RESEARCH & DEVELOPMENT OF INTELLIGENT FEEDING SYSTEM
/
精细喂鸡系统的设计

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***Abstract**: As the present feeding devices used in the chicken farm are mostly simple and less automated, an intelligent feeding system is established in this paper by comprehensive technological means like sensor detection, data processing and remote monitoring to control the feeding quantity accurately and monitor the feed intake in real time. The system consists of upper computer, control center and mechanical hardware equipment, of which the mechanical hardware equipment is about 44.2kg. Upon testing, the system takes 15s in feeding; the accuracy of feeding quantity is 90-99%, compared with 70-85% of that of traditional machine; the feeding efficiency is 1.4-1.9 times higher than that of traditional machine. Users can set the feeding parameters based on the chicken age, type of chicken and other information through the interface of the upper computer, and monitor the epidemic situation of the chicken farm, to achieve the requirement of intelligent feeding.*

***Keywords:** feeding system, real-time detection, man-machine interface, STC89C52*

***摘要**: 针对目前养鸡场喂食装置简单、自动化程度低等特点，本文通过传感器检测、数据处理、远程监控等综合技术手段，建立一套应用于养鸡场的智能喂食系统，能实现对喂食量的精确控制和对采食量的实时监控。该系统由上位机、控制中心、机械硬件设备三个部分组成，其中机械硬件设备约为 44.2kg。经实验测试，该系统完成一次喂食所需的时间为 15s；饲料量的投放精度为 90~99%，而传统机械喂食的投放精度为 70~85%；投食效率为传统机械投食的 1.4~1.9 倍。通过该系统的上位机界面，用户可以根据鸡龄、鸡种等信息自行设置喂食的相关参数，还可以实时监测鸡场疫情，达到智能喂食的要求。*

***关键词**: 喂食系统, 实时检测, 人机交互界面, STC89C52*

INTRODUCTION

The research of feeding process and feeding equipment is an important link to the feeding and management of chicken farm[1][2]. Traditional feeding method is featured by low efficiency and waste, as it mainly depends on people experience to decide the feeding parameters, and transfer the feedstuffs to each feeding manually. Feed intake is a physical quantity which indirectly reflects the growth trend and health of the chickens. Monitoring the feed intake in real time is of significance to production raising and diseases prevention [3][4][5].

At present, with the all-round development of automation and mechanization technologies, many mechanized and semi-mechanized chicken large, medium and small farms, , appeared in succession in China, which greatly increased the feeding efficiency. However, they are still in the blank stage in figuring out how to control the feeding quantity accurately and monitor the feed intake in real time. Compared to foreign countries, the automation level of the domestic feeding device lags far behind, hindering the large and scale development of the chicken farms [6][7][8].

For above reasons, a feeding system for chicken farm is developed herein. This system, developed on the basis of the traditional feeding device, can effectively feed the chickens in a timely and quantitative manner and monitor the feed intake in real time, provides such functions like residual detection and epidemic warning, offset the shortages such as single feeding function and dispersed structure and feed the chickens in a highly-intelligent and accurate way.

引言

养鸡场喂料工艺和喂料设备的研究是养鸡场饲养管理的重要环节[1][2]。传统的喂料方法主要依靠人工经验判断喂食参数，以人工卸料的方式将饲料传输到各食槽中，其效率低下，并且容易造成饲料的浪费。采食量是间接反映鸡群生长趋势、健康状况的物理量，实时对采食量进行监控对于生产养殖、鸡病预防有重要意义[3][4][5]。

目前，随着自动化和机械化技术的全面发展，国内相继出现了许多机械化、半机械化的大中小型养鸡场，喂料效率有了很大的提高，然而对喂料量的精确控制、采食量的实时监控等方面的研究仍处于空白阶段。与国外相比，国内喂料装置的自动化程度还远远不够，阻碍了国内养鸡场向大型化、规模化的发展[6][7][8]。

对此，本文研制了一套应用于养鸡场的喂食系统。该喂食系统在传统喂食装置的基础上，有效的实现了对鸡群的定时定量喂食和对采食量的实时监控，扩展出剩料检测、疫病预警等功能，弥补了现有喂料装置功能单一、结构分散的缺点，最终达到喂食系统高智能化、高精细度的目标。

STRUCTURE AND PRINCIPLE OF THE FEEDING DEVICE

This feeding device consists of charger, conveyer (including helical conveying pipe and DC gear motor), emptying device (including emptying valve and emptying pipe), feedstuff quantity detector (including ultrasonic ranging sensor, electric drive pusher and refining pusher), control system (upper computer, control center and serial communication module) and power supply system, of

喂食装置的结构与原理

该喂食装置由进料装置、输料装置（包括螺旋输料管道、直流减速电机）、漏料装置（包括漏料阀门、漏料管道）、料量检测装置（包括超声波测距传感器、电动推杆、匀料推杆）、控制系统（上位机、控制中心、串口通信模块）、供电系

which the control center is based on STC89C52 single chip. See figure 1 for mechanical structure design of the feeding device.

