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Abstract: Aiming at the heavy workload of water quality monitoring on waters like inland rivers and lakes and the shortage of small-scale surface water quality monitoring equipment, a green water quality monitoring vessel was designed and developed based on dual operation mode from the perspective of practicability. The overall design scheme was put forward, the structure design and function development were completed, the dynamic performance analysis was carried out by using the simulation software such as Ansys, and the performance index of the water quality monitoring vessel for normal operation was obtained. Through the prototype production and launching experiments, the control and function realization of the designed water quality monitoring vessel were verified, which provided the basis for real ship application.

1. Introduction

In recent years, water pollution problems such as deterioration of water quality and increase in floating garbage have become increasingly serious. As urban rivers, lakes and other waters are not only the main source of water for people's living, but also an important place for viewing and entertainment, the impact of pollutants is more direct and serious. Article 74 of the Law of the People's Republic of China on the Prevention and Control of Water Pollution revised on June 27, 2017, states clearly: “A protected area can be delineated for water bodies in scenic spots, important fishery water bodies and other water bodies with special economic and cultural values, and measures should be taken to ensure that the water quality of the protected area meets the water environment quality standards for the specified use”[1] .

For water quality monitoring, the methods commonly used at home and abroad are mainly manual on-site sampling and laboratory instrument analysis. The main monitoring methods are traditional physical and chemical monitoring methods, such as spectrophotometry, atomic absorption, atomic fluorescence, plasma emission spectroscopy, Plasma emission spectroscopy mass spectrometry (ICP-MS) and gas chromatography-mass spectrometry (GC-MS), etc. However, the instruments used in these techniques all have problems such as large volume , long sampling and testing cycles[2].

In view of the above problems, this paper designs and develops a green water quality monitoring vessel based on dual operation mode and carries out experimental verification on its feasibility and practical application, which provides a reference scheme for solving water quality monitoring problems.

2. Materials and methods

Based on the considerations of ship stability, clean energy utilization and functional monitoring of water quality monitoring, the water quality monitoring vessel designed in this paper is a catamaran. In the process of structural design, implementing the idea of modular design, the designed water quality monitoring vessel is divided into three core parts: water quality monitoring system, control system and photovoltaic power system, including core components such as water quality monitoring integrated instrument, camera, laser radar, solar battery plates and pod thrusters. The designed water quality monitoring vessel has two modes of manual control/autonomous cruise, which can realize water quality monitoring.The green power drive of the water quality monitoring ship can also be realized with the designed photovoltaic power generation system .

According to the introduction above, the water quality monitoring ship is divided into three parts: water quality monitoring system, control system and photovoltaic power generation system. In order to realize the function of the water quality monitoring vessel, detailed design of each part is required.

2.1. Water quality monitoring system

The designed water quality monitoring system is a functional module of the water quality monitoring vessel, which can effectively monitor the water environment.

Because the existing water quality monitoring and water quality monitoring are two independent processes, which consume a lot of manpower and material resources, it is difficult to achieve effective and comprehensive treatment of water pollution timely. Therefore, based on the characteristics of the hull structure, a combined functional module is designed. The designed water quality monitoring system has five parts: the water quality monitoring integrated instrument, the data transmission module, the data storage module, the power supply module and the controller module. The water quality data is collected by the water quality monitoring integrated instrument and transmitted to the control terminal by the data transmission module, then it will be displayed in real time on the control terminal and saved to the storage module. The water quality data can be directly used at a later stage. The entire hardware system accepts the instructions of the controller and is powered by the power supply module to maintain normal operation. The specific hardware structure of monitoring system is shown.

According to the "National Surface Water Environmental Monitoring Standards" promulgated in 2016, the key five routine water quality parameters were selected for monitoring and the corresponding sensors were selected based on this[2]. Specifically, it includes: (1) Temperature: DS18B20 digital temperature sensor is used. The sensor is a single-wire interface. One interface line can realize two-way communication between sensor and microprocessor. (2) Turbidity: TurbiLux near-infrared turbidity sensor; (3) PH value: E-201-CPH electrode PH sensor is used. The pH sensor is output in analog quantity and can be monitored continuously for a long time. (4) Conductivity: DJS-1 pole piece type conductivity electrode sensor is used. It can effectively prevent the polarization phenomenon occurring in the measurement; (5) Dissolved oxygen concentration: The KDS-25B dissolved oxygen sensor is used for rapid monitoring of water quality.

