Design of Integrated Water Quality Monitoring Sensor Based on Optical Detection

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Abstract

In this paper, the structure of marine water quality monitoring sensor is optimized based on sensor technology and information processing technology. A multi-parameter water quality sensor that integrates four water quality parameters monitoring functions, such as temperature, turbidity, COD and chlorophyll a, is designed, which can realize the automatic cleaning function of the optical window. At the same time, the 'dual optical channels –dual parameters' data calibration and comparison structure is proposed. This integrated sensor has the advantages of high integration, good stability, self-cleaning and simple operation, which improves the stability and reliability of water quality monitoring results.

Keywords

Multi-Parameter Sensor; Aiming Structure; Automatic Cleaning; Reliability.

1. Introduction

In recent years, the frequent occurrence of marine red tide and jellyfish phenomenon makes the monitoring and protection of marine ecological water quality imminent, and the protection of marine ecological environment has become the key content of marine economic development and construction. Water quality sensor is the main equipment for the detection and monitoring of marine water pollution. The development of integrated sensors has become an important part of intelligent monitoring and development of marine environment. Seawater monitoring has gradually developed from a single method in the laboratory to distributed in-situ online detection and monitoring of the ocean, in order to realize the real-time and continuity of marine water pollution monitoring. Using a single sensor to describe the marine water quality and environmental information has the shortcomings that cannot be overcome. The robustness of a single sensor is poor, and it is difficult to cope with the occasional faults of complex and changeable marine environment and equipment. The observed values must have contingency and uncertainty, and cannot make a comprehensive explanation of the marine environment. Multi-parameter integrated sensors can be equipped with different types of sensors to collect data in different environments according to the task requirements. At present, there are still some technical difficulties in the processing technology, structural design and detection principle of multi-parameter integrated sensors in China, which hinders the research and development of integrated sensors [1,2]. From the perspective of structural design, the integrated design of temperature, turbidity, COD, chlorophyll a and other multi-parameter sensors based on optical sensor technology is discussed to solve the reliability, sealing and easy maintenance of water quality monitoring sensors in the marine environment.

2. Multi-sensor Integrated Design

2.1 Multi-sensor Integrated System

Fig. 1 shows the multi-parameter water quality sensors, including 1- integrated sensor matrix, 2 ′1-COD sensor1, 2 ′2-COD sensor2, 3-turbidity sensor, 4-temperature sensor, 5-chlorophyll a sensor, 6-brush automatic cleaning system, and7-COD signal receiving center. The integrated sensor is divided into two parts. The upper multi-parameter sensor system integrates the temperature, turbidity, COD, chlorophyll a and other four parameter sensors, which can realize the online collection of multi-source water quality information in offshore waters. The lower part is the integrated sensor mother, built-in communication module, storage module and processor module, to achieve the optical signal processing and monitoring data storage and communication. Four different parameter sensors are evenly distributed on the sensor matrix. The light emitted by the light source of each parameter sensor is received by the spectrometer to form an optical signal. After processing by the signal processing module, the monitoring results of each parameter are obtained.

