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A wireless real-time monitoring system on intelligent underwater pollution cleaning robot

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Abstract. Intelligent underwater pollution cleaning robot is used to release microbial solution which can dissolve into water slowly into polluted river, so that the solution can react fully with pollutants, so as to achieve the purpose of river pollution control. The research of robot wireless monitoring system is based on the comprehensive application of wireless communication technology and intelligent control technology, in order to achieve real-time monitoring and centralized remote control of underwater pollution removal. Through the three-dimensional structure modeling of the intelligent underwater pollution cleaning robot, the overall scheme design and debugging test of the wireless monitoring system, it is proved that the intelligent underwater pollution cleaning robot is feasible in the intelligent and efficient underwater cleaning operation, and it is a research method worthy of reference and promotion.

Keywords: Wireless communication, intelligence, underwater pollution cleaning, robot

1. Introduction

In recent years, with the continuous improvement of industrialization and the acceleration of urbanization in China, a large number of industrial sewage, domestic sewage, agricultural and livestock sewage have been discharged into the river basin, resulting in the increasing pollution of most rivers in China [1]. Because of the variety, toxicity and biodegradability of pollution, it has been a difficult problem for river pollution control [2]. Therefore, in order to solve this problem intelligently and efficiently, an intelligent underwater cleaning robot and its monitoring system are proposed to be developed. The robot is used to release the microbial solution which can dissolve into water slowly into the polluted river, so that the solution can react fully with the pollutants, so as to achieve the purpose of river pollution control,

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and combined with wireless communication technology and intelligent control technology to realize the real-time monitoring and centralized remote control of underwater pollution removal.

Microorganisms are granular and soluble in water, the density is 1.25 g/ml and the length is 3 mm. The microbial releasing parts of the robot are cylindrical, with a radius of 330 mm and a length of 1000 mm. The cylindrical can be divided into six fan-shaped warehouses to hold the microorganism 100 kg evenly. It is required that the cylindrical be transversely put into the water with a depth of 400 mm and the rotational speed of the cylinder is 1–10 r/min.

Intelligent underwater pollution cleaning robot is a machine with more degrees of freedom in three-dimensional space and can realize many anthropomorphic actions and functions. Through the three-dimensional structure modeling of the robot and the debugging test of the wireless monitoring system, the real-time remote monitoring of the slow release of microorganisms in the polluted water source can be realized.

2. 3-D structural modeling of an intelligent underwater pollution cleaning robot

Function Module Design. According to the requirements of its use and working environment the intelligent underwater pollution cleaning robot adopts module design. It includes the functional module and the skeleton of the robot.

The functional module design of the robot consists of power supply, motor, transmission and release parts. Because the robot needs to rotate at low speed for a long time under water and has strong adaptability to the water surface, solar panels are used in the power supply part. Solar panels charge the batteries under the action of solar controller, so that the DC motor of the robot can be continuously powered. DC deceleration motor is selected as the motor part, which can meet the speed requirements of the rotary drum and is easy to install. The transmission part selects sliding bearings and stainless steel roller chains. Under the action of sliding bearing, the motor drives the rolling chain to drive the output shaft to rotate. The releasing part is designed by a rotary drum, the surface is evenly distributed with 1 mm holes. One end of the drum is connected with the output shaft and positioned by a sliding bearing. The other end is connected with the rotating shaft and positioned by a cylindrical pin [3,4]. The functional module structure of the microbial underwater release vehicle is shown in Fig. 1.

The skeleton design of the robot should satisfy two aspects at the same time. On the one hand, it should meet the requirements of functional module design. Through reasonable design, solar panels and motors can't be immersed in water. The floating ball positioning device is used to float the robot on the water surface and the depth of the whole robot into the water is about 300 mm. On the other hand, it should save manufacturing costs, reasonable material selection and key structure design.

Key Structural Design. Modeling and Analysis of Rotary Drum. Three-dimensional solid modeling of microbial underwater release vehicle using Inventor software, the execution unit of the underwater release vehicle is the rotary drum. According to its functional requirements, the rotary drum is divided into six small silos. The surface of the rotary drum is uniformly distributed with 1 mm holes. The material of the rotary drum is stainless steel welded parts. The center of the rotary drum is welded with the output shaft and the rotating shaft respectively. On one side of the rotary drum, six small doors are connected with hinges for robot loading. The physical characteristic function of Inventor software can calculate the mass of rotary drum and output shaft and rotation according to the material and connection mode of the model, i.e. $M_1 = 56$ Kg. The half-section plan of the three-dimensional model of the robot drum is shown in Fig. 2.

