry and Information Technology and Five Other Ministries on Accelerating the Green and Intelligent Development of Inland River Ships. China's informatization, (10), 13-15.

Sheng Zhenbang et al. (2010). Ship Principles. Shanghai: Shanghai Jiaotong University Press.

Tang Tianhao, Han Chaozhen (2015). Ship Electric Propulsion Technology. Beijing: Machinery Industry Press.