The Design and Implementation of the Pneumatic - Type Suction Detection System

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Abstract: When the conventional air pressure probe system is applied to the air pressure probe system in complex environment, it has the deficiency of large error and small range of detection. Therefore, the design and implementation of the air pressure probe system is proposed. Based on the design of liquid level detection, bubble detection design, TIP head plug design and hardware block diagram of pneumatic liquid suction detection project, the hardware design of pneumatic liquid suction detection system was completed. Relying on the design of software flow chart and the establishment of RS485 communication protocol, the software design of pneumatic liquid suction detection system is realized. The problem of too little pressure in passive liquid level detection, the problem of normal driving force of TIP head piston and the problem of unknown maximum driving force, etc. The design of the pneumatic suction detection system is realized. The test data show that the proposed detection system is 15.71% lower than the conventional one, and the range of detection is 56.6% higher.

Keywords: Air pressure type; Aspiration detection; Detection system; System design; Project forecast; Solutions

1. Introduction

Conventional pneumatic type liquid absorption detection system based on air pressure power sensor type liquid absorption detection, but applied in the complex environment of pneumatic suction fluid detection, restricted by pneumatic power sensor working conditions, error detection, detection range smaller deficiencies[1], is not suitable for the complex environment of pneumatic suction fluid detection, therefore proposed pneumatic suction fluid detection system design and implementation. Based on the hardware design and software design of the pneumatic liquid suction detection system, the solution to the difficulty in project prediction is proposed to realize the design of the pneumatic liquid suction detection system. In order to ensure the effectiveness of the designed detection system, the liquid test environment is simulated. Two different detection systems are used to carry out the liquid detection error and detection range simulation test. The test conclusion shows that the proposed detection system has high effectiveness.

2. The Hardware Design of the Pneumatic Liquid Suction Detection System

The pneumatic liquid suction detection system (hereinafter referred to as the system) mainly completes the liquid level detection of the TIP head before the liquid absorption, and the air bubble and plug detection during the liquid absorption process. The results are fed back to the main equipment to ensure the reliability of TIP suction. In the whole process, the system only ACTS as a passive device and only responds to the requirements of the main device, instead of actively communicating with the host. The system uses single chip microcomputer and silicon pressure sensor to monitor the air pressure in the square cylinder on the TIP head. Through the air pressure changes in the cylinder, it can determine whether the TIP head reaches the liquid level, enters the air bubble and blocks.

2.1. Liquid level detection design

When the TIP head moves down the probe liquid level, the pressure changes caused by the TIP head moving downward are ignored. The internal pressure of the TIP head is consistent with the atmospheric pressure, that is, $P = P_k$. When the TIP head reaches the liquid level and below (see the figure below), the internal pressure of the TIP head constitutes a closed space. At this point, the internal pressure changes with the depth of the invading liquid level, and the liquid level detection diagram is shown in figure 1[2].
Formula (1) can be used to represent[3] :

$$P' = P_k + P_h = P_k + \rho gh \qquad (1)$$

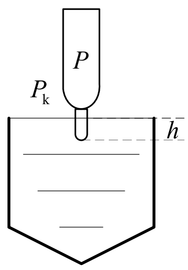

Figure 1. Liquid level detection diagram

2.2. Bubble detection design

In the normal suction process, the piston has a tensile force F, and its surface area is S. The pressure generated in the dynamic process can be expressed by formula (2) :

$$P_{活} = -F / S \qquad (2)$$

Then the pressure inside the TIP head can be expressed by formula (3) :

$$P' = P_k + P_{活} = P_k - F / S \qquad (3)$$

At this point, the internal pressure is less than the external atmospheric pressure, and the liquid is sucked into the TIP head. When a bubble enters (see figure below), the gas volume inside the TIP head increases and the pressure increases instantaneously. Its bubble detection diagram is shown in figure 2[4] :

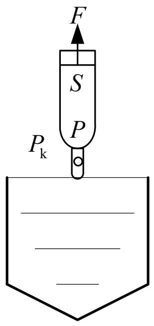

Figure 2. Bubble detection diagram

Therefore, in the continuous monitoring process of pressure, if it appears, it is considered to enter the bubble. The reliability of this algorithm needs to be verified by actual test.

2.3. TIP head plug design

When the TIP head is blocked, the pressure generated by the piston's normal tensile force can be expressed by formula (4):

$$P' = P_k + P_{活} = P_k - F / S \qquad (4)$$

At this point, the piston will increase its driving force until F_{max}. At this point, the piston stops moving or decelerates (see the figure below). The internal pressure of TIP can be expressed by formula (5) :

$$P = P_{空} - F_{max} / S \qquad (5)$$

This pressure is far less than P', which is shown in FIG. 3[5].