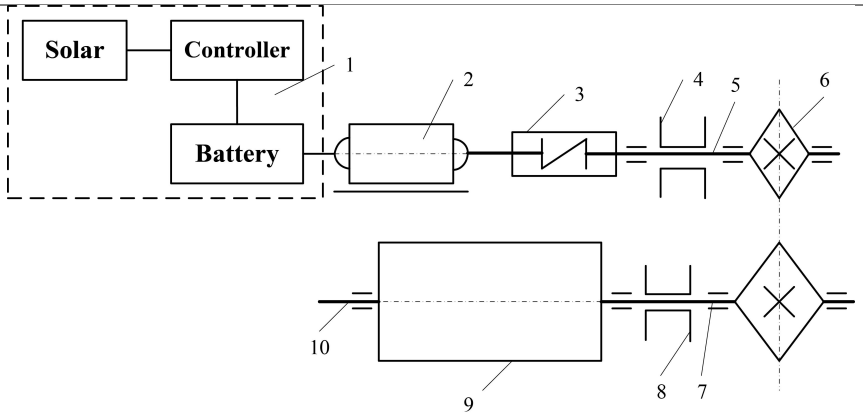

Fig. 1. Functional module structure of microbial underwater release vehicle. 1-Power supply, 2-DC deceleration motor, 3-Elastic coupling, 4-Sliding bearing I, 5-Principal axis, 6-Roller chain, 7-Output shaft, 8-Sliding bearing II, 9-Rotary drum with holes, 10-Rotating shaft.

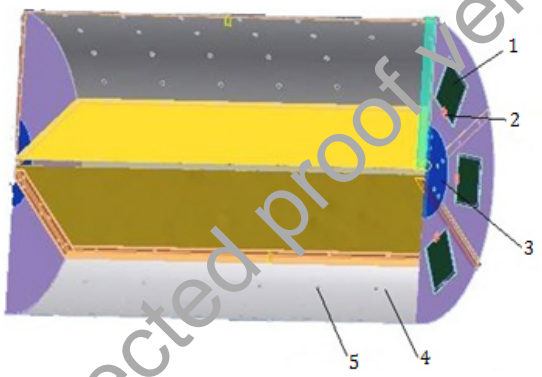

Fig. 2. Half-section plan of three-dimensional model of robot drum. 1-Fill port, 2-Living hinge, 3-Welding plate, 4-Loading bin, 5-1 mm keyhole.

Modeling and Analysis of Transmission Components. The design of transmission components is an important part in the design of robots, which involves the manufacturing cost and transmission performance of robots. The main shaft and output shaft of the underwater release vehicle are designed as stepped shafts. The main shaft is equipped with coupling, sliding bearing I, retaining ring and main sprocket. The output shaft is equipped with sliding bearing II, retaining ring, rotary drum and slave sprocket. The two stepped shafts are fixed on the sliding bearing seat and are limited by flange, retaining ring and shaft step. The 1/4 section plan of the main shaft and output shaft are shown in Figs 3 and 4.

3D Structure Modeling of Robot. After the modeling of the transmission part and release part of the robot is completed, the overall modeling of the underwater release robot is carried out by using Inventor software. The robot skeleton is welded by stainless steel. The whole device is well designed for the protection of solar panels, power boxes, motors and positioning devices of floats. The underwater releasing robot can meet the functional requirements of releasing microorganisms from its use, and the ship structure can effectively guarantee the stability of the robot's operation on water. The model of the microbial underwater release robot is shown in Fig. 5.

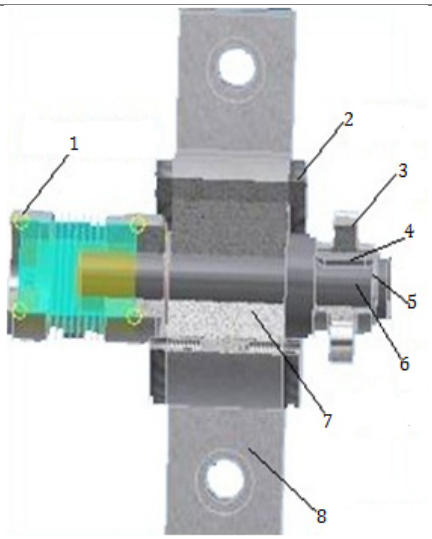

Fig. 3. 1/4 section plan of the main shaft. 1-Elastic coupling, 2-Flange I, 3-Stainless steel main sprocket, 4-Keyway; 5-baffle I, 6-Spindle, 7-Sliding bearing I, 8-Sliding bearing seat I.