统等组成，其中控制中心是以 STC89C52 单片机为核心。喂料装置的机械结构简图如图 1 所示。

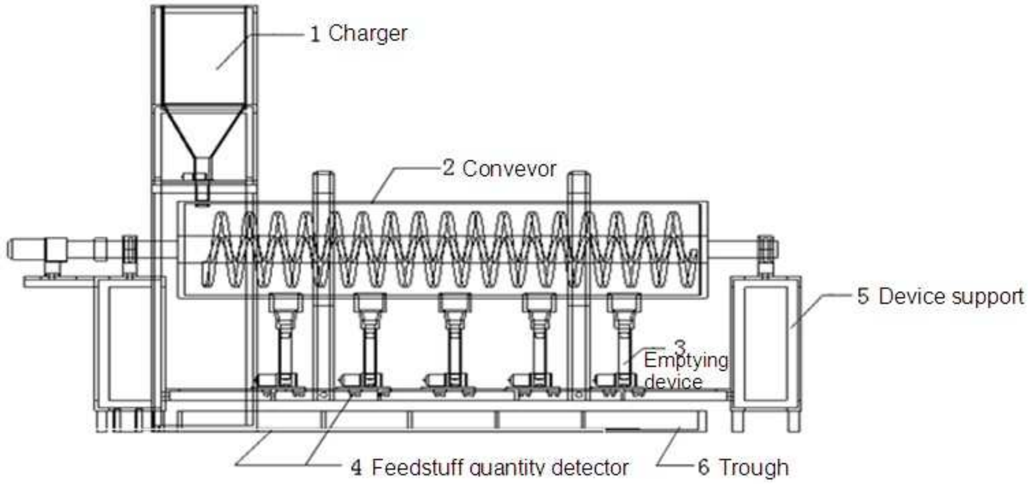

Fig. 1 - Intelligent mechanical structure for chicken feeding / *智能精细喂鸡系统机械结构*

The process of the whole system is depicted as follows: (1) Set the feeding time and quantity of that day on the interface of the upper computer; (2) When the feeding time comes, the upper computer will send the initial signal and feeding quantity to the control center through serial port; (3) Upon identifying the initial signal, the control center will drive the charger, conveyor and emptying device and then the feedstuffs will be conveyed from the charger to the feeding trough; (4) before feeding, the feed quantity detector will accurately measure the feedstuff quantity in the trough through ultrasonic ranging sensor and refining pusher and send the measuring data back to the control center while uploading it to the upper computer; (5) the control center will compare the measuring data with the feeding quantity. If both of them are equal, it will close the electrically operated valve (EOV) to the corresponding trough to stop feeding; if not, it will continue feeding. When feeding from all troughs stops, the system will enter dormant state and wait for next order. At all time when the system is powered on, user can collect and display the data of feedstuff quantity from any trough by means of the monitoring function of the upper computer.

整个系统的工作过程为：（1）用户在上位机界面中设置当日喂食时间和喂食量参数；（2）当喂食时间到达时，上位机经串口发送起始信号和喂食量参数到控制中心；（3）控制中心识别到起始信号后驱动进料装置、输料装置、漏料装置工作，实现饲料从进料装置到食槽的传输；（4）在进行投料操作之前，料量检测装置通过超声波测距传感器、匀料推杆，实现对食槽中饲料量的精确测量，并将测量数据返回控制中心，同时传送至上位机进行显示；（5）控制中心将测量数据与喂食量参数相比较，若相等则关闭对应食槽的电动阀门，停止投料操作；反之就进行对应食槽的投料操作，待所有食槽均停止投料后，系统处于休眠状态，等待下一次的操作命令。在系统上电的任意时刻，用户可以通过上位机中的监测功能，对任一个食槽中的饲料量进行数据采集并显示。

Design of feedstuff quantity detecting system

The feedstuff quantity detecting system which is used to accurately detect the feedstuff quantity in the trough mainly consists of refining module and height detecting module.

料量检测系统的设计

料量检测系统主要由匀料模块、高度检测模块组成，用于对食槽中饲料量的精确检测。

Refining module

As the feedstuffs coming from the emptying device are in irregular geometrical shape, a refining module is designed. The purpose of it is to level off the feedstuffs evenly in the trough to accurately detect the feedstuff quantity. Trough which is located below the hole of the emptying device (see figure 1) is the direct rectangle container (made of stainless steel) for chicken feeding. The whole trough is separated evenly with four iron plates, i.e., consisting of five independent sections. With the structural parameter of single trough of 39*8*10cm and the capacity of 1000g, it can be used to feed five chickens at the same time in one day. This independent trough not only prevents chickens from fighting for food, but also establishes a one-to-one relation between chicken and trough, facilitating the positioning analysis of single coop.

匀料模块

由于通过漏料装置漏下的饲料在食槽中呈不规则几何状，故设计了一个匀料模块，其功能是将食槽中的饲料均匀推平，以实现对料量的高度检测。食槽是鸡群采食的直接容器，其安装于漏料口正下方，如图 1 所示，特性为不锈钢制长方槽形容器；整个食槽被 4 个铁制挡板均匀隔开，形成 5 个独立食槽；单个食槽结构参数为 39*8*10cm，容量为 1000g，能够满足同时 5 只鸡的单日采食。通过独立式食槽，既可以避免鸡群之间的争食现象，也建立起食槽与鸡笼一一对应的关系，便于对单个鸡笼进行定位分析。

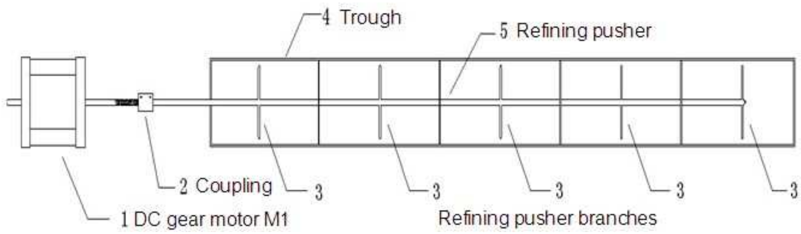

Fig. 2 - Refining device / *匀料装置*

The refining module (see figure 2) consists of refining pusher mounted in the bottom of the trough and linear motor M1. (1) Refining Pusher: 220cm L x 6cm W x 0.3cm H. The size can be neglected compared with the size of the trough. The refining pusher is composed of one main pusher and five sub-pushers. The sub-pushers are welded and perpendicular to the main pusher every 39 cm. (2) Linear motor M1 (also known as refining motor): Its parameters include 12 V DC voltage, 1200N maximum load, 540 mm/s maximum no-load speed and 600mm maximum stroke. M1 is fixed to one end of the main pusher through a coupling and directly drives the load for linear motion.

