Research on wind-assisted solar power ship system

Haomin Zhang\textsuperscript{1}, Decai Shi\textsuperscript{1}
\textsuperscript{1}School energy and power engineering, Wuhan university of technology, Wuhan, Hubei, 430063, China
*Corresponding author’s e-mail: 1350612523@qq.com

Abstract: The wind-assisted solar power boat uses the abundant wind resources generated by the special geographical environment of the lake area as the main power, and supplements the solar power technology to power the pleasure boat, which can almost achieve zero emissions and zero pollution, effectively reducing Destruction of the ecological environment. This study further improved the efficiency of wind energy utilization by sails, and achieved automation of sail control. In addition, the combination of solar energy and wind energy will make the ship's operating performance better and the scope of application wider. The promotion of the research results can greatly save the operating costs of cruise ships, and in the long run have greater economic and environmental benefits, which is in line with the concept of sustainable development. This research will also fill a gap in this area in China, and it is expected to do deeper research on some cutting-edge technologies.\textsuperscript{[1]}

1. Introduction
With the continuous development of the domestic economy, while meeting people's material needs, their spiritual needs have also increased. Tourism is the spiritual consumption demand for aesthetic, recreational and entertainment purposes, which is generated after people meet the basic material life needs, and gradually transformed from occasional to an indispensable part of life. According to the "2016 National Economic and Social Development Statistical Bulletin", out of all the 8 categories of consumption included in the statistics, tourism, education, culture, entertainment, communications, and transportation expenditures related to tourism consumption accounted for 24.9\% of total consumption. Moreover, tourism consumption has maintained a high growth for years. In the first half of 2017, the national GDP increased by 6.9\%, while the number of domestic tourists increased by 10.3\% and domestic tourism revenue increased by 13.8\% in the first three months of the same period. Tourism consumption has become the most important factor driving economic growth, \textsuperscript{[2]}. Southeastern China is rich in water resources and has many lake tourist attractions. Among them, cruise ships on the lake are an important part of the scenic area, and the number is huge. The engine is like the heart of a ship. There are mainly gasoline and diesel engines. Gasoline engine gasoline has a low ignition point, low thermal efficiency, short strokes when thermal efficiency is converted into kinetic energy, faster kinetic energy, faster agility and easy handling. It is suitable for pushing hulls and lighter boats. Diesel engines Diesel is cheap, economical, and has fewer failures. Its horsepower is greater than that of gasoline engines, and the thermal efficiency is converted into kinetic energy with a longer stroke. The kinetic energy is displayed and the acceleration response is slower. Comprehensive analysis shows that placing these two power units on the slow and light cruise ship in the lake area has a feeling of overuse, and its noise, smoke and exhaust gas, and oil leakage have a great impact on the ecological environment of the lake area, affecting tourists Travel experience is not conducive to the
long-term development of the scenic area. Therefore, it is particularly necessary and urgent to find alternatives to diesel engines.

2. Research Status at Home and Abroad

2.1 Research state in China

(1) Development and research status of wind-assisted navigation

China's research on wind-assisted navigation started late. In the 1980s, China gradually started research on wind-assisted navigation technology and achieved good results. In 1985, Wuhan Institute of Water Transport Engineering (now Wuhan University of Technology) and Nanjing Shipping Co., Ltd. jointly developed a 2000T arc-shaped wing sail to boost the launch of the ship. The energy saving effect was more than 50%. In February 1996, it was jointly designed by 708 and 711. Ningbo The 2500t sail constructed by the shipping company promoted the inauguration of the comprehensive energy-saving multi-purpose container ship "Mingzhou 22" in Japan. In July 2008, COSCO Group established the WDS (Wind Wing-Diesel Engine Hybrid Ship) project team to engage in related design studies. Since then, domestic research on wind-assisted navigation has been almost stagnant, and as of now, there have been few reports.