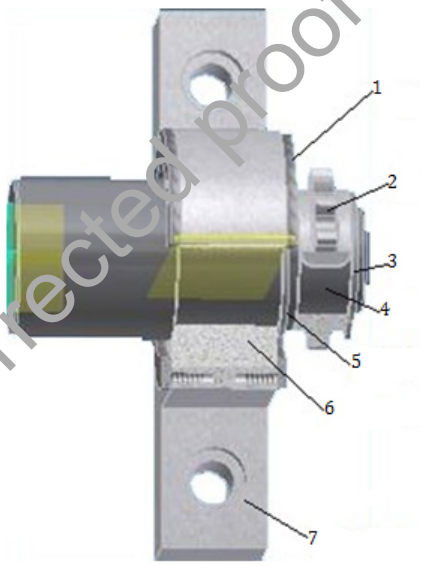

Fig. 4. 1/4 section plan of the output shaft. 1-Flange II, 2-Stainless steel slave sprocket, 3-Baffle II, 4-Output shaft; 5-Baffle III, 6-Sliding bearing II, 7-Sliding bearing seat II.

3. Selection of wireless communication technology

Network Overview of GPRS. The generation of GPRS meets the needs of mobile data services. GPRS is a new type of packet data transmission service on the existing GSM network. Based on the standardized network protocol supported by GPRS bearer service, GPRS can provide point-to-point and point-to-multipoint data services supported by IP protocol [5,6]. In the network structure, the switching connection with the circuit needs to be via MSC. The switching connection with the packet needs to be via GPRS

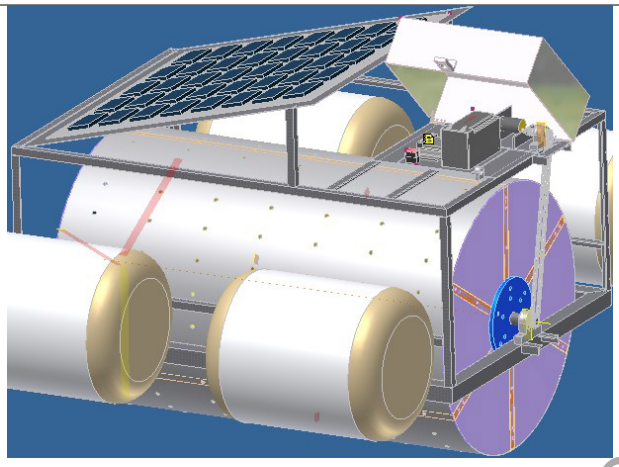

Fig. 5. The model of the microbial underwater release robot.

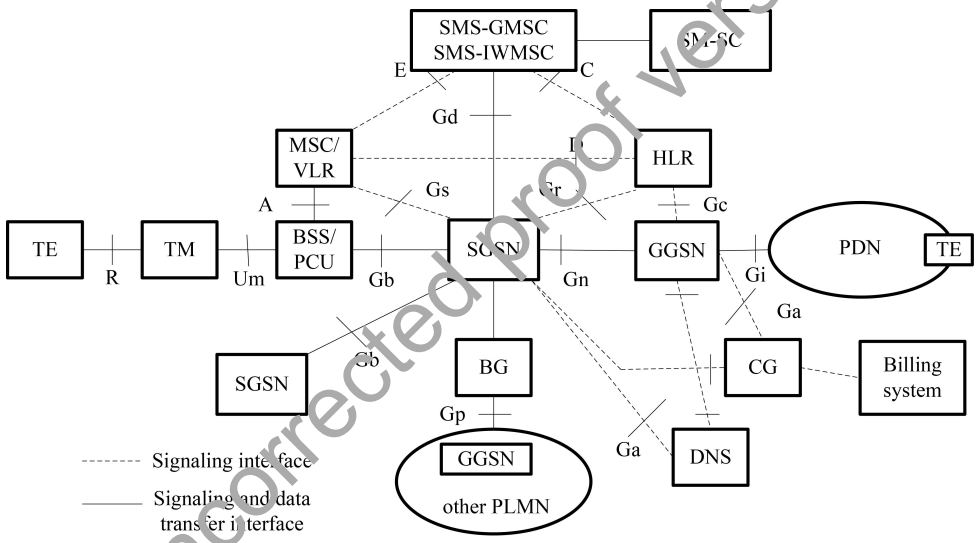

Fig. 6. GPRS network basic components.

