International Journal of Trend in Research and Development, Volume 11(5), ISSN: 2394-9333
www.ijtrd.com

Small Well-Drilling and Cleaning Robot

[1]Wang Shiyan, [2]Ma Yongkang and [3]Xiong QieXiu,
[1]Xi'an Technological University, School of Electronic and Information Engineering, Xi'an ,China

Abstract: Small-scale well drilling is the main way to obtain water in modern agricultural production, animal husbandry and other fields. However, with the increase of service life, the pipe wall formed by small-scale well drilling often has algae breeding, a large amount of sediment gushing out during use, causing water pollution and other problems. Therefore, in order to solve the problem of cleaning the pipe wall of small-scale well drilling, to avoid complicated operation and water pollution, a small-scale well drilling cleaning robot is designed to achieve efficient, environmentally friendly and safe pipe wall cleaning. Based on the STM32 main controller, the robot integrates the control system and cleaning system, including power supply voltage regulation, motor drive, detection and serial communication modules, and realizes one-button automatic and manual local cleaning functions. By automatically moving and fixing the three-phase cleaning robot arm, the robot efficiently completes the pipe wall cleaning, and automatically moves down 6cm after 12 seconds each time cleaning. Test analysis shows that the system is safe, reliable, environmentally friendly and intelligent, meeting the requirements of cleaning efficiency and easy operation. Keywords: small-scale well drilling; control system; cleaning system; motor drive; three-phase cleaning robot arm

Keywords: *Cleaning Robot, Stm32, Software Design*

I. INTRODUCTION

A. Research background and significance

my country has a serious water shortage problem, especially in arid areas, where machine-drilled well irrigation has become the main way to obtain water for agriculture. However, if the machine-drilled well pipe wall is not cleaned for a long time, it is easy to form hard scale, resulting in reduced water output and water source pollution. The current cleaning methods mainly include chemical descaling and physical cleaning, but chemical descaling has serious pollution, and physical cleaning is inefficient and unsafe. In response to these problems, this design proposes a small machine-drilled well cleaning robot as shown in Figure 1.1. The robot combines the needs of high efficiency and high safety, adopts a three-phase cleaning robot arm, and consists of a control system and a cleaning system. The control system is responsible for the execution of the overall operation instructions, and the cleaning system is responsible for the specific cleaning actions. The robot can realize automatic cleaning and manual local cleaning, effectively improve cleaning efficiency, reduce labor intensity, and meet the requirements of environmental protection and safety.

The cleaning robot designed in this paper provides a new solution to the shortcomings of traditional cleaning methods, which is expected to be promoted and applied in agriculture, animal husbandry and other industries, and provide technical support for my country's water resources management and agricultural irrigation. Through technological innovation, this design aims to solve the key problems in water resources management and promote the sustainable development of rural economic life.

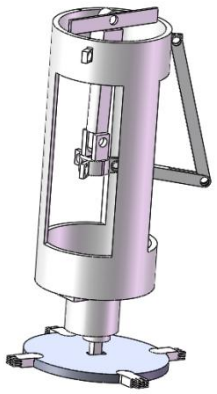

Figure 1.1 Structure diagram of minicomputer well cleaning robot

B. Key technology

During the design process of the small well-drilling cleaning robot, the whole includes the control system and the cleaning system, which mainly involves the following key technologies:

(1) Information transmission technology: This design uses a communication module to realize information interaction between the two systems, and the communication protocol uses RS485 to complete the transmission of cleaning control instructions;

(2) Power supply voltage stabilization technology: The power supply used in this design provides a stable and continuous 24V voltage for the drive control module, and the 24V voltage is converted into 12V voltage through the power supply circuit Lm7812 to supply the drive chip;

(3) Motor drive technology: The drive chip of this design uses L298N, which drives the motor to run by controlling the switches of the six power chips of the driver;

(4) Information acquisition technology: This design mainly includes a humidity and temperature acquisition module and an infrared ranging module, in which the temperature and humidity acquisition chip is DHT11 and the infrared ranging chip is GP2Y0A21YK0F;

(5) Real-time detection technology: This design uses an OpenMv camera to judge the wall environment of the well-drilling pipe and transmit the image information to the control system.