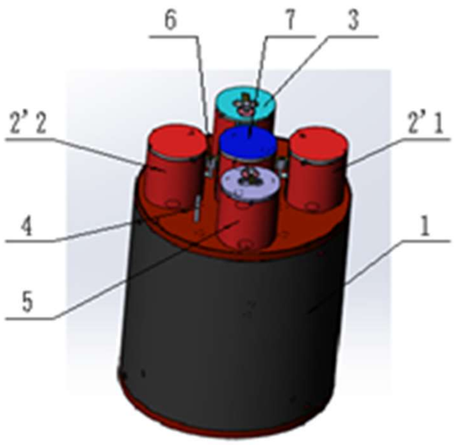

Fig. 1 Multi-parameter water quality sensor

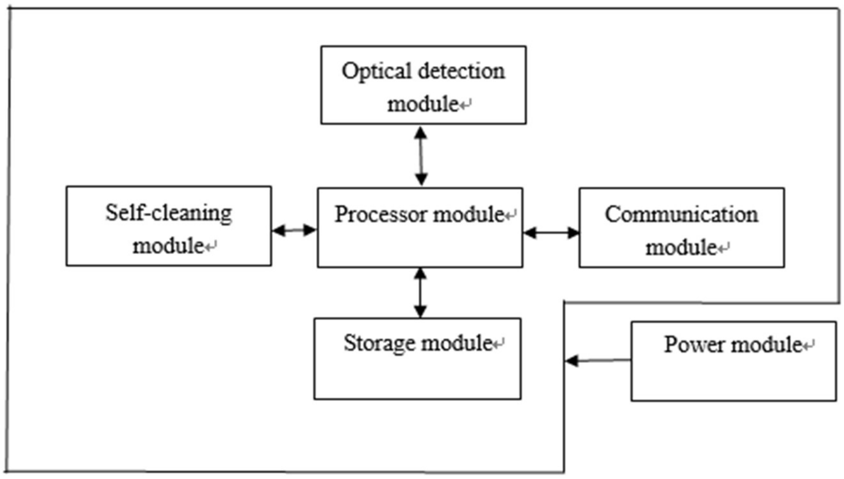

Fig. 2 Structure of Sensor Integrated Control System

Multi-parameter water quality monitoring sensor integrated system includes optical detection module, self-cleaning module, processor module, storage module, communication module and power module. In the optical detection module, a stable light source with a certain intensity is emitted by the light source, which is absorbed and refracted by seawater. The spectrometer receiver can judge the absorbance of seawater by measuring the light intensity of each wavelength. The self-cleaning module can realize the regular cleaning of the light window and ensure the stability and reliability of the data monitoring results. The processor module is the center of the whole sensor, which is used to read the light intensity signal output by the spectrometer receiver and calculate the absorbance of seawater. At the same time, instructions can be issued to control other modules of the sensor. The integrated sensor can monitor the changes of marine water quality and ecological environment in real time and continuously. The monitored water quality information is shared with the PC side through the communication module.

2.2 Contraposing Structure Design

In order to ensure the credibility and accuracy of COD measurement results, this paper designs a ' double optical channel-double parameters ' data calibration structure, which provides comparison and calibration for COD detection results and improves the reliability of COD measurement results. The sensors 2'1 and 2'2 are the same COD sensors, and they are symmetrical about the signal receiving center 7. The signal receiving center receives the optical signals from 2'1 and 2'2 sensors for processing respectively, and the two data processing results play a role in comparison and mutual calibration. As shown in Figure 3, 201 - UV source, 202 - optical path channel, 203 - optical window, 204 - brush cleaning system, 701 - signal receiver, 702 - optical window, 201'-UV source, 202'-optical path channel, 203'-optical window, 204'-brush cleaning system, 701'-signal receiver, 702'-optical window. This structure can effectively solve the problem of abrupt change in monitoring results of conventional COD sensors, provide comparison and calibration functions for monitoring results of marine water quality parameters, reduce the accidental and single influence of single point water sample detection results, and improve the anti-interference of sensors and the reliability of data monitoring results.

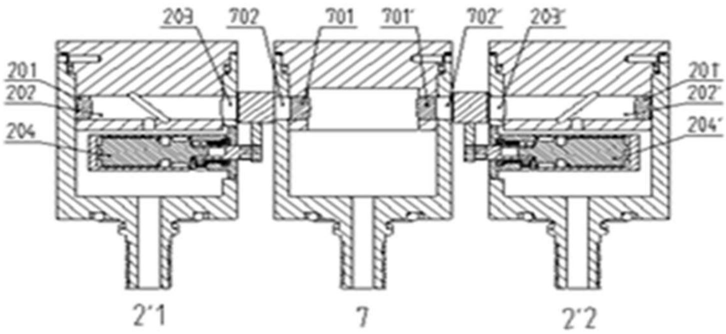

Fig. 3 Contraposing structure design

2.3 Self-cleaning System Design

When the traditional optical sensor measures the water quality of the ocean, a large number of microorganisms and shellfish and other aquatic organisms are easily attached to the outer surface of the optical window of the sensor to form a barrier film that affects the transmission of optical signals, which directly affects the accuracy of water quality measurement results and the service life of the sensor. In this paper, an automatic brush cleaning system is designed. The brush driven by a micro motor is brushed repeatedly on the surface of the light window at regular intervals. The whole brush cleaning system is embedded into each sensor as a closed whole, and each connection is completely sealed. This integrated structure design prioritizes the protection of the internal circuit of the sensor, which can realize the integral replacement and convenient maintenance. The working cycle of the motor is controlled by the circuit board according to the needs of water quality monitoring. In principle, the light window should be cleaned once in each data monitoring cycle of the sensor to ensure the accuracy and consistency of the data. Figure 4 is the self-cleaning system of COD sensor, including 601-motor protection shell, 602-motor, 603-waterproof sleeve, 604-sliding bearing, 605-OR seal ring, 606-photocoupler sensor, 607-shaft sleeve, 608-brush, 609-sealed structure, 610-sealed structure, 611-outlet seal. The brush A and B can clean the light window of COD sensor and signal receiving center at the same time, which has the advantages of small energy consumption and less space occupation.