When refining operation is needed, the control center will activate M1. The refining pusher will start reciprocating motion under the control of M1 to level off the feedstuffs within a short time through friction and vibration. Upon repeated test, when the trough is full of feedstuffs, the horizontal motion speed of the refining pusher is 490~500mm/s. The feedstuffs can be leveled off by the refining pusher through two or more reciprocating motions under this speed.

匀料模块如图 2 所示，主要包括：（1）放置于食槽底部的匀料推杆，其长度为 220cm，宽度为 6cm，高度为 0.3cm，体积相对于食槽体积可以忽略不计。匀料推杆由 1 根主推杆和 5 根分推杆组成，分推杆以每隔 39cm 的距离垂直焊钳于主推杆上；（2）控制匀料推杆的直线电机 M1（又称匀料电机），其参数为其参数为直流电压 12V、最大负载 1200N、最大空载速度 540mm/s、最大行程 600mm。M1 通过联轴器与主推杆的一端固定，其直接驱动负载做直线运动。

当需要进行匀料操作时，控制中心启动 M1 工作；匀料推杆在 M1 控制下做往复运动，并引起匀料推杆上方的饲料摩擦和抖动，使饲料能在短时间被均匀推平。经实验反复测试，在食槽为满饲料状态时，匀料推杆在水平运动速度能达到 490~500mm/s，在此速度下匀料推杆经过两次及两次以上往复运动即可将饲料推平至所需平整度。

Height detecting module

This module consists of ultrasonic ranging module HY-SPF05 and temperature sensor DS18B20; (1) Ultrasonic ranging module HY-SPF05: Two ultrasonic ranging modules are mounted horizontally right above each trough. The mean value of the feedstuff height detected by two ultrasonic sensors will be deemed as the final feedstuff height. The ultrasonic ranging module consists of ultrasonic launcher and receiver. Its parameters include 5V DC voltage, 15mA working current, 2~450mm measuring distance and 150 detection angle and 3mm measuring accuracy; (2) Temperature sensor DS18B20: The purpose of it is to compensate the temperature for ultrasonic ranging.

料量高度检测模块

料量高度检测模块主要包括:（1）超声波测距模块 HY-SPF05。每个食槽正上方水平安装两个超声波测距模块，将两个超声波传感器测得的食料高度求均值，作为最后的饲料高度。单个超声波模块由超声波发射装置和接受装置组成，其工作参数为直流电压 5V、工作电流 15mA、测量距离 2~450mm、感应角度 15^0、测量精度 3mm；（2）温度传感器 DS18B20，其作用在于对超声波测距进行温度补偿。

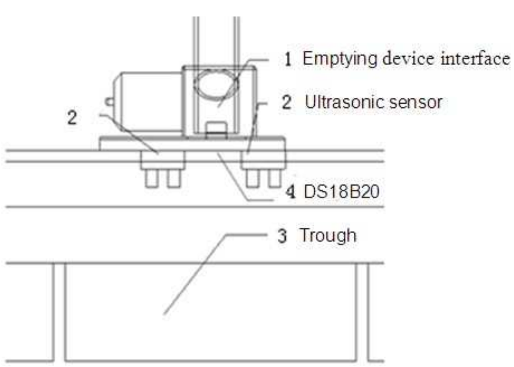

Fig.3-Height detecting module / *高度检测模块*

The ultrasonic ranging sensor is directly connected to the control center. When there is a need to detect the height of the feedstuffs in the trough, the control center will activate the ultrasonic launcher to launch the ultrasonic wave. The time interval between launching ultrasonic wave and receiving

超声波测距模块与控制中心直接相连，当需要对食槽中的饲料进行高度检测时，控制中心启动超声波发射装置发出超声波，发出超声波与接收到超声波回波的时间间隔为 t。

ultrasonic echo is t. As the propagation velocity of ultrasonic wave in the air is easily affected by the surrounding environment, it is a need to compensate the temperature for ultrasonic velocity. Upon compensation, the ranging formula is as follows [9]:

超声波在空气中的传播速度易受环境影响，对超声波速度进行温度补偿，补偿后的测距公式为[9]：

$$S = \frac{(c + \alpha * T) * t}{2} \tag{1}$$

Wherein: T is actual temperature ($°C$), $c = 331.5(m/s)$, $\alpha = 0.607 m/(s \cdot °C)$ is temperature compensation coefficient, S is the distance (unit: cm) between sensor and object to be tested. If the feedstuffs in the trough are leveled uniformly, the space (S) between ultrasonic ranging module and feedstuffs can be tested accurately through ranging operation.

式中，T 为实际温度（ $°C$ ），$c = 331.5(m/s)$，$\alpha = 0.607 m/(s \cdot °C)$ 为温度补偿系数，S 为传感器与被测物体之间的距离（ cm ）。若食槽中的饲料均匀平整，通过测距操作，可以精确获得超声波测距模块与饲料之间的距离 S。

Conversion between height and mass

To perform quantitative feeding and real-time monitoring, it is necessary to directly obtain the mass of the feedstuff in the trough [10]. The following is mapping relation between mass (marked as m) and space (marked as S) which is obtained from relation between density and mass $m = \rho * v$:

高度与质量之间的转换

为了达到定量喂食和实时监测的目的，需要直接获得食槽中饲料的质量 m [10]。由密度与质量的关系 $m = \rho * v$，得到距离值 S 与质量值 m 之间的映射关系：

$$m = \rho * v = \rho * (s * (L - S)) \tag{2}$$

Where v means feedstuff volume (unit: cm^3) in each trough, ρ means the feedstuff density (unit: g/cm^3), s means the floor area of the trough and L means the space (unit: cm) between ultrasonic ranging sensor and trough base.

