STUDY ON INTELLIGENT MULTI-CONCENTRATES FEEDING SYSTEM FOR DAIRY COW

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Abstract: To implement precision feeding for dairy cow, an intelligent multi-concentrates feeding system was developed. The system consists of two parts, one is precision ingredients control subsystem, the other is multi-concentrates discharge subsystem. The former controls the latter with 4 stepper motors. The precision ingredients control subsystem was designed based on Samsung S3C2440 ARM9 microprocessor and WinCE5.0 embedded operating system. The feeding system identifies the dairy cow with passive transponder using RFID (Radio frequency identification) reader. According to the differences of based diet intake and individual dairy cow milk yield, the system can automatically and quantificationally discharge 4 kinds of different concentrates on the basis of the cow identification ID. The intelligent multi-concentrates feeding system for dairy cow has been designed and implemented. According to the experiment results, the concentrate feeding error is less than 5%, the cow inditification delay time is less than 0.5s and the cow inditification error rate is less than 0.01%.

Key words: Precision feeding, intelligent concentrate feeding system, Dairy cow, RFID

1. INTRODUCTON

With the development of dairy cow breeding industry, more milk yield, higher milk qulity and top-priority feeding cost for each dairy cow are the

most important aspects for dairy cow farmer (Halachami et al., 1998; Hua et al., 2006). In recent years, concentrates automatic feeding system for cow is used in few of large dariy farms (Hua et al., 2006). However, in the absence of precision feeding system in the common scale dairy farm, food intake of each cow can not be calculated, feeding cost can not be estimated, milk yield and milk qulity are difficult to be increased (Halachami et al., 1998). In other words, both milk yield and quality depend on food intake, especially on the concentrates intake. In fact, the food intake varies significantly with cows, thus the computer controlled concentrates, self-feeders, feeding robots are designed to solve the automatic feeding problem of individual cow in the small scale cow farm (Halachami et al., 1998; Fang, 2005; Kuang, 1999).

Automatic TMR (Total Mixed Ration) feeding system is applied in the UK and the US firstly since 1960's. TMR feeding technique well mixes the concentrates and the coarse fodders, and realizes nutritional balance of cow, but TMR can not agree with the demand of the nutrition of the individual, cow, especially the cow with the high capability of the milk yield. Feeding robots can identify the cow ID with RFID system and can deliver the different amount of the concentrates and coarse fodders for individual cow, but the discharging mode of the robot is to discharge concentrates at first, and then to discharge the coarse fodders in sequence, or to deliver the coarse fodders at first, and then the concentrates, which results in that the concentrates and the coarse fodders can not be mixed well (Tan et al., 2007; Halachami et al., 1998; Fang, 2005).

In order to deliver automatically and accurately 4 kinds of concentrates, simultaneously mixing well during discharging, on the basis of the individual cow identification, the intelligent multi-concentrates feeding system was developed based on WinCE, 32bit high performance microprocesser, 4 precision stepper motors and a flute-wheel concentrate feeding device. Furthermore, the system includes a cow feeding database which consists of individual cow feeding information, such as the weight of the concentrates agreeing with the recipe, the feeding times and the feeding interval. The feeding database can record every individual cow's each intake concentrate weight, the intake times and the intake time per day.

2.   SYSTEM DESIGN

2.1   System Overview

The system consists of two parts, one is a precision ingredients control subsystem, and the other is a multi-concentrates discharge subsystem which

includes 4 concentrate dischargers driverd by 4 stepper motors. The former controls the latter with 4 stepper motors. The precision ingredients control subsystem was designed based on Samsung S3C2440 ARM9 microprocessor and WinCE5.0 embedded operating system. The flute-wheel concentrate feeding device was used on the discharge subsystem.

Fig. 1 shows the one concentrate discharger which mainly consists of a base frame, a feeding trough, a discharge funnel, a flute-wheel discharger, a hopper, a stepper motor, a coupling and a stepper motor driver. When the cow with passive transponder steps into the feeding area, the cow RFID reader gets the transponder data and transimates the data to the control subsystem using RS485. Then the control subsystem decodes the data, identifies the cow's ID and searches the cow's feeding information. As the weight of the concentrates agreeing with the recipe, the feeding times and feeding interval, from the feeding database. If the cow is permitted to take the concentrates, the control subsystem will calculate the respective rotation steps of each stepper motor. The steps are calculated on the basis of the discharge weight per step and the weight of the concentrate needed to be discharged. The 4 concentrate dischargers will start and complete their own task simultaneously.
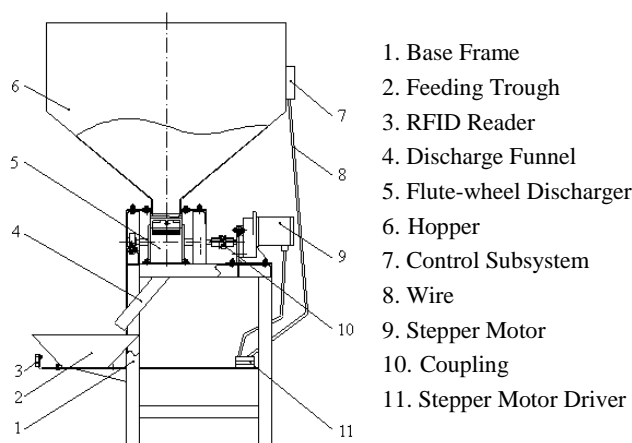