II. SYSTEM SCHEME DESIGN

A. Design Idea

Due to the difficulty of cleaning and high water quality requirements of small-scale well drilling in actual application scenarios, the cleaning tools designed need to meet the following requirements:

1) Safety protection for operators is required;
2) High cleaning efficiency and reduced labor intensity;
3) Strong cleaning ability to achieve ideal cleaning effect;
4) No harm to the environment and meeting the rigid indicators of environmental protection.

In order to meet the above requirements, the small-scale well drilling cleaning robot proposed in this design has the functions of remote control, automatic cleaning, and local cleaning. When the operator presses the automatic cleaning button, the robot drives the stepper motor to further control the wheel to drive the robot to move, and stops moving when it reaches a fixed position. The three-phase cleaning robot arm is fixed. The cleaning time is 12s each time. After the time is reached, it automatically moves down 6cm until the cleaning is completed. When the robot detects that there is stubborn dirt around that has not been cleaned, the information is processed. The operator can observe through the detection module, select the local focus cleaning mode, and manually operate the robot to repeat the cleaning until it is clean.

B. System Design

The cleaning robot system consists of a control system and a cleaning system. Among them, the control system is composed of STM32 as the main controller, power supply module, serial communication module, motor drive module, etc. The cleaning system also uses STM32 as the main controller, detection module, serial communication module, motor drive module, power supply module, etc. In terms of appearance design, this design intends to use a three-phase cleaning robot arm to make cleaning flexible and wide-ranging. In terms of communication transmission, it is intended to use the STM32 main controller to achieve high integration, less communication time, and high efficiency. The overall design block diagram is shown in Figure 2.1.

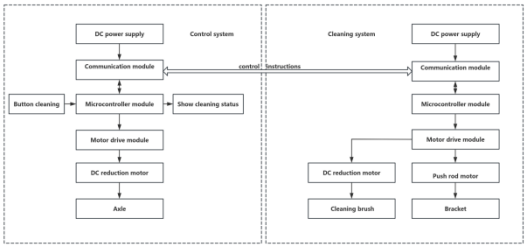

Figure 2.1 System control framework diagram

The DC power supply is powered by a 24V lithium battery, and the 24V voltage is converted into a 12V voltage through the power supply circuit Lm7812 to supply the driver chip and information acquisition module. The communication module adopts the RS485 communication protocol. The control system transmits the operator's selection information to the cleaning system. The cleaning system receives the instruction and starts working according to the selected mode. When problems are encountered during the cleaning process, the cleaning system processes the information, transmits it to the control system through the communication protocol, and feeds it back to the operator, so as to wait for the next step to run.

The microcontroller module selects the STM32f103 main controller with 64 pins. The controller and the communication module transmit information to each other, and a display channel is connected to a pin of the module to update the cleaning status to the operator in real time, so that the operator can choose the cleaning mode according to the actual situation.

The motor drive module mainly drives two parts. One is the stepper motor of the control system, which drives the sliding of the wheel axle, determines the depth of the robot going down the well, and further controls whether the robot moves forward or backward; the other is the DC reduction motor and push rod motor of the cleaning system, which respectively determine the cleaning time and the fixing and retracting of the three-phase cleaning robot arm by selecting the cleaning mode and whether the cleaning is completed.

III. SYSTEM HARDWARE DESIGN

A. Control system hardware design

The small machine well drilling and cleaning robot system consists of a control system and a cleaning system. The structural block diagram is shown in Figure 3.1

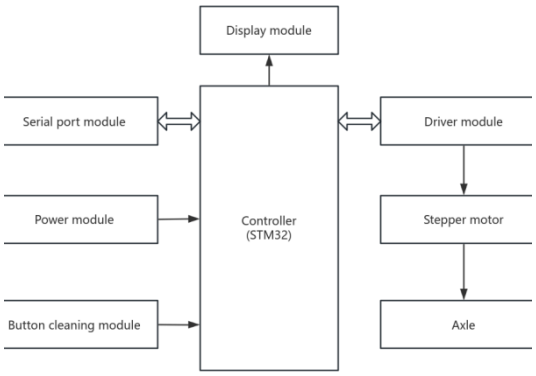

Figure 3.1 Control system structural block diagram

According to the environment in which the small machine well drilling and cleaning robot is used and the functions to be realized, the system is divided into two parts: the control system and the cleaning system. The control system is composed of STM32 as the main controller, power supply module, serial communication module, motor drive module, etc. The cleaning system also uses STM32 as the main controller, detection module, serial communication module, motor drive module, power supply module, etc.