While the feedstuff quantity detecting device is working, first activate M1 for refining operation. The feedstuffs will be leveled of after 3.2s; then the control center will activate the ultrasonic ranging module and temperature sensor. When the return time of ultrasonic ranging sensor is 600 μs and the current room temperature tested by the temperature sensor is 25℃, the space between ultrasonic ranging module and feedstuffs is 11.6cm by means of formula (1). If $L = 20cm$, $s = 312cm^2$, $\rho = 0.35 g/cm^3$, the mass is $m = 917.28g$ in the current trough by means of formula (2).

式中，v 为每个食槽中饲料体积（ cm^3 ），ρ 为饲料密度（ g/cm^3 ），s 为食槽底面积（ cm^2 ），L 为超声波测距传感器与食槽底部之间的距离（ cm ）。

当料量检测装置工作时，首先启动 M1 进行匀料操作，经过约 3.2s 饲料被均匀推平；随后，控制中心启动超声波测距模块、温度传感器工作，超声波测距传感器返回时间为 600 μs，温度传感器测得当前室温为 25℃，由式（1）得到超声波测距模块与饲料的距离为 11.6cm。若已知 $L = 20cm$, $s = 312cm^2, \rho = 0.35 g/cm^3$，由式（2）得到当前食槽中的饲料量 $m = 917.28g$。

Design of tubular helical conveyor

The helical conveyor which is used to convey granular or powdered feedstuffs is simple in structure, reliable in performance and designed in mechanical structure (See figure 4).

管式螺旋输料装置的设计

螺旋输料装置应用于颗粒或粉状饲料的传输，其结构简单、工作可靠，机械结构如图 4 所示。

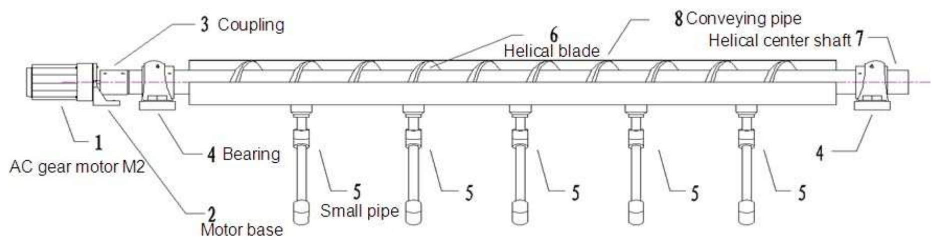

Fig. 4 - Helical conveyor / *螺旋输料装置*

It can be seen from figure 4 that the tubular helical conveyor consists of helical blades welded to the helical center shaft, AC gear motor M2 (also known as conveying motor) and main conveying pipe. (1) Helical blades welded to the helical center shaft: Stainless steel blade with 16cm external diameter, 4cm internal diameter and 16cm pitch; (2) AC gear motor M2: Its parameters include 22V AC voltage, 6W power, 13r/min rotating speed, and $3N \cdot m$ torque. The output shaft

由图 4 可知，管式螺旋输料装置主要包括：（1）焊钳在螺旋中心轴上的螺旋叶片，其为外径 16cm、内径 4cm、螺距 16cm 的不锈钢材质叶片；（2）交流减速电机 M2（又称输料电机），其参数为交流电压 220V、功率 6W、转速 13r/min、扭矩为 $3N \cdot m$，该电机的输出轴通过轴承与螺旋

of the motor is connected to the helical center shaft through the bearing to control the rotating direction and speed of the blades; (3) Main conveying pipe: With the parameters of 4cm radius and 210 cm length, it is an enclosed plastic pipe. The upper left of pipe is connected to the charger through the hole of the emptying device.

In the process of feedstuffs conveying, the control center controls the feedstuffs in the main conveying pipe by controlling the speed and direction of M2. While M2 is rotating in reverse clockwise direction, the feedstuffs will be conveyed from the left of the main pipe to the right (left to right) and distributed to the troughs corresponded to five small pipes; while M2 is rotating in clockwise direction, the feedstuffs will be conveyed from right to left and distributed to the troughs corresponding to five small pipes; When M2 stops, the feedstuffs conveying will also stop. See figure 1 for the control relation between feedstuff and main pipe. It takes about 30s to convey the feedstuffs from one side to the other side under the speeds in table 1.

中心轴相连，从而控制螺旋叶片的旋转方向和旋转速度；（3）输料主管道，其半径为 $4cm$ ，长度为 $210cm$ ，是封闭的塑料管道，其左上方通过一个漏料口与进料装置连接。

执行输料操作时，控制中心通过控制 M2 的速度和方向，从而对输料主管道中的饲料进行控制。当 M2 逆时针旋转时，使得饲料正向传输，饲料从输料主管道的左端传送到右端（从左至右），并分别从五个漏料小管道漏出至对应的食槽；反之当 M2 顺时针转动时，饲料从主管道右端传送到左端（从右至左），分别从五个漏料小管道漏出至对应的食槽；当 M2 停止转动时，饲料停止传送。M2 对饲料的控制关系如表 1 所示，在此速度下，饲料完成从管道一端到另一端的传输过程约需要 30s。

Table 1 / *表 1*

Control relation between AC gear motor M2 and feedstuff / *交输料电机 M2 对饲料的控制关系*

M2 rotating direction / *M2 转动方向*	M2 rotating speed / *M2 转速*	Conveying direction / *饲料传输方向*	Conveying speed / *饲料传输速度*
Reverseclockwise / *逆时针*	10r / min	Positive direction (Left to right) / *正方向（从左至右）*	7cm / s
Clockwise / *顺时针*	10r / min	Reverse direction (right to Left) / *反方向（从右至左）*	7cm / s

Design of electrically operated valve (EOV)

It can be seen from figure 1 that an EOV is mounted between the charger and tubular helical conveyor to control the feedstuff quantity of the conveyor. This EOV is known as the first switchgear of the charger. To separately control the charging process of each trough, an EOV is mounted between the emptying pipe and each of five trough sections. This EOV is known as the second switchgear of the emptying device. When either EOV is opened, the feedstuffs will pass through the corresponding valve. The height of the valve and the size of the feedstuffs passing through the valve per unit time are directly relative; When EOV is closed, the passing will stop. In this system, all the EOVs are of the same type. See figure 5 for its mechanical structure.