1. Base Frame
2. Feeding Trough
3. RFID Reader
4. Discharge Funnel
5. Flute-wheel Discharger
6. Hopper
7. Control Subsystem
8. Wire
9. Stepper Motor
10. Coupling
11. Stepper Motor Driver

Figure .1 The concentrate discharger diagram

2.2 Control Subsystem Design

The system hardware is designed based on Samsung S3C2440 ARM920T microprocessor, the S3C2440 provides a comprehensive set of common system peripherals and minimizes overall system costs and eliminates the need to configure additional components, the S3C2440 is perfect for general applications with cost-effective, low-power consumption, and high

performance microcontroller solution in a small form-factor (Samsung, 2004).

2.2.1 Display and Touch Panel System

The user control interface is achieved using Sharp LQ080V3DG01 640×480 TFT LCD. The LQ080V3DG01 LCD connects with S3C2440 LCD controller as shown in Fig. 2. VCLK, VLINE, VFRAME, VW are the LCD control signals generated by S3C2440 LCD controller, VD23:18, VD15:10, VD7:2 are the data ports for video data. LCD dedicated DMA of LCD controller can transfer the video data in frame memory to LCD driver
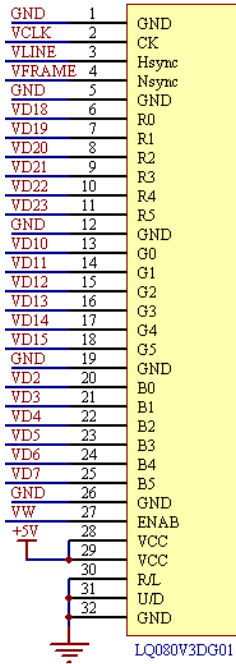

Figure 3. LCD CCFL power supply
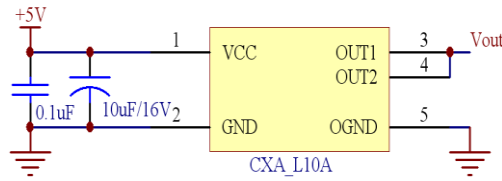

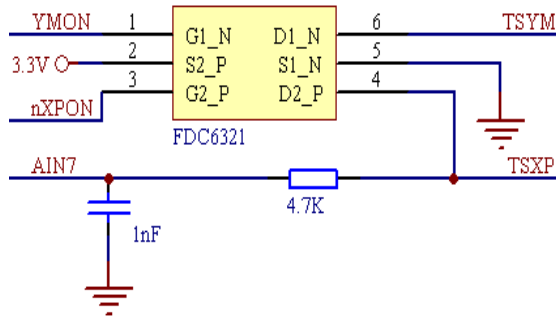*Figure .1:* LCD connection diagram   *Figure.4:* Touch panel driver circuit

Automatically without CPU intervention, sharp LQ080V3DG01 need AC power supply for backlight, the LQ080V3DG01 backlight driver circuit is designed using CXA_L10A that delivers sine wave output for CCFL (Cold Cathode Fluorescent Lamps) as shown in Fig. 3. In order to improve friendly HMI (Human Machine Interface), The LQ08V3DG01 is equipped with a 4-wire resistance touch panel. The driver circuit of the touch panel shown in Fig. 4 is designed using dual N&P channel specific IC FDC6321, and the driver circuit connects the interface unit of S3C2440 internal touch panel (Samsung, 2004; Sharp, 2003).

2.2.2 Identification System

The individual cow identification is achieved using Beijing WMTech WM-18 series RFID system. WM-18 consists of a WM-181 reader and EM4100 compatible ID cards, the work frequency is 125 kHz, and the maximal reading distance is 100 cm. The EM4100 compatible ID card is a passive battery-free transponder weared on the cow neck. When the cow with the transponder steps into the feeding area, the WM-181 reader gets the transponder data and sends the data to S3C2440 for processing through RS485 bus. It takes the system less than 150ms to transmit the data to WM-181 reader and send the data to S3C2440. The RFID system working current is less than 250 mA. The cow inditification error rate is less than 0.01%.