B. Hardware design of cleaning system

The cleaning system is composed of STM32 main controller, detection module, serial communication module, motor drive module, three-phase cleaning robot arm, etc., as shown in Figure 3.2. Among them, the main controller uses STM32F103RCT6 to control the camera to collect environmental images, and process the images collected by the camera, and transmit the image data back to the main controller of the control system. Before cleaning, receive the command of the control system, control the motor to drive the brush to rotate for cleaning.

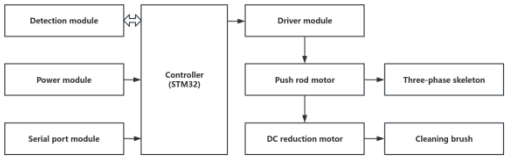

Figure 3.2 Cleaning system block diagram

IV. SYSTEM SOFTWARE DESIGN

A. Software design of minicomputer well cleaning robot

Combined with the functions to be realized by the system and the hardware selection, the system is programmed with software. First, familiarize yourself with the basic functions of STM32F103, such as GPIO, timer, external interrupt, serial port, etc. The cleaning robot is divided into a control system and a cleaning system. It is necessary to combine the two systems, write and debug the two cleaning modes respectively, and comprehensively realize the expected requirements.

The main design idea of the system is to start the detection module to observe the internal situation of the machine-drilled well pipe wall after the system is initialized, and then issue corresponding instructions through the control system to control the cleaning system to select automatic cleaning or manual local cleaning, check whether the cleaning is completed, and finally recycle the robot, and the work is completed.

The detection of the internal situation of the machine-drilled well pipe wall is completed by the detection module, which is jointly undertaken by the detection module and the infrared sensor module. The control system issues an automatic cleaning command, and the cleaning system receives the command. Start execution, the stepper motor moves down according to the program setting under the drive of the motor drive module, and the step length of the robot moving down is set to 6cm; each time it reaches the specified position, it drives the three-phase cleaning robot arm to fit the machine-drilled well pipe wall and stay at a fixed position on the pipe wall; the detection module observes the condition of the machine-drilled well pipe wall and displays it in real time on the display module; drives the DC reduction motor to drive different cleaning tools for cleaning, and sets the cleaning time for each position to 12s, and continuously moves to the bottom of the pipe wall and cleans, and finally determines whether it reaches the bottom of the machine-drilled well, recycles the robot, and the cleaning is completed.

After the control system sends a manual local cleaning command to the cleaning system, the control system drives the stepper motor to control the wheel to move down. Determine the internal condition of the machine-drilled well pipe wall fed back in the detection module, and observe whether there is a part that needs to be cleaned through the display module. If a part that needs to be cleaned is observed, the control system sends a cleaning command, and the cleaning system controls the three-phase cleaning robot arm to fit the machine-drilled well pipe wall, and the robot stays above the area that needs to be cleaned. The control system controls the button cleaning module to execute the corresponding button function, drives the DC reduction motor to work, and determines whether the cleaning degree meets the requirements. If the expected cleaning requirements are met, the robot continues to move. If there is an area that needs to be cleaned, continue to execute the above process. Determine whether the cleaning robot has reached the bottom of the machine-drilled well pipe wall. If it has reached the bottom, recycle the robot and the cleaning is completed. The overall flow chart of the system is shown in Figure 4.1:

Figure 4.1 General flow chart of minicomputer well cleaning robot software

B. Control system programming

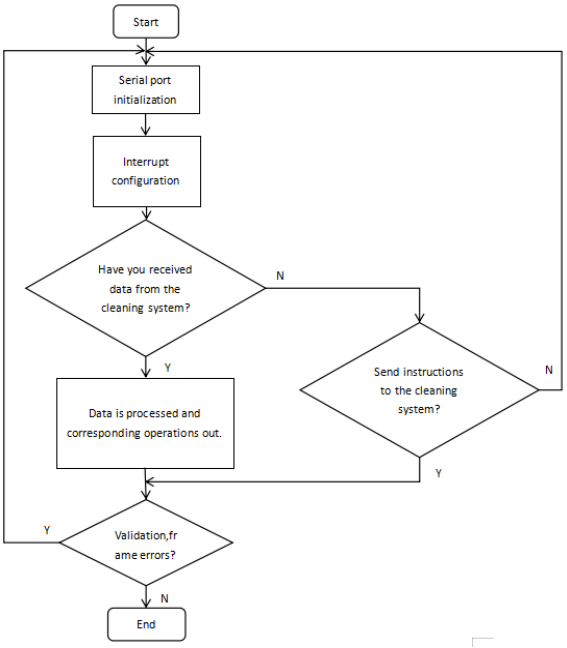

Figure 4.2 Software flow chart of serial port communication module of the control system

The control system initialization code of the small machine well-drilling cleaning robot involves the pin and peripheral configuration of the STM32 main control, including serial communication and key cleaning modules. When the serial communication module is initialized, the baud rate, data bit,

stop bit and check bit are set, the receiving and sending buffers are configured, and the receiving interrupt is enabled. The interrupt handling function is responsible for reading, storing, parsing and sending data, while monitoring the serial port status and handling communication errors. The key cleaning module processes the key input through interrupts and debounce, and sends instructions to the cleaning system. The motor drive code controls the movement, direction and speed of the stepper motor. The main loop regularly checks the serial port and key input, performs operations, and displays the system status in real time through the display module. The software flow chart of the serial communication module is shown in Figure 4.2.

The motor drive module initializes and configures the stepper motor control pins and hardware interfaces, and sets the initial state, speed and direction. Receives instructions from keys and serial communication, parses speed, direction and start-stop control, and adjusts the motor control signal to achieve precise operation. Monitor faults and implement protection measures, such as overcurrent and overheating, to ensure that the motor operates safely within the rated parameters and prevent damage from overvoltage, undervoltage, and overcurrent. Control the motor to stop according to the well depth and start-stop signals to ensure system stability and safety. The software flowchart of the stepper motor driver module is shown in Figure 4.3:

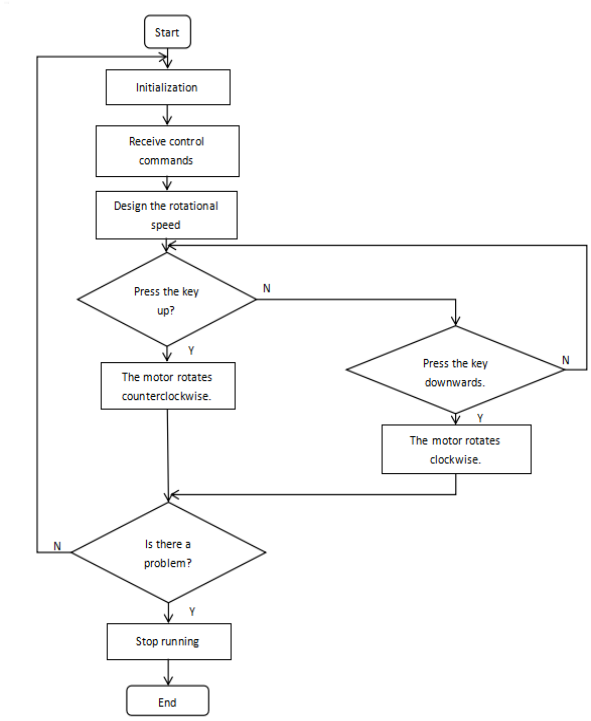

Figure 4.3 Software flow chart of stepper motor drive module

The key cleaning module controls the stepper motor in the control system, issues instructions to the cleaning system, and controls the push rod motor and DC reduction motor. First, initialize the key pins and related parameters and set interrupts. Due to the physical properties of the key jitter, it will cause false triggering, and the software timer is used to de-jitter the key. Determine whether the key is used to control the motor or issue instructions. The key status is continuously monitored and the key function is executed through the loop structure to achieve continuous operation of the key module. The software flow chart of the key cleaning module is shown in Figure 4.4:

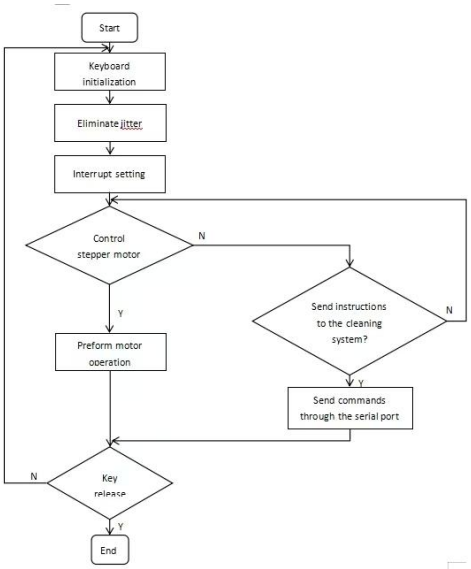

Figure 4.4 Software flow chart of key cleaning module

C. Cleaning system program design

According to the relevant configuration of the hardware part of the cleaning system of the small machine well cleaning robot, write the initialization code, configure the pins and peripherals of the STM32 master, and configure the pins and interrupt settings of the serial communication module. This module needs to receive the control instructions issued by the control system and send image information and distance information to the control system. The detection module can check the wall of the machine-drilled well pipe, whether there are pollutants, and judge whether it has reached the bottom of the well. The motor drive code needs to control the push rod motor and DC reduction motor. The main function should add the main loop to periodically check the serial communication and perform corresponding operations.

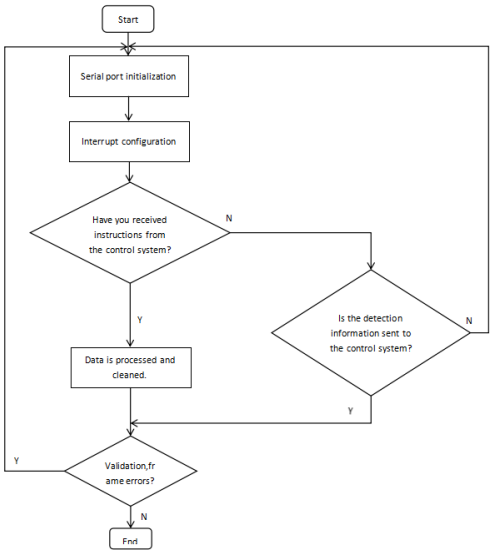

Figure 4.5 Flowchart of serial communication software

The initialization and interrupt configuration of the serial communication module and the control system are basically the same. The cleaning system needs to receive the cleaning operation instructions, so the serial port receiving interrupt should cyclically detect whether there are instructions issued, and also bear the image information of whether the cleaning is

completed and whether the robot has reached the bottom of the well. Data transmission to the control system to realize data interaction. The serial communication software flow chart is shown in Figure 4.5.

The motor drive module also needs to be initialized, configure the direction and speed of the motor, receive cleaning instructions from the control system, and work. Determine whether it has reached the top of the cleaning area, the push rod motor works, fixes the robot; determine whether it needs to be cleaned, and the DC reduction motor works to clean. Of course, for problems such as overvoltage, undervoltage, and overcurrent, to avoid motor damage, set fault monitoring, implement a protection mechanism for the motor, and immediately suspend the motor if a problem occurs.

The detection module works in combination with the camera and infrared sensor. First, it needs to be initialized and the relevant parameters and configurations are set. The software module needs to establish a connection with the camera and infrared sensor to ensure that they can work properly. As needed, set the parameters of image acquisition, including the parameter settings of the camera and infrared sensor, image resolution, exposure time, frame rate, and sensitivity of the infrared sensor. Start the camera and infrared sensor to start acquiring images and infrared data in real time. Receive the image and infrared data stream transmitted from the camera and infrared sensor, and process the data. If there is an area that needs to be cleaned or the robot reaches the bottom of the well, transmit the image data and infrared information to the control system for corresponding operations. The software flow chart of the detection module is shown in Figure 4.6:

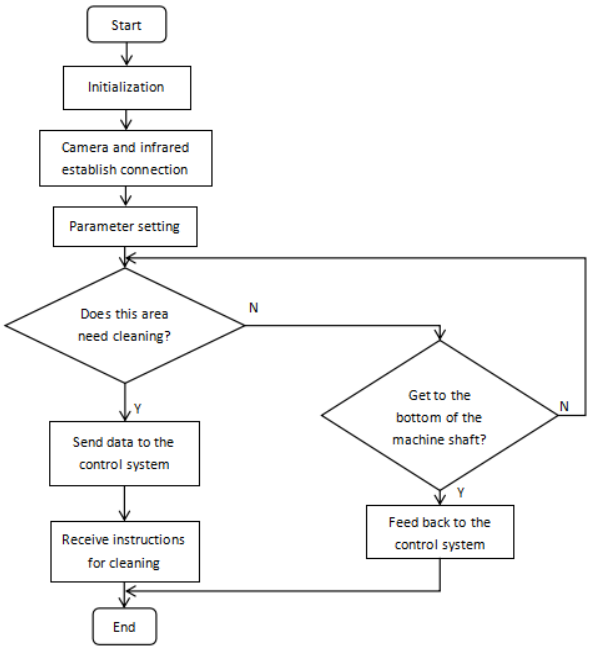

Figure 4.6 Software flow chart of detection module

V. SYSTEM TEST AND ANALYSIS

A. System test results

The overall debugging of the system first connects all the hardware devices of the system completely, and completes the writing of the software programs of each part. The robot consists of a control system and a cleaning system. Among them, the control system has a serial communication module, a motor drive module, a power module, a key cleaning module, and a display module; the cleaning system has a serial communication module, a motor drive module, a power module, and a detection module. The hardware diagram of the system is shown in Figure 5.1:

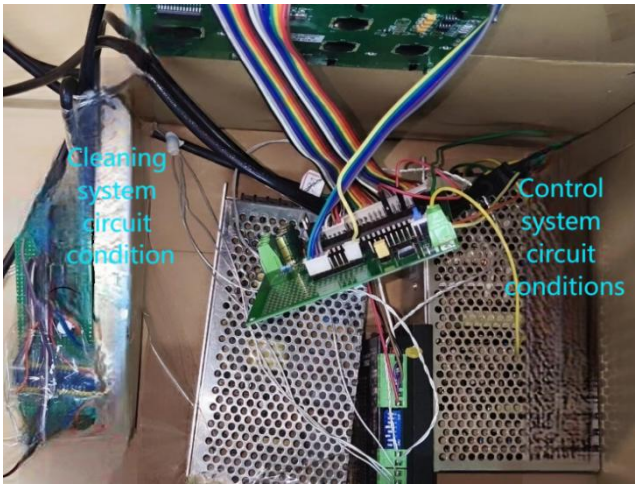

Figure 5.1 System hardware circuit connection diagram

This system is divided into a control system and a cleaning system to control the cleaning robot to achieve machine-drilled well pipe wall cleaning. The interaction between the two systems uses serial communication. Whether there is data transmission and whether there is an instruction is issued is the key to the test. We first test the serial ports of the dual systems through the serial debugging assistant to send and receive data, and then test the mutual data transmission. The serial debugging is shown in Figure 5.2:

Figure 5.2 Serial communication test diagram

After the system is powered on, combined with the designed operating environment, the robot is controlled to go down to the well to perform cleaning work. In order to clearly display the operation process, the real-time operation situation and its instructions are displayed in the display part. Make cleaning work smarter and improve cleaning efficiency. The display module test is shown in Figure 5.3:

Figure 5.3 shows the working situation of the module

For the system cleaning process and situation, simulate the actual working environment. First, ensure that the dual systems work normally to ensure the flexibility and stability of

the robot. Set the cleaning mode and observe the cleaning effect of the robot in the machine-drilled well. If an abnormality occurs, stop the operation in time to troubleshoot. The actual working situation of the simulated cleaning robot is shown in Figure 5.4:

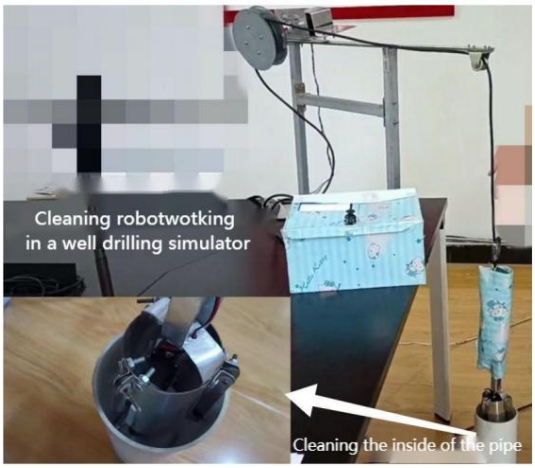

Figure 5.4 Actual working diagram of simulated cleaning robot

B. Error Analysis

The errors generated by the robot in the actual working process include errors in the sensor itself, hardware failures, machine-drilled well pipe wall environment and other factors, leading to misjudgment, transmission delay and other problems.