电动阀门的设计

从图 1 可知，为了对进入输料装置的饲料量进行控制，进料装置与管式螺旋输料装置之间安装有电动阀门，也称为进料装置的第一开关装置。为了对每个食槽进料过程单独控制，漏料管道与 5 个独立食槽之间都有对应的电动阀门，也称为漏料装置的第二开关装置。当任一电动阀打开时，允许饲料通过相应的阀门，阀门开度与单位时间通过的饲料体积直接相关；当电动阀关闭时，禁止饲料通过相应的阀门。在本系统中，各电动阀门是同一种类型，其机械结构如图 5 所示。

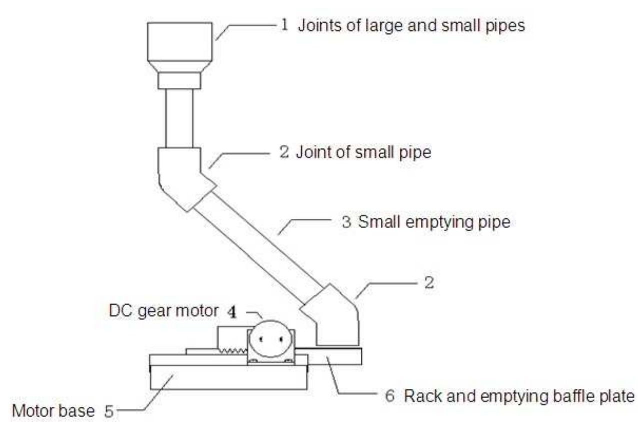

Fig. 5 - Electrically operated valve / *电动阀门*

EOV consists of: motor base, one metal rack mounted on the base of the iron trough, emptying baffle plate and DC gear motor. (1) Motor base: Fixed on the support below the hole of the emptying device with a hard iron trough separated; (2) Metal rack mounted on the base of the iron trough: As the width of the rack is the same as the width of the iron trough and the length is

电动阀门主要包括:（1）电机底座，其固定于漏料口下方的支架上，底座中间被一高硬度铁皮槽隔开；（2） 1 根安装于底座铁皮槽上的金属齿条，其宽度与铁皮槽同宽，长度为铁皮槽长度的 2/3（略比漏料口半径大），因此齿条可以

2/3 of the length of the iron trough (slightly larger than the radius of the emptying hole), the rack may be moved right and left in the iron trough; (3) emptying baffle plate: It is a hard wood plate with one side connecting to the rack; (4) DC gear motor: Its parameters include 6V DC voltage, 3W power, 150r/min rotating speed, and 0.6 $\mathrm{N}\cdot m$ torque. As the motor is fixed on the base and the output shaft is embedded in the rack, the motor drives the rack to move left and right.

In this system, the diameter of the emptying hole is 3cm and the diameter of the output shaft of DC gear motor is 3mm. In the charging state, all the EOVs will be opened and the feedstuff can be sent to the troughs through the emptying pipe. When the charging operation stops, the control center will control the rverseclockwise rotation of the DC gear motor and the gear will drive the emptying baffle plate the move rightward. Under this case, the emptying hole is closed; when there is a need to open the EOVs for charging, the control center will control the clockwise rotation of the DC gear motor and then the EOVs open. See figure 6 for the opening width of the valves and the adjustment process of the helical conveyor direction. In the figure, M3 is the DC gear motor of the first gear switch for controlling the charger and M4-M8 are the DC gear motors (or trough motor) of the second gear switch for controlling the emptying device. Relays 1-3 are used to control the rotating direction of the conveying motor M2 to control the conveying direction of the tubular helical conveyor.

在铁皮槽中左右移动；（3）漏料挡板，其特性为高硬度的木板，其一端与齿条相连；（4）直流减速电机，其参数为直流电压 6V、功率 3W、转速 150r/min、扭矩为 0.6 $\mathrm{N}\cdot m$，机身固定在底座上，输出轴嵌在齿条中，因此能带动齿条左右移动。

本系统中，漏料口直径为 3cm，直流减速电机输出轴的直径为 3mm。当电动阀门处于投料状态时，阀门全开，饲料能完全通过漏料管道漏入食槽中。若需要停止投料操作时，控制中心控制直流减速电机逆时针旋转，齿轮带动漏料挡板向右移动，此时漏料口被完全挡住，停止饲料下漏；当需要再次打开电动阀门进行投料操作时，控制中心控制直流减速电机顺时针旋转，即可达到电动阀门的全开状态。电动阀门开度和螺旋输料方向的调节过程如图 6 所示。图中，M3 为控制进料装置的第一开关装置的直流减速电机，M4～M8 为控制漏料装置的第二开关装置的直流减速电机，也称为食槽电机。继电器 1～3 是用于控制输料电机 M2 的转向，从而实现控制管式螺旋输料装置中的输料方向。