Service Support Node (SGSN) and GPRS Gateway Support Node (GGSN). Connecting with other networks requires corresponding gateway devices, whose structure is shown in Fig. 3 [7].

GPRS Working Principle. GPRS works by routing management to address and establish data connections. When the mobile station produces a PDU (packet data unit), it is processed into LLC frame by LLC layer and sent to SGSN through air interface [8]. SGSN sends data to GGSN. GGSN decomposes the received message and converts to a format that can be transmitted in a public data network, which is finally sent to the users of the public data network [9]. When a public data network user transfers data to a mobile station, the routing between the data network and GGSN is established through the standard protocol of the data network. The data unit PDU sent by the data network user is sent to GGSN through the established routing. Then GGSN sends the PDU to the SGSN where the mobile station is located. SGSN encapsulates the PDU into SNDC data unit, then processes it into LLC frame unit through LLC layer, and finally sends it to the mobile station through air interface [10]. When a data packet from an

Table 1
Comparison of several wireless communication methods

Comparative indicators \ Communication mode	GPRS	GSM	CDMA
Reliability	High	Commonly	Higher
Error rate	Low	Higher	Higher
Operational costs	Lower	Higher	High
Communication rate	High	Lower	Higher
Transmission delay	Short	Long	Long
Network protocol	Support	Nonsupport	Support
Maintenance cost	Low	Higher	High

external network arrives at GGSN, it is placed in a "container" and sent to SGSN. These "containers" are transparent transmission in the GPRS backbone network. For users, it is as if they are connected directly to the external network through a router (GGSN). In data communication, this type of data stream is called "channel" [11].

GPRS Network Advantages. As can be seen from Table 1, GPRS has more advantages than GSM short message and CDMA. GPRS network has the advantages of wide coverage, stability and reliability, low communication cost, strong network capability and no geographical restrictions [12].

GPRS and EtherCAT Networking. TCP/IP protocol is the most commonly used form of networking between computers. It can interconnect computers which running completely different operating systems, so that they can communicate with each other. It is a real open system, which consists of data link layer, network layer, transmission layer and application layer. CX2030 controller manufactured by Beifu Germany adopts modular slot design, beautiful and compact appearance. The TwinCAT software platform based on PC embedding is compatible with all functions of traditional PLC, motion control function, EtherCAT bus function and configuration (HMI) function. It has powerful functions that traditional PLC and single-chip computer can't match. EtherCAT bus is based on Ethernet interface protocol and directly reaches the I/O layer of control system. It can connect with GPRS network and realize wireless transmission of real-time data through TCP/IP communication protocol.

4. Overall design scheme of wireless monitoring system

Upper Computer Monitoring Scheme. The wireless real-time monitoring system of intelligent underwater pollution cleaning robot is designed by modularization. The communication design of the host computer is divided into four modules: data acquisition module, data transmission module, database server module and monitoring center module. GPRS DTU includes TCP/IP protocol stack and TCP/IP data communication functions. OPC server and GPRS DTU use TCP/IP protocol for real-time two-way communication. Wireless OPC server has a fixed public network IP address. COM/DCOM is used to communicate between man-machine interface and wireless OPC server [13].

Data transmission scheme for wireless monitoring. The monitoring objects of the wireless real-time monitoring system of the intelligent underwater cleaning robot mainly include the depth of water inflow, the speed regulation of the drum, the speed regulation of the traction, the online feedback of the pollution control area, the electric control system and the motor fault alarm, etc. These monitoring objects transmit real-time data under the action of BECKHOFF CX2030 controller and its module through position sensor signal, drum speed detection signal, traction speed detection signal, visual transmission signal, button control signal and servo motor working parameters. Using EtherCAT control bus and

