Design of the Suspended Cleaning equipment for Pigsties

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Abstract. In view of the traditional pig captivity mode and the characteristics of the pigsty, this paper Analyzed the task of pigsty cleaning work, and designed a cleaning equipment with the suspension mechanism and the cleaning mechanism to meet the cleaning task, without changing the existing enclosure facilities. The rope transmission and the adsorption electromagnet are used to Switch cleaning steps.

1. Design scheme
The traditional small-scale captive breeding is an important component of the current pig industry. Compared with the development of feed supply, epidemic prevention and health care, and other aspects of breeding, the captive breeding facilities are basically still at the traditional level, with poor working environment and high labor intensity. However, the existing pig breeding equipment is basically only suitable for industrial scale breeding [1]-[4]. It is still blank space for small-scale captive facilities in the field of modern animal husbandry equipment. Therefore, on the premise of not changing the existing enclosure facilities, it is of great significance to develop automatic equipment, especially the cleaning equipment suitable for small-scale enclosure, to promote the modernization of pig industry.

The pigsty in the traditional enclosure is usually surrounded by walls and cement solid bottom. After simple domestication, the piglets develop the habit of dividing the pigsty into the feeding area in front and the excretion area in the back. Different from the large-scale pig farms, the leaky floor is widely used, and the pig manure can be cleaned intensively when it falls under the floor; the traditional pig pen adopts the solid floor, and the pig manure is basically accumulated in the drainage area of the pen.

As far as the task requirements of the actual cleaning equipment are concerned, it is necessary to be able to put down the cleaning equipment at the entry position of each pigsty, collect the pig manure in the whole drainage area, reach the exit position and lift it above the height of the enclosure wall, and then send it 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.

As shown in Fig.1, the transformation scheme is shown for feeding and cleaning automation in traditional captive mode. The hanging track is installed above the drainage area of each pigsty, depending on the roof span beam of the enclosure. The whole equipment is composed of a cleaning mechanism and a suspension mechanism. The former is installed on the track, which can drive the whole equipment to slide stably over the discharge area of each pigsty, while the latter is installed under the former, which can be lowered or pulled up at the designated position to enter or leave the pigsty, and can be driven to slide for collecting pig manure within the designated area in the pigsty.
2. Mechanism design

The cleaning equipment is composed of the suspension mechanism and the cleaning mechanism, as shown in Fig. 2.

Fig. 1 Schematic diagram of traditional enclosure and transformation scheme

Fig. 2 Schematic diagram of cleaning mechanism, 1 - L-shaped bar; 2 - angle iron track; 3 - upper limit sensor; 4 - lower limit sensor; 5 - guide rod; 6 - sliding block; 7 - cross expansion bracket; 8 - cleaning bucket; 9 - chain; 10 - chain wheel; 11 - electromagnet2 and sleeve 2; 12 - brake disc; 13 - winding groove wheel; 14 - electromagnet1 and sleeve 1; 15 - positioning sensor; 16 - auxiliary groove wheel; 17 - groove wheel; 18 - suspension frame
The suspension mechanism is composed of a moving unit at the upper end and a driving unit at the lower end. The moving unit includes a suspension frame, two pairs of vertical groove wheels, a sleeve named sleeve1 and an adsorption electromagnet named electromagnet1 inside sleeve1; The driving unit consists of a winding sheave, a brake wheel, two auxiliary sheaves with parallel axes, a sleeve named sleeve2 and an adsorption electromagnet named electromagnet2 inside sleeve2, two sprockets installed symmetrically, and a pair of a sprocket and a chain.

The track is made of angle iron of GB 50×50, which is fixed on the triangle beam of the shed through L-shaped bars. Two thirds of the bottom surface of the angle iron is in contact with the beam frame, and the other third is reserved for the roller on the suspension frame to pass. The suspension frame can be clamped into the two side plates of the angle iron through two pairs of vertical groove wheels, which can ensure the reliable sliding without breaking away from the track during the moving process.

The cleaning mechanism includes two guide rods, a sliding block, two cross expansion brackets, a cleaning bucket and four limit switches. One side of the upper end of the cross expansion bracket is hinged on the suspension frame, and the other side is hinged on the slide block sheathed on the guide rod. The lower rod of the cross expansion bracket is hinged on the upper part of the rear side plate of the cleaning bucket.

