Design of the Electric Control System for the Cleaning Equipment of Pigsties

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Abstract. According to the control requirements of cleaning equipment, this paper designs a corresponding electrical control system. The design detection system is designed to realize horizontal and vertical positioning of the cleaning mechanism with electromagnetic proximity switches. The control circuit is designed with a VB1 model PLC as the main controller, and the system control flow is analyzed to switch the steps of entering a pigsty, collecting pig manure, and returning and dumping pig manure.

1. Introduction

The pigsty in the traditional enclosure is usually surrounded by walls and a cement solid bottom, and the pig manure is basically accumulated in the drainage area of the pigsty [1, 2]. In view of the characteristics of the pigsties and the cleaning task, a cleaning equipment was designed, composed of a suspension mechanism, a driving unit, a cross expansion frame, and a cleaning bracket, as shown in Fig. 1 [3]. The suspension mechanism can be powered by the driving unit to lead the whole cleaning equipment to slide along the track, and the cleaning bracket can be powered by the driving unit to rise or fall.
Figure 1. Composition diagram of the cleaning equipment

The driving unit is composed of two electromagnets, a driving grooved wheel and a sprocket coaxial with it.

2. Analysis on the driving system

According to the system scheme and the mechanism composition of the cleaning equipment, the power of the cleaning mechanism is provided by the motor outside the pigsty, and transmitted to the driving grooved wheel through the traction cable.

The vertical and horizontal movement of the cleaning bucket can be switched by alternating two electromagnets between the suspension frame and the angle iron, the suspension frame and the brake wheel, which are named electromagnet 1 and electromagnet 2 respectively and spring mounted on the suspension frame.

The chain wheel can drive the chain to put down the cleaning bucket, or lift the cleaning bucket after lifting the front end of the bottom of the cleaning bucket.

The cleanup work should follow these steps: putting down the cleaning mechanism at the entrance mark of one pigsty, driving the cleaning equipment forward to the exit mark to collect the pig manure in the drainage area, lifting the cleaning mechanism over the height of the enclosure wall, and sending the cleaning equipment to the designated place outside the enclosure to pour the pig manure. After finishing the cleaning work for one pigsty, the same steps shall be completed in turn for other ones.

In order to detect the horizontal positioning of the cleaning mechanism in the enclosure, small bars are welded on the rail as marks, at the position of the pig manure dumped outside the pigsty, the entrance and exit of each pigsty, as shown in Fig.2.
As shown in Fig. 1, the electromagnetic proximity switch, called position switch, is installed on the upper side of the suspension mechanism. By counting the number of marks that the cleaning mechanism glides through, it can be determined whether the cleaning equipment reaches the entrance and exit of each pigsty. In order to determine the vertical position of the cleaning bucket, two electromagnetic proximity switches, called upper limit local switch and lower limit local switch, are installed on the left and right sides of the suspension frame. The upper and lower limit positions of the cleaning bucket can be determined by detecting the position of the slider at the upper end of the cross expansion frame on the guide rod.

3. Design of circuit hardware for the control system
Considering pigs' activities in pigsties, the operation speed of the mechanism must be very low in the actual cleaning process from the perspective of safety and cleaning effect.

A 51K90NG-CF model single-phase reducer motor is used as the drive motor, with rated power of 90 W, rated torque of 0.66 N·m, rated speed of 1350 rpm, and reduction ratio of 1:60. The torque of its output shaft is 39.6 N·m, and the rotating speed is 22.5 rpm. According to the ratio of the diameter of the winding groove wheel and the sprocket is 3:1, the torque that can be further converted to the sprocket is 118.8 N·m, and the rotation speed is 7.5 rpm, which can meet the power demand of the cleaning bucket well.
The system control circuit is shown in Figure 3, using VB1-20MR-A PLC as the main controller [4]. The distribution of input and output points of the PLC is described in Table 1.

**Table 1. The PLC I/O distribution diagram**

| terminal | device connected                        |
|----------|-----------------------------------------|
| X0       | position switch                         |
| X1       | upper limit switch                      |
| X2       | lower limit switch                      |
| X3       | switch for jogging forward              |
| X4       | switch for jogging up                   |
| X5       | switch for jogging down                 |
| X6       | switch for jogging backward             |
| X7       | start button in automatic mode           |
| X10      | sudden switch                           |
| X11      | manual/auto switch                      |
| Y0       | relay for electromagnet 1               |
| Y1       | relay for electromagnet 2               |
| Y2       | relay for forward of the motor           |
| Y3       | relay for backward of the motor          |
| Y4       | alarm bell                              |

An YHN-P50/27 model high suction electromagnet is adopted for both electromagnets, with suction of 500N, power of 10W, power supply of 24V and current of 0.42A.

Three XS188I model electromagnetic proximity switches of switch-output type NPN are used to realize above mentioned functions, with an inductive distance of 8 mm, and power supply of 24V.

A suspension type cable trailing Drag chain is used to supply power from the far end outside the pigsty to the suspension frame. The three sensors share 24V power lines, plus their respective signal lines, and actually five lines are used.

When the system is in manual mode, the movement of cleaning mechanism should be controlled remotely manually, including jogging up, jogging down, jogging forward, and jogging backward. A VE-Y04B model four-way wireless remote control is used to realize these operating function.