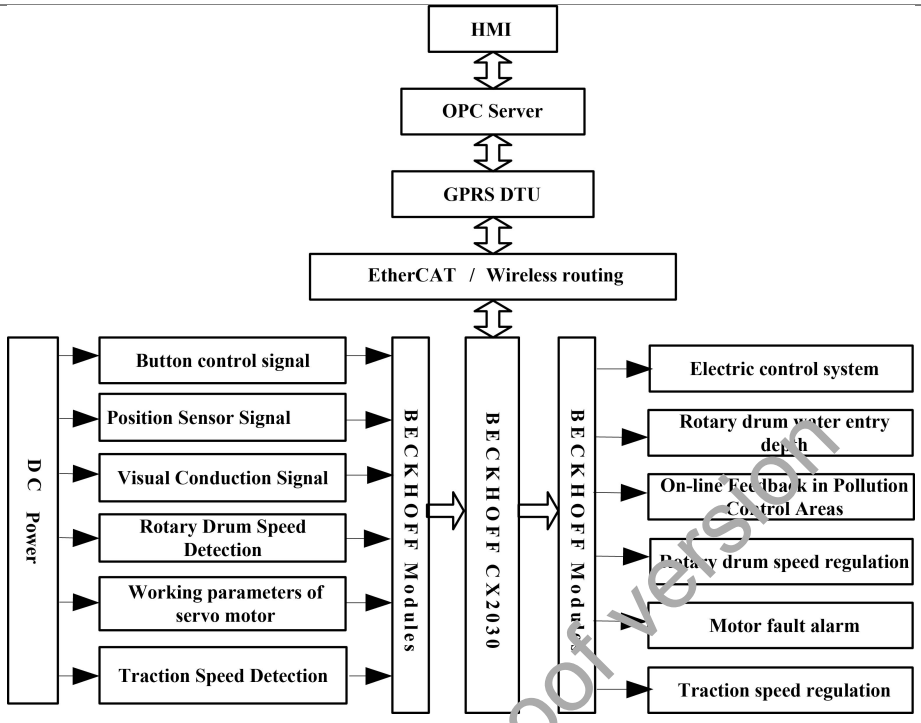

Fig. 7. Data transmission scheme of wireless monitoring system for the robot.

wireless communication technology, real-time wireless monitoring of underwater cleaning robot is carried out [14,15].

The total data transmission scheme of the intelligent underwater pollution cleaning robot real-time monitoring system which based on wireless communication technology is shown in Fig. 7. Data acquisition module mainly includes BECKHOFF module and sensor, data transmission module mainly includes GPRS DTU, wireless router and EhterCAT, database server module mainly includes OPC server, monitoring center module includes OPC client and human-machine interface software.

5. System debugging test and analysis

Test Environment. The debugging test of wireless monitoring system for underwater pollution cleaning robot was carried out in Huangshi area pollution control in rivers. The object of the debugging test is to clean up the pollutants in the river. The test area is 1000 square meters, and the pollution nature is serious pollution. The traction speed of the robot is 0.1 m/s.

Operation Test of Intelligent Underwater Pollution Cleaning Robot. Test preparation and monitoring process. Before the test operation, check the electronic control system and adjust the camera angle. At the same time, in order to prevent the excessive torque of the drum caused by the excessive traction speed or the excessive depth of the drum into the water, it is necessary to test the traction speed and the drum depth to determine the matching traction speed and the maximum depth of the drum into the water. When the preparatory work is ready, the wireless monitoring system is started, and the monitoring interface (HMI) enters the initialization process. Pay attention to the network connection is normal or not. It is necessary to restart GPRS DTU or stop checking under abnormal circumstances. After normal networking, matching