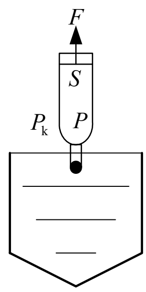

Figure 3. Block the probe diagram

Therefore, in the continuous pressure monitoring process, if $P << P'$ occurs, the TIP head is considered to be blocked.

2.4. Design of hardware block diagram of pneumatic suction detection project

Through theoretical analysis, the system is composed of the following parts: power supply part, main control part, pressure acquisition part and communication part. In addition to the early development and testing, the program also needs to debug the download interface. The hardware block diagram of the barometric suction detection project is shown in Figure 4[6] :

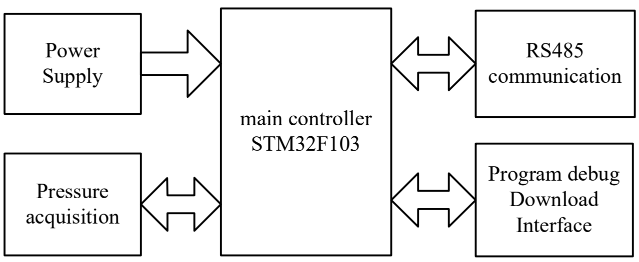

Figure 4. Hardware block diagram of pneumatic liquid suction detection project

The hardware design of the pneumatic hydraulic system was completed based on the design of liquid level detection, bubble detection, TIP head plug design and the hardware block diagram of the pneumatic liquid suction detection project.

3. Software Design of Pneumatic Liquid Suction Detection System

3.1. Software flow chart design

Compared with the primary system, which is the slave device, the whole program executes the instruction based on the main device after the system is powered on. After receiving the prepared detection level sent by the main device or starting the suction command, the system starts the liquid level, plug and bubble detection, and waits for the query status command of the main device after the detection is completed. When the query status command is received, the liquid level is detected, blocked, or bubble status is uploaded. The program is divided into main program and serial interrupt service subroutine. The main program flow chart of the pneumatic suction detection project is shown in figure 5[7]. Flow chart of its pneumatic suction detection project serial port interrupt service subroutine, as shown in figure 6[8] .

3.2. Set up RS485 communication protocol

Interface type: RS485 interface; Baud rate: 9600bps; 1 bit start bit, 8 bit data bit, 2 bit stop bit, no parity bit. The protocol format of pneumatic suction detection project is shown in Table 1[9]:

Table 1. Air Pressure Suction Detection Project Protocol Format Table

Start	ID	CMD	Datalen	Data	Chksum	Endstr
0XAA	XX	XX	XX	XX	Arithmetic plus and 0X7F	0X55

START: Start code 0XAA; ID:1 byte (0X01- -0xff), broadcast address: 0XFF; CMD: command, 1 byte; Datalen: 1 byte; DATA: Datalen byte Data; Chksum: check code, which is obtained by adding 0X7F to the previous bytes. Endstr: stop code 0X55. Note: so data transfer, high byte first, low byte second[10].

The above commands are sent from the machine and received by the host.