The chain bypasses the sprocket in the driving part. One end of it is connected to the front bottom plate of the cleaning bucket, and the other end is connected to the upper part of the rear plate of the cleaning bucket. When the sprocket rotates forward, the cleaning bucket is forced to move up after the front end of it is pulled up. Instead, the sprocket rotates reversely, the cleaning bucket is put down. Correspondingly, the cross expansion bracket is compressed or extended, and the slider moves forward and backward on the guide rod.

3. Design of transmission system
The drive unit is installed inside the suspension frame. The traction cable is wound on the winding sheave and the auxiliary sheave in a sequential cycle, and sufficient friction can be generated between the cable and the winding sheave. When the force of the traction cable is within the allowable range, the sheave and the cable will not slide relative to each other.

The top view of the winding sheave and two auxiliary sheaves is shown as Fig.3. The cable and three grooves of the winding sheave are in complete contact to ensure sufficient friction. When the cable traction winding sheave rotates, the three sheaves rotate in the same direction.

![Fig. 3 Schematic diagram of rope](image)

winding sequence

There is a set of electromagnet sleeve device between suspension frame and angle iron, and brake wheel, as shown in Figure 2. The sleeves are fixed on the suspension frame, the adsorption electromagnets are placed in sleeves, and there is a small gap between electromagnets’ side and the sleeves, between theirs adsorption section and the brake disc or angle iron.
When the electromagnetic 1 or electromagnetic 2 is electrified to absorb the brake disc or angle iron, the corresponding sleeve 1 or sleeve 2 can prevent the movement of the suspension frame or the brake disc relative to the suspension frame. When electromagnet 2 absorbs the brake wheel and the electromagnetic 1 is separated from the angle iron, the traction cable can pull the suspension mechanism to slide along the angle iron; When electromagnetic 1 absorbs the angle iron and electromagnetic 2 is separated from the brake wheel, the traction cable can make the brake wheel and the coaxial sprocket rotate.

4. Practical application and conclusion
Generally, there is a small angle slope at the bottom of the pigsty. In this project, the height of the wall is 1000mm ± 50mm, the height of the cleaning bucket is 200mm, and the vertical height of the bottom of the suspension frame from the ground is 1500mm.

There are three sections of the cross expansion bracket, and each rod is 750mm, so that when the cross expansion bracket is completely compressed, the bottom of the cleaning bucket can be higher than the pigsty wall; while the cleaning bucket falls on the ground inside the pigsty, the cross expansion bracket cannot reach the full extension state.

Through calculation, the effective diameter of the brake disc (twice the distance from the center point of electromagnet 2 to the axle center) is set as 420mm, the inner diameter of the winding groove wheel is 180mm, the diameter of the dividing circle of the sprocket is 60mm, and the maximum weight of the full load of the designed cleaning bucket is 15kg.

When electromagnet 2 is powered off, electromagnetic 1 is electrified and adsorbed the angle iron to ensure that the suspension frame will not slide and the cleaning bucket can go up or down. The adsorption force of electromagnet 1 $F_1$ can be given by the following expression, where $F_1$ is the static friction between the end face of electromagnet 1 and the angle iron, $\mu$ is the static friction coefficient of "steel -steel". Then $m_1$ and $m_2$ are the weight of cleaning bucket and pig manure respectively, and $r$ and $R_1$ are the pitch circle radius of the sprocket and the radius of the winding groove wheel respectively.

$$T_1 = \frac{F_1}{\mu} = \frac{(m_1 + m_2) \cdot g \cdot r}{\mu \cdot R_1} = \frac{(2kg + 15kg) \times 9.8N/kg \times 30mm}{0.15 \times 75mm} = 444.23N \tag{1}$$

When electromagnet 1 is powered off, electromagnet 2 is powered on to ensure that the brake disc and suspension frame are fixed, and the linkage can drive the cleaning mechanism to slide along the track. The adsorption force of electromagnet 2 $F_2$ can be given by the following expression, where $F_2$ is the static friction between the end face of electromagnet 2 and the brake disc, and $R_2$ and $R_3$ are the radius of the winding groove wheel and sleeve 2 respectively.

$$T_2 = \frac{F_2}{\mu} = \frac{(m_1 + m_2) \cdot g \cdot r}{\mu \cdot (R_2 - R_3)} = \frac{(2kg + 15kg) \times 9.8N/kg \times 30mm}{0.15 \times (200mm - 25mm)} = 190.4N \tag{2}$$

Two YHN-P50/27 model electromagnets are selected, with a suction of 500N, a diameter of 50mm and a height of 27mm, so that all the setting functions work.

Acknowledgments
Foundation project: Science and technology cultivation project of Suzhou polytechnic institute of agriculture (Project No.:19PY1004).

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