An Offshore Cleaning Vessel Based On Integrated Treatment Of Solid-liquid Pollutant

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Abstract. Aiming at the diversity pollutant species in offshore waters, people can’t collect the liquid contaminants and solid contaminants pollutants at the same time. So we designed a new type of offshore cleaning vessel based on integrated treatment of solid-liquid pollutant for practical. We proposed the general design of the program, completed the structural design and functional development. And we implement the integrated efficient monitoring and clean-up of the solid pollutants mainly composed of floating garbage and the liquid pollutant dominated by oil, by using the integration cleaning of solid-liquid pollutants technology and the intelligent recognition pollutants technology. We verified the control and function of the cleaning vessel through the production of ship prototype and the ship experiment.

1. Introduction
With the sustained and rapid development of the global economy, it has also caused a large number of industrial pollutants and other household wastes, which are increasingly aggravating the pollution of the marine environment when they are discharged into the ocean. The blue economy, which appeared in the government work report in 2019, has also become an important development sector in the future.

In the collection of solid and liquid pollutants, the common methods at home and abroad are manual salvage and large-scale mechanical cleaning. Due to the limited carrying capacity of marine environment, pollutants must be treated in time for the sustainable development of marine ecology. It requires high cleaning efficiency and reasonable cleaning method. Nowadays the traditional cleaning process of solid and liquid pollutants is independent of each other, which on the one hand, consumes lots of manpower and material resources, and on the other hand, it is difficult to realize the timely, effective and comprehensive cleaning of marine pollution.

Aiming at the problems above, we design the new type of offshore cleaning vessel based on integrated treatment of solid-liquid pollutants, and verified the feasibility and practical application of the device by experiments, so as to solve the problem of the mixed distribution of solid and liquid pollutants in the offshore.

2. Materials and methods
In this paper, the catamaran structure is designed for the ship hull considering the stability of the ship, the storage of pollutants and the timeliness of pollutant cleaning.
In the process of structural design and modular design concept, we divided the cleaning vessel into three core parts: integrated pollutant cleaning mechanism, control system and photovoltaic propulsion system. Including pollutant cleaning plant, pollutant collection plant, camera, laser radar and solar panel. We adopts terminal control and autonomous cruise mode on the offshore cleaning vessel, which can independently clean pollutants, and also the design of photovoltaic power generation system can realize the green power drive of offshore cleaning vessel.

2.1. Integrated pollutant cleaning mechanism
In this part we show the designed integrated pollutant cleaning mechanism which is the functional module of offshore cleaning ship, it can effectively deal with various combinations of solid and liquid pollutants.

At present, the traditional cleaning process of solid and liquid pollutants is independent of each other, and it is difficult to realize the timely, effective and comprehensive cleaning of marine pollution. Therefore, we designed a variety of combined functional modules according to the characteristics of hull structure. The integrated solid-liquid pollutant cleaning mechanism is composed of five parts, namely, contaminant information acquisition module, contaminant cleaning module, data transmission module, power supply module and controller module. The contaminant information is collected through the camera and other devices, then transmitted to the control system through the data transmission module. All modules are commanded by the management of the controller system and powered by the power module.

The hardware and working process of the integrated pollutant cleaning mechanism include five parts. First part is the solid interception device, it can collect floating garbage and other solid garbage, others such as the smaller garbage and liquid pollutants flow to the second part for cleaning. Second part is the impurity filter box, which adopts multiple filter grids. And the box body is equipped with 7 filter screens, whose diameter of the filter holes are regular, the first and second filter holes are 4.00mm, the third and fourth filter holes are 2.36mm, the fifth, sixth and seventh filter holes are 1.70mm. Third part is the oil cleaning tank, which adopts the inclined plate oil separation method. The tank body is connected with the negative pressure suction device, and the density difference of oil and water is used to clean up the oil in liquid pollutants. Forth part is the multi-medium filter box, contains triple filtration, The first filter unit is anthracite, quartz sand filter material and gravel layer; The second filter unit is activated carbon filter material and gravel layer; The third filtration unit is a microfiltration membrane. Fifth part is the water quality testing tank, electric control valve and drainage pipe are installed in the water quality testing box. If the water body fails to meet the water quality discharge standards through the water quality testing device, the water will be stored in the sewage collection box.

2.2. Control system
The control system includes hardware system and software system. It can realize environmental information collection, autonomous obstacle avoidance, terminal control, automatic cruise and other functions. The terminal control software can be used to realize the control of the offshore cleaning vessel. It can also switch to the autonomous cruise mode, through which the offshore cleaning vessel can achieve independent water cleaning.

2.2.1. Hardware system.
The hardware control system of offshore cleaning ship mainly includes: autonomous cruise system and terminal control system onboard, water pump, camera, radar, GPS, GPRS communication module, ultrasonic sensor, STM controller and other equipment. The camera is installed on the cradle head and controlled by the steering device (Figure 1). It can gather information about the environment from the rotation. As shown in Figure 2, the terminal control system is controlled by the manager. The terminal control function gained the environmental information by camera, and the terminal controls the steering and speed of the offshore cleaning ship. The shipboard control system is composed of...
industrial computer, general bottom control system and GPRS communication system. In addition, a variety of sensors have been installed to obtain the status information of the water quality monitoring vessel.