Before each water quality detection of the integrated sensor, the processor sends out a self-cleaning control signal, and the driving motor controls the cleaning brush for circular motion to realize the cleaning of the optical window. After the light window is clean, the position of the brush is determined by the optocoupler sensor. It is required that the brush cannot block the light window and affect the reception of the light source signal. Otherwise, the position of the brush needs to be adjusted. After the brush cleaning system works, the signal is sent by the processor module, and the multi-parameter sensor can monitor the water quality data.

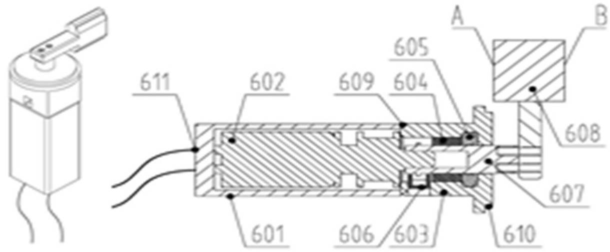

Fig. 4 Double-sided brush cleaning system

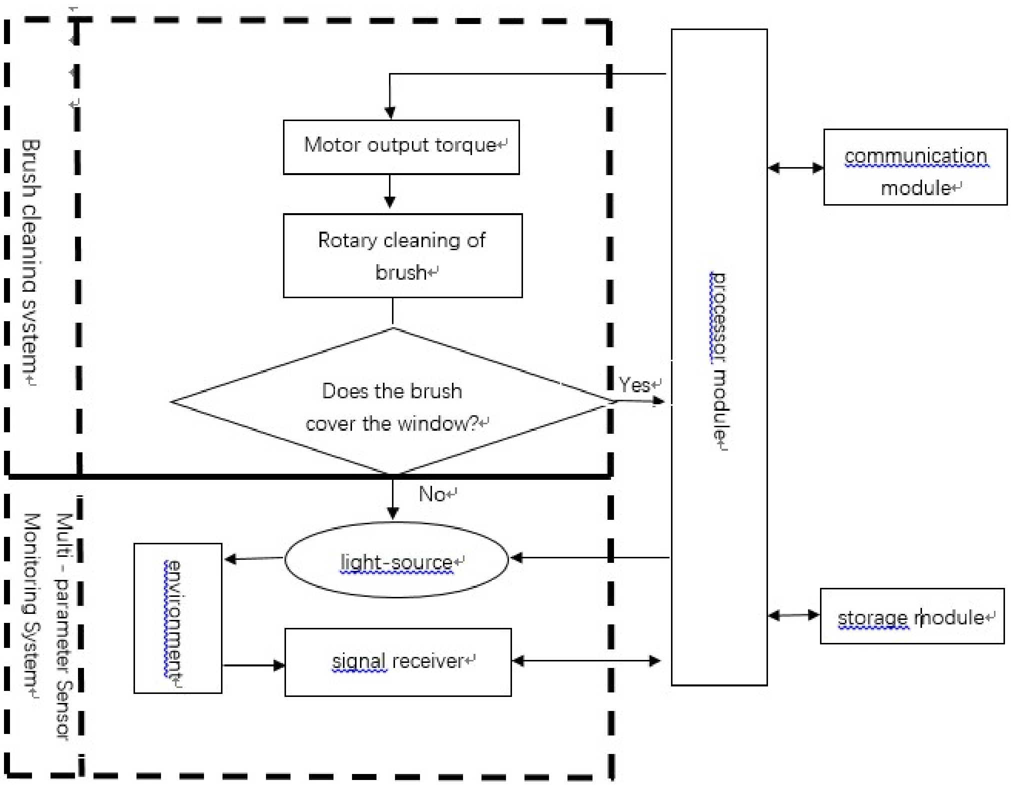

Fig. 5 Working principle diagram of brush cleaning system

3. Comparative Tests

In the laboratory, the integrated water quality sensor and the four traditional sensors (monomer hairless brush) of temperature, turbidity, COD and chlorophyll a were placed in seawater for continuous monitoring of water quality parameters. The data were recorded once a day at 10: 00, and the data monitoring results for 45 days were continuously recorded. The COD monitoring value was taken as the mean of the two opposite COD sensors. The water quality monitoring results are compared as Fig 6. Monitoring data 1 is the integrated sensor monitoring data, and monitoring data 2 is the traditional sensor monitoring data.