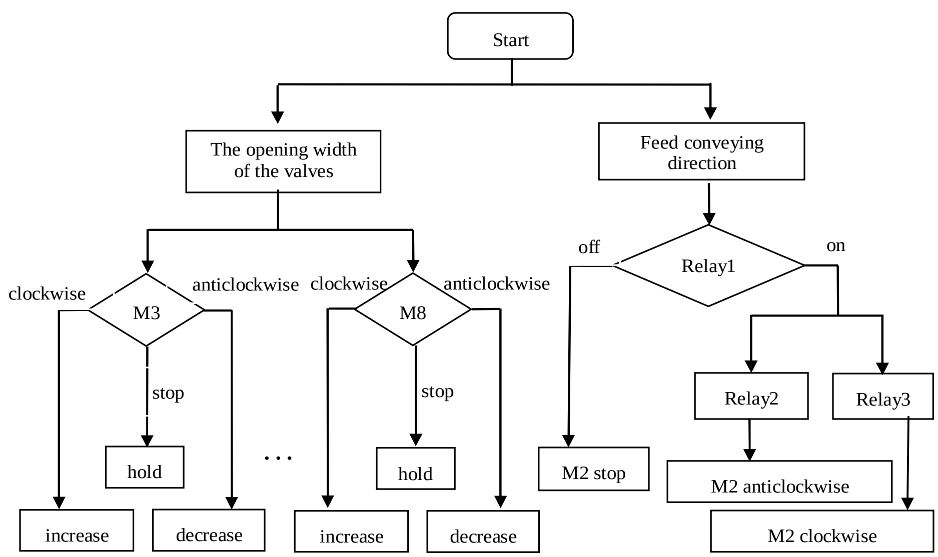

Fig. 6 - EOV and adjustment process of helical conveyor direction / *电动阀和螺旋输料方向的调节过程*

DESIGN OF CONTROL SYSTEM

Control system mainly refers to data collection and control system and interface control system. Based on the core of STC89C52 single chip, the parameter collection and control system sends the parameters obtained from the sensors mounted on the trough to the upper computer through serial port after the controls by refining motor M1, conveying motor M2, DC gear motor M3 and trough motors M4-M8 are completed. The interface system is a good presentation of man-machine interaction. It is responsible for controlling the feeding time, displaying the status of the trough and sending out epidemic warning signal.

Data collection and control

Data collection and control means the above-mentioned control center. It takes STC89C52 single-chip and its peripheral circuit as the core. See figure 7 for the control principle. It can be seen from this figure that the data are collected through each ultrasonic ranging module; the relay and motor driver directly connected to I/O port are used to

控制系统的设计

控制系统主要指数据的采集与控制、界面控制系统。参数的采集与控制系统，是由安装在食槽上的多个传感器检测出对应的参数，以 STC89C52 单片机为核心，完成对匀料电机 M1、输料电机 M2、直流减速电机 M3、食槽电机 M4~M8 等的控制，并经串口将相关的参数传回上位机。界面控制系统实现人机交互过程，完成对喂食时间的控制、食槽状态显示、疫病报警等功能。

数据的采集及控制

数据的采集及控制即指前述的控制中心，是以 STC89C52 单片机及其外围电路为核心，其控制原理如图 7 所示。图中，各个超声波测距模块对数据进行采集；与 I/O 口直接相连的继

control motors to complete corresponding feeding; the upper computer uses RS232 serial port to receive feedback data and send feeding parameters through MAX232 level switch and single chip. The initialized serial communication parameters are 9600 baud rates, 8 data bits and 1 stop bit without parity check bit.

电器、电机驱动用于控制电机完成相应喂食操作；上位机通过 RS232 串行口经 MAX232 电平转换与单片机实现通信，用于接收反馈数据和发送喂食参数，串口通信参数初始化为 9600 波特率、无奇偶校验位、8 数据位和 1 停止位。

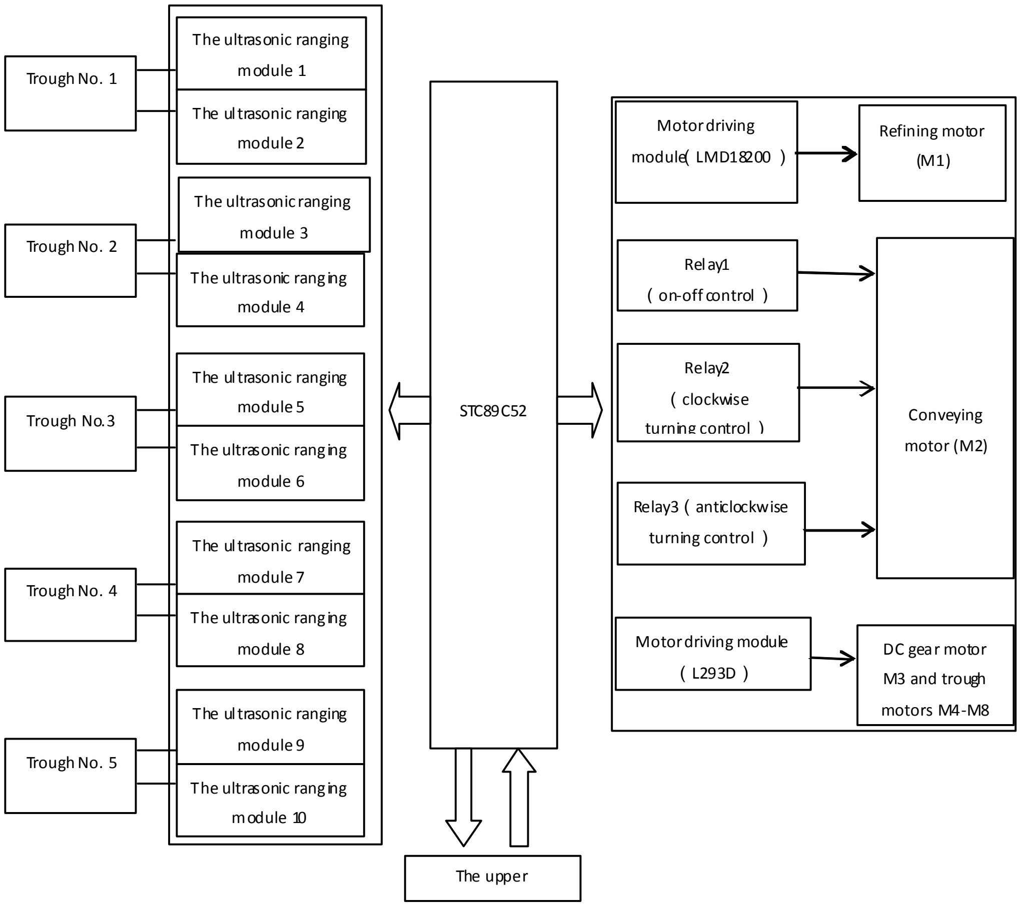

Fig. 7 - Principle of controlling system / *控制系统的原理*

Feedstuff quantity checking and feeding control

Feedstuff quantity checking and feeding control play a crucial role in improve the feeding accuracy and monitoring the trough state. Their steps include: (1) Upon receipt of the feeding signal, the control center will check the feedstuff quantity in each trough to see which trough has the set quantity; (2) The conveyor controlled by the control center begins to convey feedstuffs to each emptying device; (3) The control center opens the second gear switch of the emptying device to the trough in which the feedstuff quantity fails to reach the set value for releasing the feedstuffs; (4) The control center circularly checks the feedstuff quantity in each trough in proper order to see if they are up to the set value and close the second gear switch of the emptying device to the qualified troughs. If all the troughs are qualified, M1-M8 will be closed.