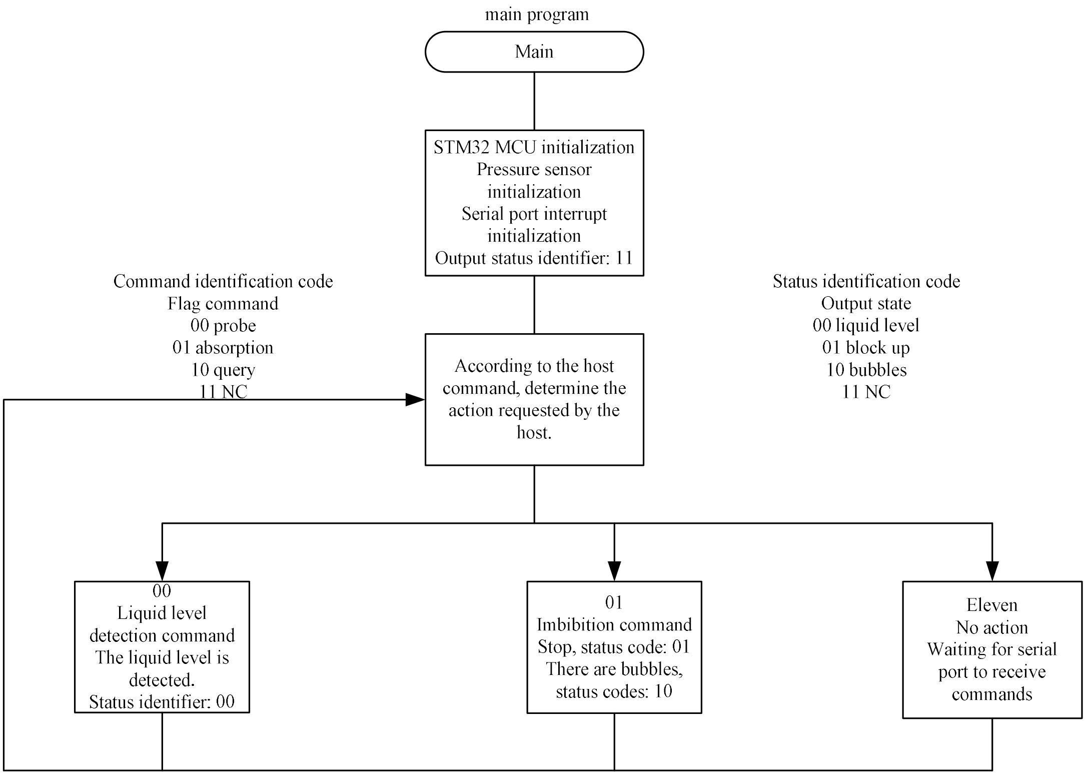

Figure 5. Pneumatic suction detection project main program flow chart

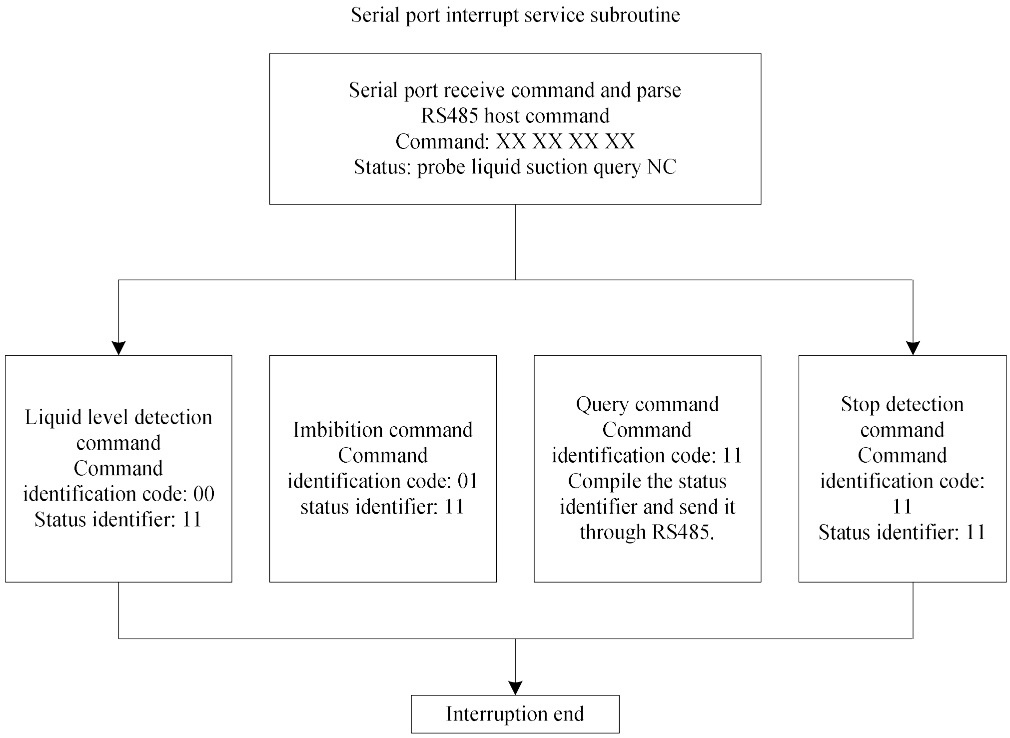

Figure 6. Pneumatic suction detection project serial port interrupt service subroutine flow chart

4. Project Forecast Difficulty and Solution

4.1. The problem of too little pressure in passive liquid level detection

It was originally envisaged that when the TIP head moved down the detection liquid level, the internal piston of the TIP head was pumped downward, so that the pressure would change rapidly when the liquid level was touched. The TIP head piston does not work. As a result, the pressure changes only at 100Pa (10mm depth) when the TIP head penetrates into the liquid surface. The liquid level may not be accurately detected without the cooperation of the main equipment. The solution, if it cannot be detected, requires the main equipment to cooperate with the detection.

4.2. The normal and maximum driving force of the TIP head piston is unknown

During the normal suction process, the pressure in the cylinder is lower than the air pressure because of the constant speed of the piston. Thus, the liquid is pressed into the TIP head. When the TIP head is blocked, the piston is not driven enough, and the pressure in the piston decelerating movement cylinder will continue to decrease. Pressure sensors monitor pressure values to determine whether they enter the bubble and plug. And when the TIP head is blocked, the piston will be driven by the maximum driving force. At this time, there is the maximum pressure of a cylinder, which is also the maximum pressure of pressure sensor selection. But now the normal and maximum driving force of the piston is unknown, so there is some resistance to the programming. Solution: after the completion of hardware and software, carry out parameter debugging and adjustment on site, and complete the design and implementation of the pneumatic liquid suction detection system.