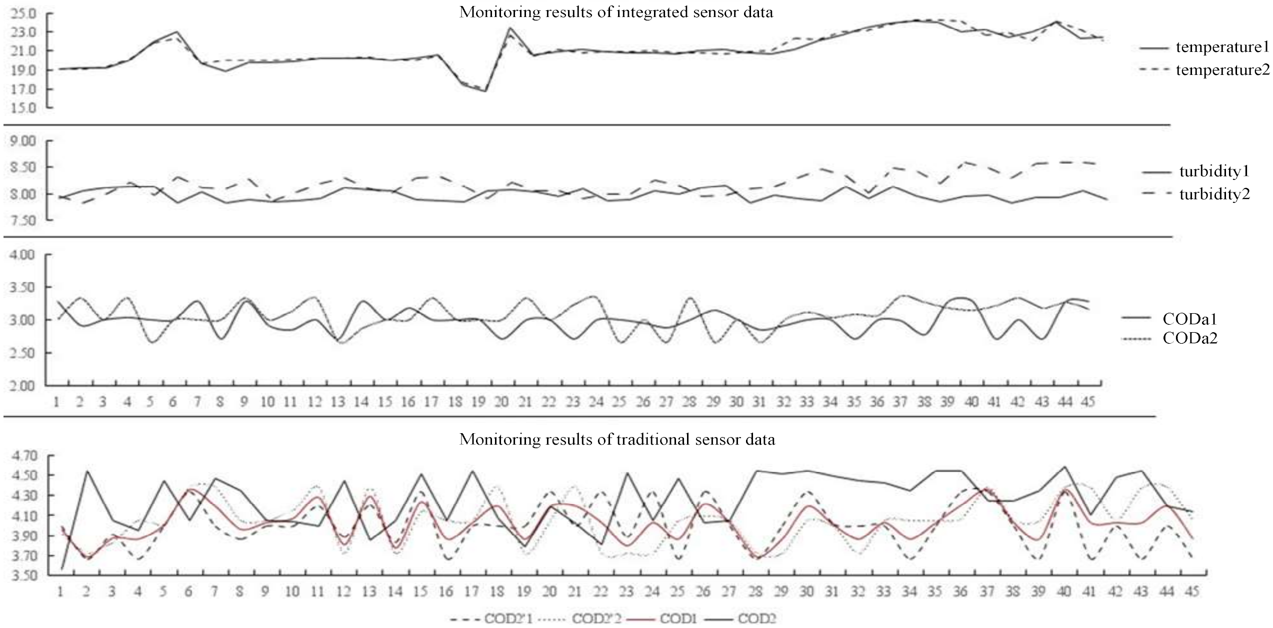

Fig. 6 Data monitoring results

According to the monitoring results of seawater quality, it can be seen that there is no significant difference in the monitoring results of temperature sensors on the whole, and the monitoring results of turbidity and chlorophyll a gradually show differences after 30 days of continuous monitoring, that is, the monitoring results of integrated sensor data are more stable, while the traditional sensor is automatically cleaned by brushless, and a large number of microorganisms are gradually attached to the surface of the light window in the long-term use process, resulting in a large deviation of the monitoring results. Moreover, in the process of monitoring COD parameters by integrated sensors and traditional sensors, the data fluctuation of the former is significantly smaller than that of the latter, and the two-parameter design can better reduce the instability of data monitoring.

Therefore, there is little difference between the integrated sensor and the traditional sensor in the short term, and the former has better weather resistance and stability in the long-term use, while the contrast COD structure design can continue to work as an emergency equipment when one of them fails or is abnormal, avoiding the interruption of water sample parameter acquisition process.

4. Conclusion

In this paper, a multi-parameter integrated water quality sensor is designed to solve the problems of short service life and low reliability of the results of the marine water quality monitoring sensor, which integrates the monitoring functions of temperature, turbidity, COD, chlorophyll a and other four parameters. It can realize continuous online water quality monitoring, and has the advantages of high integration, good stability, automatic cleaning, and simple operation. Each sensor is equipped with an independent brush cleaning system, which can independently realize the cleaning of microorganisms attached to the surface of the sensor light window. A COD parameter detection structure of "dual optical channels – dual parameters" was designed. The comparison structure can be calibrated with each other, which reduces the accidental and unitary influence of single-point water sample detection results. The research results of this paper have an important role in promoting the development of marine environmental monitoring equipment industry.

Acknowledgments

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