料量检测与喂食控制

料量检测与喂食控制是实现提高喂食精度、监控食槽状态的关键，其工作步骤为：（1）控制中心收到喂食信号后，检测各个食槽中食料量，确定食料量达到设定量的食槽；（2）控制中心控制输料装置开始输送食料，食料由输料装置传输到各个漏料装置中；（3）控制中心打开食料量未达到设定量的食槽对应的漏料装置的第二开关装置开始漏料；（4）控制中心依次循环检测各个食槽中的食料量是否达到设定量，并关闭食料量达到设定量的食槽对应的漏料装置的第二开关装置停止漏料，当检测到所有的食槽中的食料量均达到设定量后，则关闭 M1～M8。

Design of the upper computer's feeding interface

Man-machine interaction interface is designed for the upper computer through VB6.0. This interface has such functions like feeding setup, residual monitoring and warning and should be able to directly control and test the feeding system. It accesses to Microsoft access 2003 database through ADO component, helping user to effectively manage and save the data in real time [11].

上位机喂食界面的设计

上位机选用 VB6.0 设计了友好的人机交互界面，交互界面设有喂食设置、食槽内饲料余量监测与报警等功能，能对喂食系统直接进行控制和检测。界面通过 ADO 组件访问后台 Microsoft access 2003 数据库，有效地实现了对数据实时管理和存储[11]。

Setting of feeding parameters

To facilitate user operation and meet the feeding requirements given by the chicken farms, the feeding setting system consists of two sub-systems, “quick setting” and “advanced setting”. The “quick setting” sub-system is used to set parameter on the basis of the expert system in the database. It will operate feeding according to the experience of feeding parameters given by the expert system as long as the basic parameters (such as chicken age and type) are set by the user, further facilitating user operation and making the promotion of the intelligent feeding system easier. “Advanced setting” sub-system is used to set parameters according to the needs of the chicken farms. User can set the feeding time, feeding frequency and feeding quantity separately through this subsystem to meet their needs.

喂食设置参数的设定

为了方便用户进行操作及满足不同养鸡厂的喂食要求，喂食设置系统主要包括“快速喂食设置”和“高级喂食设置”两个子系统。其中，“快速喂食设置”子系统是基于数据库中的专家系统进行设置的，用户只需设置所养殖鸡类的基本参数（包括鸡龄、鸡种等信息），系统将根据专家系统提供的经验喂食参数进行喂食操作，大大方便了用户的操作，同时更加利于该设备的推广。“高级喂食设置”子系统是根据养鸡场的自身需求来设置的，用户能对喂食时间、喂食次数和喂食量等参数单独设定，以此满足不同的用户需求。

Real-time feeding monitoring and disease warning

To avoid disease and decide the feedstuff quantity, the system will check the residual feedstuffs in each trough to decide whether additional feedstuffs are needed and the added quantity and take the result as a measuring indicator of disease warning (in case of any epidemic disease, the residual will exceed the threshold value more than one time) [12][13]. When the system is powered on, it will monitor the feedstuffs in the troughs in real time, helping the user to get to know the feedstuff condition in the trough in real time. If the residual in certain trough is three times higher than the threshold value, hidden epidemic threat of the chickens using this trough or mechanical fault may exist. Under this situation, the system will send a warning single through characters and buzzer and locate the suspected trough. At the same time, user can check the historical data of this abnormality and feeding quantity for statistical analysis and quantity adjustment.

喂食实时监测及鸡病预警

为了预警鸡病、确定需喂食的饲料量，系统在每次喂食时都会检测每个食槽内饲料的剩余量，以此判断是否需要添加饲料以及需要添加的饲料量，同时也作为鸡病预警的一个衡量指标(若存在疫病，饲料剩余量会多次大于阈值)[12][13]。该系统在上电的过程中，系统可以对食槽中的饲料量进行实时监测，方便用户实时了解食槽中饲料情况。此外，若某食槽中饲料剩余量超过阈值 3 次，则说明相应食槽的鸡群可能有鸡病隐患或者机械故障，系统会以出现报警字符和蜂鸣器鸣叫的形式向用户发出警告，定位可疑食槽。同时用户可以查询异常情况的历史数据及喂食量的历史数据，方便用户进行统计及喂食量的调整等。

TESTING

Test conditions and methods

The test time is May and June and the test location is the chicken farm in Yucheng district, Ya’an city, Sichuan province. Table 2 shows the parameters of the mechanical structure and performance upon the actual test of R&D system. To demonstrate the objectivity of the test results, 3 types of feedstuffs and 15 three-month old chickens are used for testing. At the same time, to fully ensure the stability of man-machine interface and hardware system, an all-round software performance test for man-machine interface is conducted.