The designed water quality monitoring integrated instrument is located on the outer side of the hull and is connected with the hull by bolts to facilitate the replacement of the sensor. In the gap between the sensor probe and the bolt, it is necessary to apply a waterproof sealant for sealing.

2.2. *Control system*

The designed control system includes two parts: hardware system and software system. It can realize functions such as environmental information collection, obstacle avoidance, manual control and autonomous cruise. When the water quality monitoring ship is working, the shore-based control software can be used to realize the manual control of the water quality monitoring ship operation; it can also be switched to the autonomous cruise mode, by which the water quality monitoring ship conducts ergodic cruise for independent water quality monitoring.

2.2.1. Hardware System
The water quality monitoring ship hardware control system mainly includes: the shore-based control station and the ship-borne control system with the control terminal, radar, camera, GPS, GPRS communication module, ultrasonic sensor, STM controller and other equipments[3]. As shown in Figure 1(a), the camera is mounted on the bow and controlled by the steering gear. It can turn 180° from top to bottom and left to right to collect the surrounding environment information. As shown in Figure 1(b), the designed shore-based control terminal is controlled by the manager. The manual control function mainly receives the surrounding environment information through the camera and controls the steering and speed of the water quality monitoring vessel by the direction key and the speed control bar of the shore-based control terminal. The shipboard control system consists of an industrial computer, a general-purpose bottom control system and a GPRS communication system. Various sensors are also installed inside to obtain the status information of the water quality monitoring ship.

(a) Installation of camera head and pan/tilt. (b) Ground-based control terminal.

Figure1.control system hardware diagram.

2.2.2. Software System
The water quality monitoring ship software system corresponds to the hardware system and is divided into a shore-based intelligent terminal control system and a ship-borne industrial computer control system. The two communicate with each other through GPRS. Through the main interface of the control system, data like the GPS coordinates, speed, heading, energy consumption and internal environmental information of the water quality monitoring vessel can be displayed to realize the monitoring of the speed, direction and working time of the navigator .

The software system is written by JAVA and designed with module design method.The main functions of the system are divided into multiple independent modules. Each module realizes its corresponding function. and it can realize the use of multiple functions at the same time when called by the main function of the system. The control software is divided into video display, water quality monitoring numerical real-time backhaul, navigation information feedback, navigation control, navigation mode switching and other display modules. The system communicates with the water quality monitoring ship through the GPRS module and the wireless bridge and obtains various information such as video information[4], water quality data and hull navigation status returned by the shipboard control system, which will be displayed on the operation interface after processing so that the operator can get more concise and clear information. With manual / automatic switching function, the system can be directly used to control the navigation of water quality monitoring vessels accurately under different working conditions[5] .

2.3. *Photovoltaic propulsion system*
The designed photovoltaic propulsion system includes photovoltaic power generation system, energy storage system and pod propulsion system. The photovoltaic power supply system is designed to realize stable power supply through the adjustment of the photovoltaic controller and the battery. In the choice of propellers[6], the water quality monitoring vessel uses a full-rotation pod propeller, which is more compatible with electric propulsion and can improve the flexibility of the water quality monitoring vessel.

2.3.1. Photovoltaic power generation system

The designed photovoltaic power generation system of water quality monitoring ship is mainly composed of solar panels, controllers and inverters. Among them, the solar panel uses a Sunpower 24V semi-flexible solar panel with light weight and large laying area, which adopts a full coverage arrangement on the surface of the water quality monitoring vessel[7]. By designing a bypass diode between the positive and negative electrodes of the solar panel, the hot spot effect formed on the surface of the panel caused by the blockage of the wind turbine blade can be effectively avoided.