(2) Development and research status of solar ships

In September 2003, China's first solar-powered cruise ship was put into use on the Summer Palace; in 2010, China's first independently-designed solar-fuelled tour boat was launched on the Huangpu River. In recent years, scientific research institutes and universities such as China Shipbuilding and Ocean Engineering Design and Research Institute and universities are actively carrying out research and development of solar-powered ships and built some solar-powered boats. Judging from the development of domestic solar ship technology, this technology has gradually matured as a large ocean-going ship. In 2016, Hubei's first solar electric boat was put into use in the tourism industry.

2.2 Foreign Research Status

(1) Development History and Research Status of Wind Assistance in Foreign Countries

Research on wind-assisted navigation was earlier in foreign countries. In the 1960s, Germany began to study the 10,000-ton large-scale wind-assisted transport ship "DYNA"; in the 1970s, the United States took the "Atlantic" as the research object to achieve growth and energy saving; in the 1980s, France established known as the world's largest passenger ship "La Fayette", during the same period, Japan built the world's first modern sail-assistance commercial tanker, which does not require manual sailing; In 2004, Japan already had 14 sails to help it navigate the sea. In 2008, the world's first kite-pulled freighter was jointly designed and built by the German Company and the Shipping Company to complete the trial voyage.

(2) Development History and Research Status of Solar Ships Abroad

In 1997, a solar-powered passenger ship appeared on Lake Geneva; in 2000, Australia built a hybrid energy catamaran ferry that integrates solar, wind, fuel cells and fuel; in July 2006, there were already solar passenger ships in the UK carrying passengers in Hyde Park Operation; In August 2008, Japan installed a solar photovoltaic system; in March 2010, a catamaran named "Planet Solar" in Switzerland, achieved complete reliance on solar energy Driver to run. In 2012, Turano successfully completed an 18-month voyage around the world, known as the world's largest solar ship.

Recently, Aquarius MRE, a marine wind and solar power system of Japan's Eco Marine Power (EMP), has obtained a U.S. patent; construction of an ultra-luxury solar yacht built by Duffy London is expected to be completed by 2020.

3. Structural optimization and design

(1) Hardware design
Because the entire system needs to collect information including wind speed, wind direction, and total ultraviolet radiation. Therefore, the acquisition sensors used are wind speed and direction indicator and total solar radiation sensor.

The main control chip is intended to use STM32F103RCT6. This MCU has the advantages of rich peripheral resources, low power consumption, and a wide range of working environments (working environment temperature in high power mode -40°C-85°C/low power mode working environment Temperature -40°C-105°C), can ensure stable operation in the harsh temperature environment. The chip has 512K bytes of Flash, and can be expanded with FLASH through the SPI interface to store the data needed during navigation.

The external SRAM is planned to use IS62WV51216. The chip can provide up to 1M bytes of SRAM.

The SPI interface FLASH uses W25Q128, which can expand the 16M byte storage space for the system, which is used to store the data used in the sailing process.

The system uses a servo motor as the power output. The servo motor has better mechanical performance than a stepper motor. Due to the larger inertia of the sail, it is more choice to use a servo motor with a stronger overload capacity. At the same time, the servo motor can perform closed-loop control. Monitor the running position in real time.

The matrix keyboard is used to select the corresponding routes, and the LCD displays necessary data information to realize human-computer interaction.

The control of the sail angle is intended to use a servo motor. A servomotor refers to an engine that controls the operation of mechanical elements in a servo system. It is an auxiliary motor indirect speed change device. The servo motor can control the speed and position accuracy very accurately. It can convert the voltage signal into torque and speed to drive the control object. The rotor speed of the servo motor is controlled by the input signal and can respond quickly. In the automatic control system, it is used as an actuator and has the characteristics of small electromechanical time constant, high linearity, and starting voltage. It can convert the received electrical signal converted into angular displacement or angular velocity output on the motor shaft. The windsurfing effect is shown in Figure 1.