![Figure 1. Install camera head and flat shift or tilt(Hardware control system)](image1)
![Figure 2. Ground control terminal(Hardware control system)](image2)

2.2.2. Software system.
The software system of offshore cleaning ship is corresponding to the hardware system, which is divided into autonomous cruise system and shipborne industrial computer control system. Though the main interface of the control system, GPS coordinates, speed, heading, energy consumption and internal information of the offshore cleaning ship can be displayed, so as to realize the monitoring of the ship's speed, direction and working time.

The software system is written by C language and adopted module design method. The main functions of the system are divided into several independent modules. Each module implements its corresponding function. When the main function of the system is called, a variety of functions can be realized at the same time. The control software is composed of several display modules such as video display, real-time return trip of pollutant cleaning value, navigation information feedback, navigation control and navigation mode switching. The system communicates with the water quality monitoring ship by GPRS module and wireless bridge, then acquires the video information, water quality data, hull navigation status from the ship control system. After processing, it will be displayed on the operation interface, so that operators can get more concise and clear information. The system owns terminal autonomous switching function, which can be directly used to control the navigation of water quality monitoring vessels under different working conditions.

2.3. Photovoltaic propulsion system
The photovoltaic propulsion system consists of photovoltaic power system and pod propulsion system. The photovoltaic power system aims to achieve a stable power supply by adjusting the photovoltaic controller and the battery. We choose the fully rotating pod propeller, which is more compatible with electric propellers and can improve the flexibility of offshore cleaning vessels.

2.3.1. Photovoltaic power system.
The photovoltaic power system designed for the water quality monitoring ship is mainly composed of lithium battery, solar panel, controller and inverter. Solar panels adopt the Sunpower 24V semi-flexible solar panels with light weight and large laying area, and full coverage arrangement is adopted on the surface of the offshore cleaning vessels.

2.3.2. Pod propulsion system.
The pod propulsion system is the key part of output in the whole power system. Adopted two small Azipod pod propellers, which are placed symmetrically on the rear side of the offshore cleaning vessel. The propulsion motor is directly connected to the propeller, located outside the engine room, and is
connected to the hull through a coupling. The rotary mechanism can drive the steering of lower mechanism of the pod propeller, so as to realize the flexible change of the water quality monitoring bow.

2.4. Performance analysis of offshore cleaning vessel

2.4.1. Design volume parameters for the offshore cleaning vessel.
Aiming at the offshore coastal area, the main task is the integrated cleaning of solid and liquid pollutants. Considering there may be many obstacles such as floating and passing vessels, the cleaning vessel requires better flexibility and obstacle avoidance performance. Therefore, referring to the work of Yunzhou Intelligent Technology Co. LTD., overall design dimension under the condition of meeting pollutant cleaning requirement (Table 1).

| Cleaning vessel parameters | Parameter values |
|----------------------------|------------------|
| Design chief (L)           | 1.1m             |
| Molded breadth (B)         | 0.7m             |
| Strip width (b)            | 0.15m            |
| Strip spacing (K)          | 0.38m            |
| Moulded depth (H)          | 0.3m             |

2.4.2. Analysis of the resistance performance of offshore cleaning vessels during voyage

2.4.2.1. Calculation of hull resistance.
At present, we didn’t have precise formula to calculate the resistance, most of which are estimated based on experimental or empirical formulas. As the accuracy of this estimation method is hard to ensure, in order to obtain more accurate navigation resistance, this paper calculates and analyzes the resistance of hull at different velocities through ANSYS CFX software. As shown in Figure 3, the velocity flow diagram and hull stress analysis diagram of the offshore cleaning ship can be intuitively seen.

![Figure 3. Velocity flow diagram and hull stress analysis diagram](image)

The water quality monitoring vessel is a small, low-speed catamaran. Due to the low speed, the calculation of the resistance of the offshore ship is basically fit with the expected design results.

2.4.2.2. Calculation of effective power.
The effective power of the vessel can be obtained after determining the speed of the offshore vessel.

The general speed of the cleaning vessel is 6 km/h, and the cleaning vessel is powered only by the photovoltaic power generation system:
- Consumes power of cleaning ship: $P_s = R_t \cdot V_s / \eta = 0.151 \text{kW}$
- Motor consumption: $W = P_s \cdot t = 1.212 \text{kW} \cdot \text{h}$
Solar panel generation: \[ W_1 = P \cdot t = 2.384 \text{kW} \cdot \text{h} \]

Consumes power of the cleaning device: \[ W_2 = P \cdot t = 1.464 \text{kW} \cdot \text{h} \]

Lithium-ion batteries provide the power: \[ W_3 = W + W_2 - W_1 = 0.292 \text{kW} \cdot \text{h} \]

It is calculated that the cleaning vessel can maintain a working speed of 6km/h when only powered by photovoltaic power system, and can operate continuously for about 8 hours, which meets the requirements of cleaning operation.

3. Conclusion

In this paper, an integrated cleaning scheme for offshore solid and liquid pollutants is presented. An offshore cleaning vessel is designed in detail and the dynamic performance and energy consumption are analyzed. By prototype test, the feasibility of the control and function of the offshore cleaning vessel is verified, which provides a reference for the development of new and efficient offshore cleaning scheme. The offshore cleaning vessel not only can improve efficiency and accuracy of energy, but also reduce the consumption and eliminating fuel costs of it. In addition, the combination of terminal control mode and autonomous cruise mode will greatly reduce the intensity of labor and provide a good working environment for employees. The offshore cleaning vessel has the characteristics of reasonable structure, simple operation, low power consumption and wide operation adaptability, etc. It has a high practical value for the cleaning of solid and liquid pollutants in the offshore environment.

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