Research on solid-state fermentation process in a closed environment with multiple interferences

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Abstract: A closed battery detection system consists of a semiconductor alcohol sensor, a temperature sensor, a STM32F103 microcontroller, and a Windows 10 operating system computer. The ZigBee communication and RS485 communication technology are used to detect the temperature and alcohol concentration of the Dianchi Lake online, which solves the problem of manual sampling and damage to the sealing of the Dianchi Lake. Field tests have shown that the acquisition system data meets the manual physical and chemical test data.

1. Introduction
In the brewing process of many Chinese liquors, the crops need to be solid-state fermentation. The fermentation pit has strong airtightness and a long fermentation period. During the fermentation process, the pit environment has obvious phased changes in alcohol content. Monitoring the changes in alcohol content and fine-tuning related processes in time can effectively improve the yield and quality of liquor. Traditional wineries use manual collection and physical and chemical testing techniques to monitor the pits. The monitoring cost is high, the frequency is low, and the sealing damage of the pits is serious. To solve the current situation, an online monitoring instrument for pits based on the Internet of Things technology is proposed.

2. overall design
The monitoring pole is designed in three parts: the design of the perception layer; the design of the information processing layer; the design of the information transmission layer. The sensing layer sensor is a temperature sensor and an alcohol sensor. The signal controller uses STM32F103 single-chip microcomputer to control the collection, processing and display of information. The networking layer follows the ZIGBEE protocol networking mode. Through terminals, coordination, and routing, the signals of the entire pit factory are processed uniformly, and the information is finally transmitted to the upper computer for processing.
3. Perception layer design

3.1 Sensor selection
Alcohol sensors mainly include semiconductor alcohol sensors and electrochemical alcohol sensors. The pit environment monitoring cycle is long, in order to reduce power consumption, semiconductor sensors are selected.

The information obtained by the alcohol sensor requires attention to the ambient temperature and alcohol concentration. The airtightness of the pit is strong, and the alcohol concentration often exceeds the optimal range of the sensor, and it is necessary to build a separate air chamber environment for concentration dilution. On the other hand, the temperature sensor and the alcohol sensor are arranged close to each other to obtain the real-time temperature of the pit, and collect multiple sets of data to fit temperature compensation.

![Temperature compensation curve of wine precision monitoring in cellar pool](image1)

3.2 Signal acquisition
Semiconductor alcohol sensor is composed of metal oxide semiconductor and heating wire. When the concentration of alcohol gas in the monitoring environment changes, the corresponding sensor resistance value will also change. Using this property, construct a circuit to obtain real-time resistance change information.

![Semiconductor alcohol sensor structure](image2)

The $V_C$ circuit is the sensor power supply circuit, and the $V_T$ circuit is the heating wire circuit. The voltage across $R_L$ is the output voltage of the sensor probe. When $R_S = R_L$ is the best output range, the output voltage at this time is shown in formula (1):
4. Design of Information Processing Layer

4.1 Control objectives
The entire control system is mainly divided into acquisition frequency control, acquisition air chamber control, information display, and networking communication control.

The entire control system is mainly divided into acquisition frequency control and acquisition air chamber to control the solid-state fermentation process for more than two months. It is necessary to control the acquisition frequency of the sensing layer to achieve low power consumption. When signal is collected, the key to realize the dilution of alcohol concentration in the air chamber is to reasonably control the air valve of the air chamber and the switch of the pump. The information of each detection instrument needs to be displayed on the display screen for the recorder to record. Finally, all the control rod information of a factory area is summarized through the networking.

4.2 Control process
As the core processing device of a device, the controller needs to ensure the correctness of the logic of the detection rod. A complete detection process includes: air chamber opening, pump opening, signal acquisition circuit work, signal processing, display screen, data transmission, etc.

5. Signal transmission layer design
The number of solid-state fermentation pits determines the number of detection rods required. In order to ensure the accuracy of the data, each cell needs to be equipped with multiple monitoring rods, so the entire detection system needs dozens to hundreds of monitoring rods. The surrounding environment of the pit needs to avoid circuit laying pollution, so wireless transmission is used for signal transmission.

The power supply of the signal transmission circuit running inside the monitoring rod comes from an independent lithium battery, which can be replaced and supplemented after a fermentation is completed. Therefore, in order to satisfy the use of electric energy in the fermentation process, the power consumption of the communication circuit is an important indicator. In wireless transmission, the ZigBee communication circuit has low power consumption and the communication distance is about 10 meters. The communication distance can be greatly increased by adding routing, which does not pollute the pit environment and meets the communication needs.

RS485 communication is adopted between the coordinator and the host computer, which is connected through a serial port.