For the errors of the sensor itself, especially the clarity of the camera, and the jitter during the movement of the robot, the image is blurred; the non-straight pipe wall of the machine-drilled well causes the infrared sensor to misjudge the arrival at the bottom of the well. Hardware failure may be caused by overvoltage, undervoltage or underwater, resulting in motor drive damage, motor failure, and driver failure; in addition, in order to make the motor work stably, a stabilized power supply is used to power the motor.

There may be various changing conditions for the machine-drilled well pipe wall, such as bending, blockage, and serious pollution, which will affect the cleaning effect of the robot; environmental interference under the machine-drilled well, water flow, pipe wall vibration, etc. affect the robot's stay to perform cleaning work, which will affect the accuracy of the data sent by the cleaning system to the control system.

In addition, when designing a printed circuit board, some signal lines will be relatively close, which will have a great impact on signal transmission. Because dual-system control is adopted, serial communication is adopted between the two systems. Factors such as noise, electromagnetic interference or poor lines may cause data bit errors or redundancy, resulting in errors when interacting with data.

SUMMARY

This work is a small machine-drilled well cleaning robot, based on the main control chip STM32F103RCT6, to solve the problem of algae breeding and large-scale silt outflow on the machine-drilled well pipe wall caused by long-term use of machine-drilled well water in some rural areas, causing water pollution and affecting people's physical condition.

This design is mainly composed of a control system and a cleaning system, including a serial communication module RS458, a stepper motor, a push rod motor, a DC reduction motor, a display module, a key cleaning module, and a detection module. The control system controls the cleaning system to clean the machine-drilled well pipe wall. The cleaning system can clean the machine-drilled well pipe wall in two modes: automatic cleaning and manual local cleaning. The functions are realized:

(1) It improves the low efficiency and high cost caused by the current mainstream chemical descaling and physical cleaning.

(2) Automatic cleaning can automatically control the motor to move down 6cm to continue working after 12s, reducing manpower.

(3) Manual local cleaning is when there are stubborn stains on the machine-drilled well pipe wall. By adjusting the robot's working position and working time, it is more flexible.

(4) The display module is added to make the machine-drilled well robot more intelligent and can observe the environment inside the machine-drilled well pipe wall.

(5) It is easy to operate, avoiding complex operation and water pollution, and is green and environmentally friendly.

The robot can already perform cleaning work according to the basic preset functions, but due to factors such as time and conditions, the detection module needs to be further promoted. It is hoped that the design of the robot will be further improved in the future to make the cleaning robot more intelligent.

References

[1] Liu Meihuan, Liu Yang. Discussion on farmland mechanized well irrigation system [J]. Henan Water Resources and South-to-North Water Diversion, 2014(17): 50-51.
[2] Du Xiaohong, Zhang Shixin. Analysis of problems in well drilling engineering [J]. Journal of Weifang University, 2012, 12(02): 100-102.
[3] ZHAO Xiangdong. Design and application of water well pipe cleaning device [J]. Cleaning World, 2010, 26(03): 40-43.
[4] Yang Jianfeng. Research on automatic floor cleaning robot based on multi-sensor [D]. Nanjing Agricultural University, 2017.
[5] ZHU Shilin. Design of Computer Flat Knitting Machine Control System [D]. Zhejiang University of Science and Technology,2010.
[6] Zhu Lijuan. Design and research of smart home control system based on STM32 [D]. Xizang University,2018.
[7] Yang Yueqi. Design and implementation of operating environment and condition monitoring system for medical equipment based on Internet of Things [D]. Southeast University,2019.
[8] Zuo Yihai, Zhang Kai, Kong Xian-Yi, Pu Jia-wen, Zhao Yi-peng, HOU Yu-Jun. Design and Research of Underwater Pipeline Cleaning Robot [J]. Machinery Management Development, 2023, 38(02): 110-112. (in Chinese)