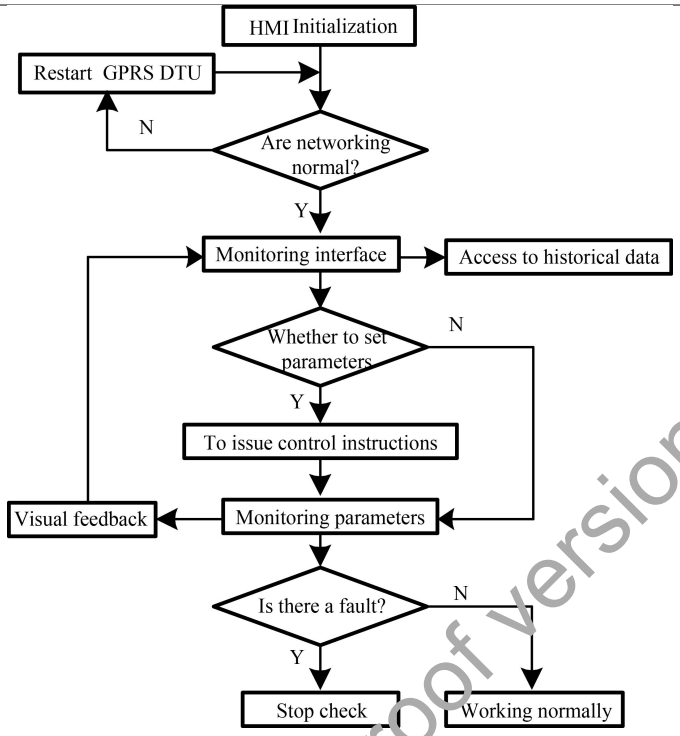

Fig. 8. The data monitoring flow of the intelligent underwater pollution cleaning robot.

related parameters are set on the HMI, and give control instructions to real-time observe the image angle and adjust relevant parameters online. After the wireless monitoring system works normally, driven by the traction speed, the intelligent underwater pollution cleaning robot begins to work. If there is a malfunction alarm, the system will automatically send out alarm to remind the operation to stop. Figure 8 shows the data monitoring flow of the intelligent underwater pollution cleaning robot.

Test Scheme. In order to verify the overall system performance, operation efficiency and cleaning rate of the intelligent underwater pollution cleaning robot, the whole testing process is divided into three groups. In test a, the underwater penetration of the drum was 20 cm and the speed of the drum was 10 r/min, 15 r/min and 20 r/min, respectively. In test b, the underwater penetration of the drum was 30 cm and the speed of the drum was 10 r/min, 15 r/min and 20 r/min, respectively. In test c, the underwater penetration of the drum was 40 cm and the speed of the drum was 10 r/min, 15 r/min and 20 r/min, respectively. During the test, the depth of water inflow and the speed of the drum are automatically adjusted on-line. The pollution control rate and operation efficiency are calculated and solved by the simulation software according to the comparison of the total amount of pollutants in the sector area of the image within the walking displacement. The overall performance and anti-torque ability of the system are calculated by setting the limit value of the rotation of the drum and alarm prompts are used.

Test results. Through many tests, the average value of the middle distribution of each test result is obtained, and the results of the cleaning test are shown in Table 2. The test results show that the wireless monitoring system of the intelligent underwater pollution cleaning robot has stable performance. When the depth of the drum is 30 cm and the speed of the drum is 10 r/min, the cleaning rate of the robot is outstanding. At the same time, when the depth of the drum is 40 cm, the speed of the drum is 20 r/min, and the robot often appears abnormal alarm, which indicates that the anti-torque ability of the drum

Table 2
Test results of intelligent underwater pollution cleaning robot

Test item	Depth of entry/cm	Rotating speed/r/min	Cleaning rate/%	System performance
a	20	10	86.6	Normal
		15	97.8	Normal
		20		Normal
b	30	10	85.6	Normal
		15	96.5	Normal
		20		Abnormal parking
c	40	10	87.5	Normal
		15	97.4	Normal
		20		Abnormal parking

in underwater operation needs to be improved, and the structure design of the intelligent underwater pollution cleaning robot needs further study. However, the robot's wireless monitoring system works well.

6. Conclusion

The application of intelligent technology, measurement and control technology, wireless communication technology and man-machine interface in intelligent underwater pollution cleaning robot greatly improves the mechanization and automation level of underwater cleaning operation, thus greatly improving the efficiency of cleaning operation. Based on the application of GPRS and EtherCAT networking technology, the wiring engineering of the whole machine and the failure rate of the electronic control system are greatly reduced, and the flexibility and cheapness of the system monitoring terminal are improved, which is conducive to the centralized monitoring of the joint operation of the underwater cleaning operation group. The application of image technology and computer simulation software is conducive to real-time feedback and scientific calculation of pollution removal rate and operation efficiency.

The test results of the wireless monitoring system of the intelligent underwater decontamination robot prove that the intelligent underwater decontamination robot is feasible in the intelligent and efficient underwater decontamination operation and it is a research method worthy of reference and promotion. At the same time, the design of the anti-torque capability of the rotary drum needs to be improved when the depth of water entry and the speed of the rotary drum are large.

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