The output circuit is powered by 24V switching power supply and paralleled with four relays to switch the suction state of electromagnet 1 and electromagnet 2, and to control the movement state of the motor.

**4. Design of the control program**

While the cleaning equipment is sliding along the track, the mark on the track is detected and counted by PLC, via the position switch. The position for dumping pig manure outside the pigsty is taken as a starting point, where the count value \( Q_n \) is zero. When the cleaning mechanism moves forward or backward, \( Q_n \) is increased or decreased by one for each passing mark. \( Q_{n_{\text{ent}}} \) respects \( Q_n \) at entrance mark of a pigsty, and the relationship exists between it and the pigsty number \( n \) can be shown as the following expressions.

\[
Q_{n_{\text{ent}}} = 2 \times n - 1
\]
Figure 4. The flow chart for a cleaning process

When the system is in automatic mode and the cleaning equipment stops initially at the beginning point. At this time, the position switch and upper limit switch is triggered, and the lower limit switch is not. The system controls the cleaning equipment to clean each pigsty in turn with seven steps, and $Q_{n,\text{ent}}$ of the current pigsty to be cleaned is set in register D10 in the PLC. The knocking times of the cleaning bucket when pouring pig manure is set in register D0. The flow chart is shown in Fig. 4, and the analysis of each action and action switching is as follows.

1. The electromagnetic iron of the brake wheel is energized to drive the grooved wheel to rotate forward, and the cleaning mechanism moves forward. For each position signal detected by the position switch, add 1 to the value of D1.

2. When the value of D1 increases to equal to D10, the cleaning equipment stops moving forward. Electromagnet 2 is powered off, and electromagnet 1 is powered on. The driving grooved wheel continues to rotate forward, and the back of the cleaning bucket is close to the ring wall.
(3) When the lower limit switch is triggered, it indicates that the cleaning bucket has been placed at the bottom of the pigsty. Electromagnet 1 is powered off and electromagnet 2 is powered on. The driving grooved wheel rotates forward, and the suspension frame slides forward, pulling the cleaning bucket to collect pig manure.

(4) When the position switch is triggered again, add one to the value of D1, and the cleaning of the current pigsty is finished. Electromagnet 1 is energized again, and electromagnet 2 is de energized. The driving grooved wheel reverses, the chain drives the opening part of the cleaning bucket to rise, then pull up the cleaning bucket.

(5) When the upper limit switch is triggered, the cleaning bucket stops rising. Electromagnet 1 is powered off and electromagnet 2 is powered on again. When the driving grooved wheel reverses, and the cleaning equipment slides to initial position. Every time the position switch is triggered, the value of D1 minus one.

(6) When the value of D1 is reduced to 0, it indicates that the cleaning equipment moves back to the initial position, i.e. the position for dumping pig manure. Electromagnet 1 is powered off again, and electromagnet 2 is powered on. The driving grooved wheel rotates forward, and the cleaning bucket descends. When the bottom edge of the back side of the cleaning bucket is placed at the side of the cesspit, it stops, while the front end can continue to fall, and the pig manure is poured out. The downlink can be controlled by timing. In order to ensure dump completely, the riving sheave can be controlled to rotate forward and backward repeatedly, and the bottom of the back side of the cleaning bucket can be knocked repeatedly on the side of the cesspit. For each stroke, the value of D2 minus 1.

(7) The driving grooved wheel rotate reverse. When the upper limit switch is triggered, the cleaning bucket stops going up. The cleaning equipment returns to its initial state, and a complete cleaning operation is completed.

When the cleaning equipment returns to the initial position, the value of D0 and D1 is updated to adapt to the next pigsty, and a renewed cleaning operation is carried out. After the operation for all pigsty, the cleaning mechanism stops at the initial position. In case of emergency during operation, press the emergency stop switch to stop, and continue to operate in the following steps by manual operation. It is realized with the device that smaller quantities of pig manure are cleaned with more frequency and environmental hygiene is improved in enclosure.

5. Conclusion
The control system shall be tested and operated after commissioning. After the breeder confirms that the equipment is in the initial position and press the automatic start button, the equipment can operate normally and complete the cleaning operation of the whole row of pigsty. With the help of manual remote control and observation, the operation accuracy and cleaning rate can be improved.

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References
[1] WANG Defu, HUANG Huinan, ZHANG Hongjian, LIU Jianyu, DONG Xin. Analysis of Research Status and Development on Engineering Technology of Swine Farming Facilities. Transactions of the Chinese Society for Agricultural Machinery, 2018 (11): 1 - 14.
[2] XU Wenzhe, OUYANG Ping, LOU Fuxiang, et al. Livestock manure treatment in China utilization status and countermeasures. Chinese Agricultural Science Bulletin, 2017, 33 (23): 106 - 112. (in Chinese).
[3] TAO Jie, SHI Zhongming, WU Fan, Design and implementation of a low cost automatic facility for pig pen, Farm Machinery, 2009 (23): 80 - 82.
[4] TAO Jie, Guo Qifang, Nie Qiong. Design and Implementation of Environmental Monitoring System in a Pig Farm Based on Zigbee and PLC, Jiangsu Agricultural Sciences, 2015 (12): 458 - 462.