6. Actual measurement and display
6.1 Test platform construction
The front of the monitor rod test board is mainly composed of LCD display and buttons, and the back is mainly composed of core modules, component circuits and sensor interfaces. The module with antenna in Figure 6 below is the STM32 core control module, and the other interfaces are: No. 1 is the power switch interface; No. 2 is the lithium battery charging interface; No. 3 is the lithium battery interface; No. 4 is the alcohol sensor interface; No. 5 is the temperature sensor interface; No. 6 is the motor board control end interface; No. 7 is the power switch, No. 8 is the power adapter interface, and No. 9 is the RS485 interface.

The construction method of the simulated pit is: put the alcohol that has been manually detected into a closed measuring cup, put a temperature sensor probe in the measuring cup, a gas valve pipe at the alcohol end of the air chamber, and a calibrated thermometer. The top of the measuring cup is closed
with the soil above the solid cellar, and the sealing depth is 20 cm. The alcohol sensor probe uses the TGS2620 model, placed at the top of the air chamber, and the pipeline is buried in the simulated cellar.

Figure 3 Test board of solid state fermentation monitoring rod

6.2 Testing process

The functional test of the monitoring instrument is mainly divided into five aspects: power consumption test; motor operation test; air chamber tightness test; signal acquisition test; networking test.

Port 1 of the test board is connected to a DC 3.7V power supply, port 4 is connected to an alcohol sensor module, port 5 is connected to a temperature sensor module, and port 6 is connected to a motor module. When the hardware is powered on, the ZigBee networking signal light is on, the upper computer page starts to display the temperature, and the system networking function is normal. The signal acquisition test process is: change the detection period to continuous monitoring, start the monitoring rod-the air valve outside the pit is opened, the air valve inside the pit is closed, the motor running distance is a-after a delay of 1 minute, the air valve outside the pit is closed. The air valve in the pit is opened, and the motor stops after running distance b (a:b=9:1)-the two air valves are closed, with a delay of 1 minute, the alcohol concentration collection is completed-the air valve is opened and the motor is reset.

7. Results and analysis of field operations

Put the monitoring rod into the fermentation environment of a large winery in Anhui. The monitoring pole is 2 meters long, with a conical structure at the lower end for easy penetration into the mud layer of the pit, and the top is equipped with a control circuit, a display screen, and a networking antenna. The depth of the pit to be tested is about two meters, the fermentation space is about 15 cubic meters, and the upper part is covered with about 20 cm of soil.

The monitoring rod runs normally for a fermentation cycle. The monitoring rod is sampled and monitored every 6 hours, and the data at 12:00 every day is taken as the fermentation curve fitting data. The following table shows the curve fitting data for 7 consecutive days in the sampling period from No. 1 pit pool to No. 3 pit pool.

| Terminal 1 | 1     | 2     | 3     | 4     | 5     | 6     | 7     |
|------------|-------|-------|-------|-------|-------|-------|-------|
| Temperature (°C) | 26.3  | 25.9  | 25.8  | 25.8  | 26.0  | 26.0  | 26.1  |
| Alcohol concentration (ppm) | 38952 | 38863 | 38864 | 38826 | 38827 | 38834 | 38828 |

| Terminal 2 | 1     | 2     | 3     | 4     | 5     | 6     | 7     |
|------------|-------|-------|-------|-------|-------|-------|-------|
| Temperature (°C) | 26.1  | 26.0  | 26.0  | 26.0  | 26.1  | 26.3  | 26.0  |
| Alcohol | 38937 | 38982 | 38926 | 38926 | 38883 | 38842 | 38945 |
Table 3. Data sheet of terminal cellar No. 3

| Terminal 2 | 1    | 2    | 3    | 4    | 5    | 6    | 7    |
|-----------|------|------|------|------|------|------|------|
| Temperature (°C) | 25.8 | 26.0 | 25.9 | 26.0 | 26.2 | 26.5 | 26.3 |
| Alcohol concentration (ppm) | 38897 | 38953 | 38973 | 38879 | 38945 | 38953 | 38899 |

Finally, the upper computer fits the brewing curve to reflect the alcohol concentration of the pit environment.

It can be seen from the data that in the seven days, the temperature collection system in the factory area showed that the temperature in the pit was about 26°C. Compared with the laboratory personnel sampling and testing records of the factory area, the alcohol concentration content was between 38,000 and 40,000 ppm. By comparing the data collected manually, the monitoring rod data is consistent with the actual fermentation pit data. At the same time, in the field test, the lithium battery power supply used meets the energy consumption demand of 3 months, and the motor is running normally. In each stage of the fermentation process, the monitoring rods are sampled and inspected, and the gas chamber structure is disassembled. There is no liquid residue and water vapor traces in it, and the airtightness is good.

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