试验测定

实验条件与方法

试验时间在 5～6 月，试验地点选在四川省雅安市雨城区养鸡场。经过对研发系统的实际测试，其机械结构性能参数如表 2 所示。为了体现测试结果的客观性，测试共采用了 3 种类型的鸡饲料，15 只 3 个月月龄的鸡进行测试，同时在人机交互界面中进行了全方面的软件性能测试，充分保证人机交互界面及硬件系统的稳定性。

Table 2 / *表 2*

Performance parameters of whole machine / *整机性能参数*

Net weight of mechanical structure /*机械结构净质量*	Mechanical structure size /*机械结构尺寸*	Rated power /*额定功率*	Rated voltage /*额定电压*	Rated current /*额定电流*	Storage battery capacity /*蓄电池容量*	Diameter of emptying pipe /*漏料管道直径*	Parameter of refining pusher /*匀料推杆参数*
44.2kg	1.73m×0.55m ×2.6m	60w	12v	5A	960VAH	4cm	220cm×6cm×0.3cm
Length of main pipe /*主管道长度*	**Diameter of the emptying hole of main pipe /*主管道漏料口直径***	**Single trough capacity /*单个食槽容量***	**Number of trough /*食槽数量***	**Trough parameter /*食槽参数***	**Storage tower capacity /*储料塔容量***	**Number of ultrasonic sensors on one trough /*单槽上超声波传感器数量***	**Total number of ultrasonic sensors /*超声波传感器总数***
1.98m	6cm	1kg	5	39cm×8cm×10cm	30L	2	10

Result analysis

Tables 3 and 4 show the results of feeding accuracy test and feeding efficiency test. Feeding accuracy means the ratio of actual feedstuff quantity and desired feedstuff quantity. Feeding efficiency means the feedstuff quantity released by the system each hour (Unit: kg/h).

结果分析

喂食系统精确度测试表，投食效率测试表如表 3~4 所示，其中投放精度定义为实际投放的饲料量与期望的饲料量之比，投食效率定义为每小时系统投放的饲料量，单位为 kg/h。

Table 3 / *表 3*

Feeding accuracy test / *饲料投放精度测试*

Feedstuff quantity/g /*饲料投放量*	Feeding accuracy of the traditional machine /*传统机械喂食精度*	Feeding accuracy of this system /*本系统喂食精度*
1000g	0.70~0.75	0.90~0.99
500g	0.80~0.85	0.92~0.99
300g	0.80~0.85	0.92~0.99
200g	0.80~0.85	0.92~0.99
100g	0.70~0.75	0.92~0.99

Feeding accuracy test in table 3 demonstrates that the quantitative feeding accuracy of this feeding system is relatively high and better than that of the traditional mechanical feeding system.

表 3 的饲料投放准确度测试表表明，该喂食系统在定量喂食精度上准确度较高，优于传统机械式的喂鸡系统。

Table 4 / *表 4*

Feeding efficiency test / *投食效率测试*

Type of feedstuff /*饲料种类*	Traditional machine /*传统机械投食*	This system /*本系统投食*
1#	100 kg/h	185 kg/h
2#	100 kg/h	160 kg/h
3#	100 kg/h	140 kg/h

Note: The feedstuffs are granular. See above for feedstuff type.

In table 4, the granular sizes of 1#, 2# and 3# are presented from small to big. The test result demonstrates that the feeding efficiencies for different types of feedstuffs are basically the same when traditional system is used, while the feeding efficiencies vary with granular sizes when this system is used. The smaller the size is, the higher the feeding efficiency is. As the feeding efficiency of this system is higher than that of the traditional system, the operation effectiveness is improved.

注：饲料均采用颗粒饲料，种类见上

表 4 中，1#、2#和 3#的饲料颗粒尺寸是由小变大的趋势。试验结果表明传统机械式喂鸡系统在不同饲料品种情况下投食效率相当，而本系统则根据饲料颗粒的大小不同，投食效率不同，颗粒越小，投食效率越高，并且投食效率均比传统纯机械式的喂鸡系统要高，提高了作业实施的有效性。

CONCLUSIONS

The intelligent feeding system in this article integrates the basic functions of charging, conveying, feeding at regular time and quantity and residual checking and the extended functions of epidemic warning and feedstuff warning. It can offset the shortages of the existing feeding device such as single function and dispersed structure to meet the feeding requirements on an intelligent basis.

(1) The mass of the model machine is 44.2kg, which can feed 15 chickens and takes about 15s in feeding, greatly increasing the feeding speed.

(2) This system is a full automatic working system with the feeding accuracy of 90-99%, higher than that of the traditional machine (which is only 70-85%); the feeding efficiency is 1.4-1.9 times higher than that of traditional machine.

(3) The system is equipped with favorable man-machine interface, which facilitates user operation and can provide such functions like epidemic warning, abnormality positioning, user warning and timely check the abnormal position to see if the epidemic disease exists.

结 论

本文研制的智能喂食系统，实现了集进料、输料、定时定量喂料、剩料检测为一体的基本功能，并实现了集疫病预警、饲料预警等为一体的扩展功能，弥补了现有喂料装置功能单一、结构分散的缺点，从而达到智能喂食的要求。

1）样机的质量为 44.2kg，可实现 15 只左右鸡的喂食，完成一次喂食所需的时间约 15s，大大提高了喂食速度。

2）本系统采用全自动操作，饲料量的投放精度为 90~99%，高于传统机械喂食的精度 70~85%；本系统的投食效率为传统机械投食的 1.4~1.9 倍。

3）该系统拥有友好的人机交互界面，方便用户的操作，还可以提供疫病预警功能，定位异常位置，提醒用户及时排查该位置的鸡群是否存在疫病。

As the system has better feeding accuracy and working efficiency compared with those of manual feeding, it offsets the shortages of the traditional machine such as poor automation, low efficiency and inaccurate feeding. Besides, it is featured by lower cost and is able to feed chickens in an efficient and scientific manner, better preventing epidemic disease.

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该系统在喂食精度和工作效率等方面均高于人工喂食方式，弥补了传统机械式装置自动化程度低，工作效率低，喂食精度不高的缺陷，并且成本较低，具备高效率喂食、科学喂食和鸡群疫病预警等功能。

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