2.3.2. Energy storage agency

At present, commonly used batteries are nickel-cadmium, nickel-hydrogen, sealed lead-acid, lithium ion, etc. They have large differences in technical indicators such as service life, charge and discharge times. In order to ensure navigation safety and improve endurance, the water quality monitoring vessel needs to store enough electric energy before each operation, but it cannot guarantee the exhaustion of electric energy after each returning. Therefore, the selected battery should have no memory effect to meet the design requirements. This paper designs a lithium ion battery. In addition to its low overcharge resistance, the specific energy and nominal voltage are also prominent and its self-discharge rate is slow. In engineering applications, based on the consideration of the placement of flexible solar panels and pod propellers, lithium batteries are placed in the hull to provide regulation for the input and output of electricity.

2.3.3. pod propulsion system

The propulsion system is the key part of the output of the entire power system. As shown in Figure 7, the designed water quality monitoring vessel uses two small Azipod pod propellers, symmetrically placed on the rear side of the water quality monitoring vessel. The propulsion motor is directly connected to the propeller and is located outside the cabin and connected to the hull through a coupling. The slewing mechanism can drive the steering of the lower mechanism of the pod propeller to realize the change of the water quality monitoring ship heading. The joint between the coupling and the cabin and the motor are required to be watertight.

2.4. Analysis of the dynamic performance of water quality monitoring vessels

2.4.1. Water quality monitoring ship volume parameter design

Since the designed water quality monitoring ship working areas are inland river, artificial river with low density of floating garbage, so the designed hull volume should not be too large, avoiding waste of resources and affecting the beauty of the water. Referring to the design parameters of the water quality monitoring vessel designed by Wuhan Feichi Machinery . and the unmanned navigation channel monitoring vessel of the Yangtze River[8], the volume parameters of the water quality monitoring vessel designed in this paper are shown in Table 1.

Table1.Water quality monitoring ship volume parameters Unit (mm).

Project	Parameter
Total length	3000
Total width	1800
Sheet width	450
Total height	500
Deep water	180

2.4.2. analysis of resistance performance of water quality monitoring ship during navigation

(1) Calculation of hull resistance

At present, the design of the craft has no precise formula to calculate the resistance, and most of them are estimated according to the test or empirical formula. Because the accuracy of this estimation method is difficult to guarantee, in order to get more accurate navigation resistance, this paper calculates and analyzes the resistance of different speeds of the aircraft through Freeship software. The hull type value table is imported into Freeship, and the boundary conditions are set to obtain the resistance of the water quality monitoring ship under different speeds in the Freeship simulation environment. As shown in Fig. 2, frictional resistance, cohesive resistance ,wave resistance and total resistance of the water quality monitoring ship hull can be visually obtained[9].

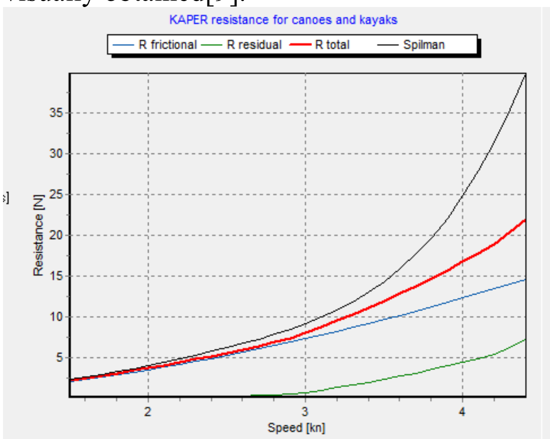

Figure2.Resistance curve of water quality monitoring ship at different speeds

The designed water quality monitoring ship is a small low-speed catamaran. The resistance is mainly frictional resistance , a small part of the cohesive resistance and attached body resistance, etc. The total resistance of the water quality monitoring ship increases with the increase of speed. Due to the low speed of the design, the resistance calculation of the water quality monitoring vessel is in line with the expected design results.

(2) Calculation of the effective power

After determining the resistance of the water quality monitoring vessel, the effective power of the water quality monitoring vessel can be obtained:

$$P_E = R_t \times V_s \quad (1)$$

Then the total motor power is:

$$P_s = P_E / \eta \quad (2)$$

Where Rt is the total resistance of the water quality monitoring vessel; Vs is the maximum speed of the water quality monitoring vessel; η is the efficiency coefficient.