![Figure 1. The effect of lowering the sail](image)

(2) Software design

In terms of software design, the route setting and the current time setting are realized by triggering an external interrupt by pressing a button, and the data collection and control response are completed in a timer interrupt.

When the user turns on the system, the system will prompt the user to select the route and set the current time through the LCD. The LCD will display the selection information to guide the user to complete the configuration. After the configuration is complete, wait for the timer interrupt to trigger.

After entering the timer interruption, perform data collection. First determine the current wind condition. When the wind direction is unstable (judgment of wind direction instability: establish a one-dimensional array with a wide n, and store the wind speed and direction data collected when the timer is interrupted n times. The wind speed and direction analysis is performed every n times, and a
certain threshold value is exceeded, and the sail is retracted. In consideration of energy saving, the control system enters a dormant state after the sail is retracted. If the wind condition is normal, compare the wind energy and light energy benefits, and execute the response through the servo motor.

If you need to switch routes, trigger external interruption by pressing the button, enter the setting interface to set, and return to the main function after completion. The specific PID formula is as follows:

\[ u(t) = K_p e(t) + \frac{1}{T_i} \int_0^t e(t)dt + T_d \frac{de(t)}{dt} \]

4. Expected economic benefits and promotional value

(1) High energy utilization

The sail angle of attack adaptive control system can make the wind energy utilization rate reach a very high level. In addition, the photovoltaic power generation film is laid on both sides of the sail wing, which does not affect the shape of the sail wing, and increases the photovoltaic power generation area of the hull by 70%, thereby achieving the purpose of improving energy efficiency. The ship's intelligent wind and solar hybrid propulsion system makes full use of wind and light energy, and the collected energy provides power or auxiliary power for the ship's travel.

(2) Good ship propulsion effect

When the sail assists the sail, the self-adaptation of the angle of attack of the sail keeps the maximum beneficial windward area at any time to assist the cruise. When the light energy utilization effect is good, the photovoltaic power generation area is expanded through the wind-solar conversion device. The angle adaptive control system controls the sail to automatically turn to the largest facing surface, increasing its power generation efficiency, thereby achieving the purpose of advancing the cruise ship. According to preliminary calculations, taking a traditional diesel-powered cruise ship as an example, a traditional cruise ship carrying 80 people uses this system to achieve zero emissions and pollution. Compared with the traditional electric cruise ship, a rough estimate can improve the endurance of 60%, and the energy obtained by the intelligent wind and solar hybrid propulsion system of the ship at a maximum sailing speed of 30% is clean and pollution-free. As international laws and regulations place increasing demands on the greening of ships, the effective use of clean marine energy can reduce the discharge of ship pollutants.

Full use of natural resources reduces energy consumption and saves costs. At the same time, the risk of polluting urban waters after a ship accident is also avoided. In addition, through the improvement of this set of wind-solar complementary propulsion system, it can provide auxiliary power and daily electricity for more ship types, such as ocean steamers, ore ships, etc.

5. Conclusion

The ship mainly uses the natural resources of solar energy and wind energy, and selects the use of main energy sources according to the weather conditions. In this way, the combustion of diesel will be reduced during the travel of the ship, thereby reducing the emissions of toxic and harmful substances, which is of positive significance for environmental protection. The use area of natural resources has been expanded and utilization efficiency improved. When the solar panel is laid on the sail, when it is clear, not only can the solar energy provided by the direct sunlight on the sail board be used, but also the energy brought by the sunlight reflected on the sail board by the water surface. The utilization efficiency of solar energy is improved, and the effect of wind on the ship can be used to help control the navigation direction of the hull.

In short, the solar wind-assisted power generation ship studied in this project has significant advantages such as small emissions, large solar utilization area, significant wind-assisted effects, and small hull space occupation. Compared with ordinary lake cruise ships, the energy saving and emission reduction effect of this power boat is very obvious.
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