Design of a Robot for Pipeline Weld Quality Inspection

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Abstract: In the quality assessment of welding engineering, quality of the weld can reflect the welder’s technical level, and also serves as the basis for preliminary judgment of the quality of the weld. Therefore, the appearance quality inspection of the weld has an important position in the welding quality assessment. This paper designs a pipeline weld quality inspection robot based on visual inspection. Inspectors control the motor, lights and camera pan-title of the pipeline robot through WiFi to realize the accurate positioning of the robot and the shooting and transmission of real-time images. The movement distance of the robot is recorded by the encoder to ensure the accurate positioning of the robot; the motor speed is adjusted to ensure the level of the pipeline robot body; the height and rotation angle of the pan-tilt are adjusted to ensure that the camera shoots the weld image radially at the center of the pipeline. The experiment shows that the transmission of robot image is smooth, and actions can be completed according to instructions.

1. Introduction
The inspection of pipeline weld quality is a very important task in pipeline engineering. With the improvement of welding production automation, the quality of welds mainly adopts the method of visual inspection technology, and the inspection of the inner weld surface mainly depends on robots[1]. According to this requirement, this paper designs a pipeline weld quality inspection robot based on visual inspection, which can enter the pipeline, take images of the inner weld surface and send it to an external host computer for processing, and use visual inspection technology to detect the inside quality of the pipeline weld automatically.

2. System overall design
In order to achieve pipeline weld quality inspection, pipeline weld quality robots need to be able to move in the pipeline, shoot weld images from different angles, and transmit the images to the host computer for processing. To implement these functions, the overall design system of the pipeline robot is divided into seven modules, and the system block diagram is shown in Figure 1:
According to the system block diagram, when the pipeline weld quality inspection robot is working in the pipeline, first, weld image collected by the image acquisition module is sent to the communication system via the microcontroller control module, and the host computer receives and processes the weld image information and robot-related status information through the network interface. The host computer transmits the control instructions to the MCU control module through the communication interface module to realize the control of the image acquisition module, auxiliary light source module and power module. The power module provides energy for the system.

3. Hardware design of pipeline weld quality inspection robot

The hardware composition of the pipeline weld quality inspection robot mainly includes an image acquisition module, a communication interface module, an MCU control module, an ACROBA-E module[2], an auxiliary power source module, and a power module. The Hardware block diagram of pipeline weld inspection robot is shown in Figure 2:

3.1 Image acquisition module

The image acquisition module mainly realizes the function of pipe weld images acquisition from different angles in the pipeline, and transmits the images to the communication module, then sends the image to the host computer for processing[3]. In order to match the wireless router video interface of the communication interface module, the robot designed in this paper uses a wireless network high-
3.2 Communication interface module

The communication interface module mainly realizes the data communication between the host computer and the pipeline weld inspection robot, including transmit the images collected by the image acquisition module to the host computer and the relevant control instructions from the host computer to the MCU control module[4]. Based on the data transfer volume and the communication distance, the communication interface module chooses a wireless communication mode and uses a wireless router to provide WiFi signals. The wireless router communicates with the Single chip microcomputer through the TTL serial port module.

3.3 MCU control module

The MCU control module mainly realizes the functions of communication with the host computer, control of other modules, and collect relevant status information of the pipeline weld inspection robot[5]. STM32F103RCT6 is selected as the MCU, and its minimum system schematic diagram is shown in Figure 3:

![STM32F103RCT6 minimum system schematic diagram](image)

3.4 ACROBA-E

ACROBA-E uses a motor to provide power to the robot, uses an encoder to record the walking distance of the robot, and adjusts the balance of the robot body by controlling the speed of the motor to keep the camera level to take pictures. The robot which moves in the pipeline to collect images takes a certain amount of time, and it may encounter obstacles in the process of collecting images. Therefore, the power motor of the pipeline robot needs to meet the basic characteristics of slow speed and large torque. Based on the above analysis, the JGA25-370 DC geared motor is selected[6], and the motor drive module is L298N dual H-bridge motor drive chip[7]. The schematic diagram of L298N motor drive circuit is shown in Figure 4:
Figure 4 Schematic diagram of L298N motor drive circuit

The MCU controls the forward and reverse rotation of the motor by connecting with the pins IN1, IN2, IN3, and IN4, and the MCU output port PWM is connected with the enable control terminals ENA and ENB to control the motor to stop.