Because the water quality monitoring ship speed needs to consider the speed limit of the relevant waters.What's more, the speed should not be too fast to avoid excessively increasing power consumption, affecting the endurance ability and producing potential safety hazards. Therefore, the speed of the water quality monitoring ship is designed at 3.5kn. At this speed, the resistance of the water quality monitoring vessel is 78.4N.

Calculated by equations (1) and (2), the power consumption at this time:

$$P_s = R_t \times V_s / \eta = 267.71 \text{ (W)} \quad (3)$$

In the formula, Rt is the total resistance, and the calculation can obtain 78.4N; Vs is the maximum sailing speed, taking 3.5kn; η is the efficiency coefficient, taking 0.5125[10].

Photovoltaic power:

$$P_1 = \eta_1 \cdot S \cdot \eta_2 = 212.5 \text{ (W)} \quad (4)$$

It can be seen from the above simulation and calculation that the photovoltaic power generation can maintain the power consumption of the water quality monitoring ship with only a small amount of energy supplementation during the normal operation of the drifting ship.

3. results

This paper presents a designed scheme for a water quality monitoring vessel, which is designed in detail and analyzes the dynamic performance and energy consumption. Through the prototype test, the feasibility of the control and function of the designed water quality monitoring vessel was verified, which provided a reference for the development of new efficient and intelligent water quality monitoring vessels. The designed water quality monitoring vessel has improved energy efficiency and accuracy while reducing energy consumption and eliminating fuel costs. In addition, the manual control mode is combined with the autonomous cruise mode, and the shore-based control software is simple and easy to use, which will greatly reduce the labor intensity and provide a good working environment for the staff. The water quality monitoring ship has the characteristics of reasonable structure, simple operation, low power consumption and wide adaptability of operation, and it has high practical value in floating water cleaning and water quality monitoring.

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References

[1] Zhou G.X, Ren H.L, Feng G.Q, Yan C.B. Structural strength assessment of catamaran type cleaning ship[J]. *Ship Engineering*, 2013,42 (1): 17-20.
[2] State Environmental Protection Administration, State Administration of Quality Supervision, Inspection and Quarantine - Surface Water Environmental Monitoring Standard, GB3838-2002.
[3] Dong Z.P, Wan L, Song L.F, Mao Y.S. Design of micro-small USV control system based on adaptive expert S-plane algorithm[J].*China Shipbuilding*,2017,58(2):178-187.
[4] Jian P.B, Mei X.G. Design of Ultrasonic Rangefinder Controlled by Single Chip Microcomputer [J]. *Applied Mechanics and Materials*, 2014, Vol. 3360 (599), pp. 1470-1473.
[5] Li P.F; Meng Q; Zhang W.H. Study on Image Target Enhancement Algorithm and Feature Location Technique [C]. Proceedings of 2014 IEEE Computers, Communications and IT Applications Conference (ComComAp), 2014.10.
[6] Qi Z.Y, Wang S.T, Tian G.Z. Coordinated Control of Wind-Solid Complementary Power Generation System[J].*Acta Energia Sinica*,2010,31(5):654-659.
[7] Zhang Y, Yuan C.Q, Yan X.P. Construction of a small cruise ship photovoltaic system based on ship-shore integration[J]. *Ship Engineering*, 2013, 35(5): 48-49.
[8] Tu C.Y. The first unmanned navigation channel survey vessel in the shallow section of the Yangtze River Taipingkou Channel, China Water Transport Network, 2018.
[9] Chang S.P;Wang Y.S;Pang Z.Y;Study on hydrodynamic performance of hydration movement of waterjet propulsion catamaran based on CFD[J].*China Shipbuilding*,2010,51(2):15-19.
[10] Zhang L.H, Liu F.H, Lou F. Design, Experiment and Optimization of Single Unmanned Vehicle[J]. *China Shipbuilding*,2016,57(4):132-138.