5. Experimental Results and Analysis

In order to ensure the effectiveness of the design of the pneumatic liquid suction detection system proposed in this paper, a simulation test was conducted. In the test process, different liquid is used as the test object to carry out the simulation test of detection error and detection range. The complexity of liquid environment, liquid performance and pressure environment are simulated. In order to ensure the effectiveness of the test, the conventional detection system is used as the object of comparison to compare the results of two simulation tests and present the test data in the same data chart.

5.1. Detection error correlation

During the test, two different detection systems were used to carry out the work in the simulated environment, and the variation of liquid detection error was analyzed. The comparison results are shown in Table 2.

Table 2. Detection error comparison table

Case type number	A pressure suction detection system is proposed%	Conventional pneumatic absorption system/%
1#	3.4	15.6
2#	5.1	23.5
3#	3.4	19.5
4#	4.1	18.5
5#	3.5	20.1
6#	2.6	21.5
7#	3.4	18.3
8#	3.5	19.6
9#	1.2	18.4
10#	5.2	17.5

Put forward according to the comparison table, table 1 detection error detection system, with conventional detection system of liquid detection arithmetic mean error, and it is concluded that the liquid average efficiency of conventional detection system is 19.25%, the detection system of liquid average efficiency of 3.54%, error detection system is put forward by the conventional detection system by 15.71%.

5.2. Detection range correlation

During the experiment, two different detection systems were also used to carry out work in the simulated environment and analyze the variation of liquid detection range. The comparison curve of the test results is shown in figure 7.

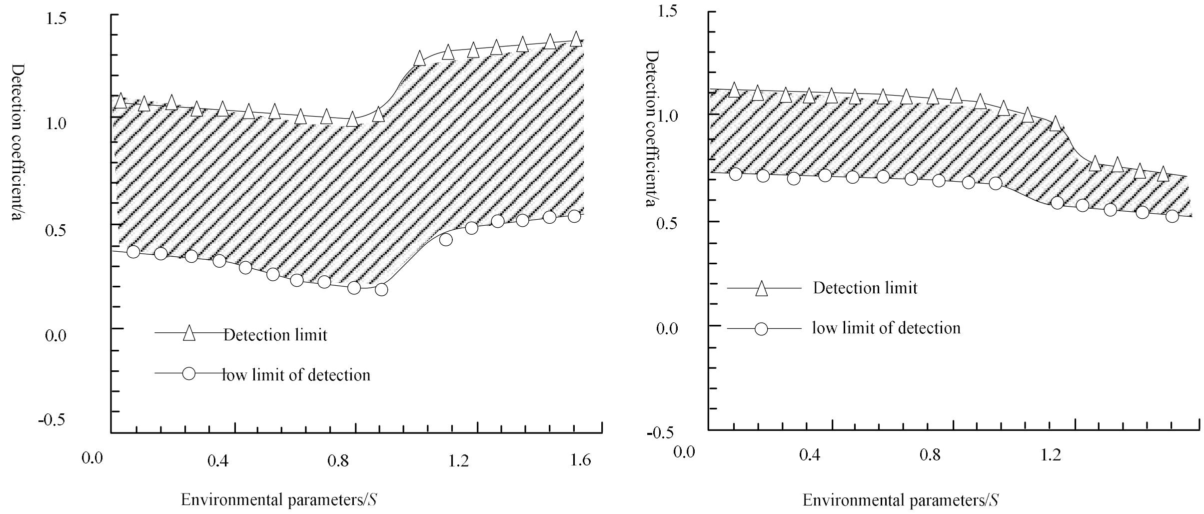

Figure 7. Detection range comparison diagram

Because of the detection range is equal to the product of the environmental parameters and detection coefficient, figure 7, using the environment parameter as the abscissa, detection coefficient as the ordinate, the shadow area of detection range, the proposed detection system, with conventional detection system detection range of arithmetic mean processing, it is concluded that regular detection system detection range is 34.7%, the detection system detection range is 91.3%, it is concluded that the proposed detection system more conventional detection system detection range increased by 56.6%, suitable for complex environment of air pressure type liquid absorption detection.

6. Conclusions

In this paper, the design of the pneumatic suction detection system is proposed. Based on the hardware design and software design of the pneumatic suction detection system, solutions to the difficulties in project prediction are proposed to realize the research in this paper. Experimental data show that the method designed in this paper is highly effective. It is hoped that the study in this paper can provide a theoretical basis for the liquid absorption detection system.

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