3.5 Auxiliary light source module

Because the inside of the pipeline is very dark, the pipeline weld quality inspection robot needs an auxiliary light source to expose the inside of the pipeline. The robot designed in this paper uses LED lights as the auxiliary light source. The 12 LEDs are arranged in a ring, two groups of LED lights are connected in parallel, and installed around the camera to meet the basic requirements of the light for the image taken by the camera. The on and off of the LED light is controlled by the IO port of the MCU. When the IO port outputs a high level, the LED light is on, and when the output is low level, the LED light is off. The schematic diagram of LED light control circuit is shown in Figure 5:

Figure 5 Schematic diagram of LED light control circuit

3.6 Power Module

The design of the power module of the robot uses lithium batteries. In the robot system, the driving voltage required for L298N is 6V, the power supply voltage of the wireless router is 5V, and the working voltage of STM32 is 3.3V. The schematic diagram of the power module is shown in Figure 6:
4. **Software design of pipeline weld quality inspection robot**

The robot software design is divided into the design of the upper computer and the lower computer.

4.1 **Upper computer design module**

The upper computer and the router establish a connection through WiFi and use the TCP/IP protocol to transmit data. First the program needs to access the router's IP address and control port. The upper computer program flow chart is shown in Figure 7:

![Figure 7 Program flow chart of the upper computer](image)

4.2 **Lower computer design module**

The purpose of the lower computer program design is to control the power module, image acquisition
module and auxiliary light source module according to the instructions of the upper computer, and acquire the output data of the Hall encoder and the tilt angle sensor. The data is transmitted to the upper computer, and the program flow chart of the lower computer is shown in Figure 8:

In order to realize the functions, the lower computer program can be divided into three parts: one is the serial communication program, the lower computer receives the control data transmitted by the router through the serial port, and also sends the collected information of robot movement distance and body tilt angle to the router through the serial port, and then transmitted to the upper computer; the second is the state data acquisition program, according to the system design, the system needs to collect the output data of the Hall encoder and the tilt angle sensor, use these data to record the movement distance of the pipeline robot, and control the robot car body to keep level; the third is the control program of the peripheral circuit of the MCU. After receiving the instruction, the lower computer needs to control the motor, the pan-tilt and the auxiliary light source according to the instruction.

5. Pipeline Weld Quality Inspection robot test
The purpose of the experiment: test whether the image transmission of the pipeline robot is smooth, whether the PC and mobile phone can receive the image, and whether the robot can make corresponding actions according to the instructions.
Experimental device: pipeline robot, mobile phone, PC.
Experimental program:
(1) Turn on the power of the pipe robot and wait for the router to operate normally.
(2) Connect to the wireless network of the router with PC and mobile phone, and login to the address http://192.168.8.1:8083/?action=stream, observe the image information taken by the pipeline robot.
(3) Use the upper computer software in the PC to send control instructions to control the pipeline robot to make corresponding actions.
The host computer interface is shown in the figure 9
Through experimental tests, both the PC and the mobile phone can receive the image information taken by the pipeline robot, and the upper computer in the PC can control the robot to move forward and back, rotate the steering gear and turn on and off the lights, which meets the design requirements.

### 6. Summary

Based on the functions to be realized by the pipeline robot, this article selects the device and designs the circuit of the robot hardware. According to the data transfer relationship between the upper computer software and the lower computer software of the pipeline robot, the robot software design is completed, so that the pipeline robot can communicate with each other through Wi-Fi. The robot shoots the weld image and transmits the image to the outside of the pipeline in real time.

### 7. References:

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