2.3   Discharge Subsystem Design

The discharge subsystem includes 4 dischargers. Each discharger mainly consists of a flute-wheel discharger, a stepper motor, a stepper motor driver, a coupling, a hopper and a discharge funnel. The output shaft of the stepper motor connects the input shaft of the flute-wheel discharger with the coupling.
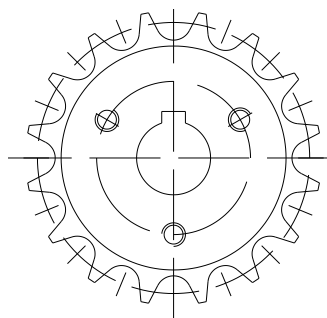
2.3.1 Flute-wheel Discharger

Figure.5 Flute-wheel diagram

Due to that the configuration and manufacture technology are simple, that it does not make the pellet broken, as well as the higher discharge rate with high accuracy, the flute-wheel discharger is selected as the delivering device. The discharge capability of the flute-wheel discharger is influenced by the effective length of the flute-wheel, the flute number, and the cross-section area of each flute. According to the result of experiment, the suitable range of the rotation speed of the flute-wheel is from 9r/min to 60r/min, if the rotation speed is out of the suitable range, the flute can not be filled with

pellet because of the higher liner velocity. Fig. 5 shows the flute-wheel designed as taper arc flute (Tai, et al., 2003).

2.3.2 Stepper Motor System Design

According to the recipe for the individual cow, the control subsystem generates 4 stepper driver pulse signals and drives the flute-wheel concentrate feeding devices to discharge the 4 kinds of the concentrates simultaneously. In order to improve the concentrates discharge accuracy, a 3-phase stepper motor 110BYG350 equipped with a 3-phase stepper motor driver 3H110MS is used. The DIP switchpack is provided on the driver to select the basic step angle of the stepper motor from 1 to 16 divisions. The stepper motor rotates smoothly at the basic step angle 0.3o/pulse and it is low vibration even at low speed.

2.4   Software Design and User Operation Interface

```
                    ┌─────────────┐
                    │    Start    │
                    └──────┬──────┘
                           ▼
              ┌────────────────────────┐
              │  System initialization │
              └───────────┬────────────┘
                          ▼
       ┌──────────────────────────────────────┐
       │  Concentrate discharge calibration    │
       └──────────────────┬───────────────────┘
                          ▼◄──────────────────┐
              ┌────────────────────────┐       │
              │    Cow identification   │       │
              └───────────┬────────────┘       │
                          ▼                     │
                    ◇─────────────◇             │
                   ╱ Feed concentrates ╲   No   │
                  ◇  for the cow or not? ◇──────┘
                   ╲                   ╱
                    ◇─────────────◇
                          ▼ Yes
       ┌──────────────────────────────────────┐
       │ Automatic feed and records the feed   │
       │            information                │
       └──────────────────┬───────────────────┘
                          ▼
                    ┌─────────────┐
                    │     End     │
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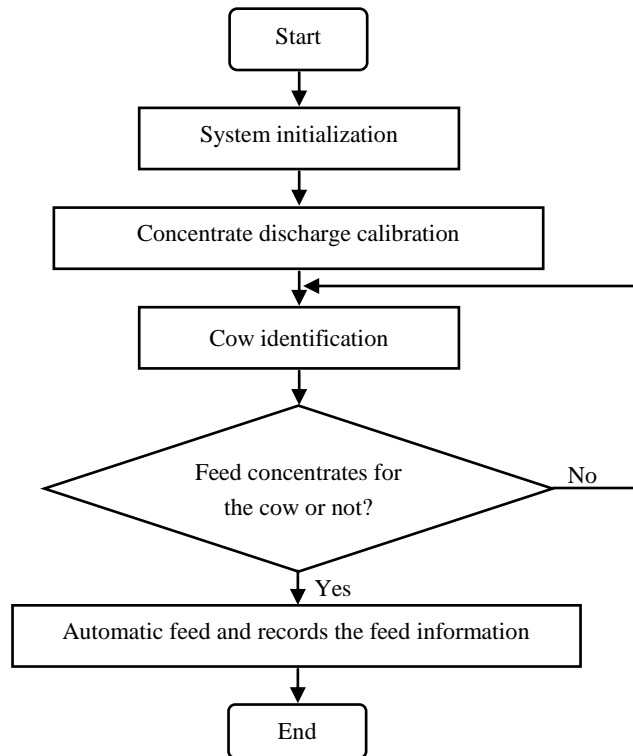
Figure.6 Flow chart of intelligent multi-concentrates feeding

The system software is designed based on WinCE 5.0 embedded operationg system, and is programmed in C/C++ language under embedded

VC development environment. The user operation interface is a very concise and friendly graphical interface, by operating LCD touch panel, the user can calibrate the concentrates discharge weight, input the individual cow intake multi-concentrates recipe, set up the cow management database, manage the concentrate feeding database, query and report the individual cow feeding data. On the other hand, the system can communicate with the host management PC through RS485 bus. The system receives the cow database data, the individual cow recipe, the individual cow concentrates intake times and the concentrates intake interval, in addition, the system transmits the intake times and the weight of individual cow concentrates to the host manage PC. The flow chart of the intelligent multi-concentrates feed for the individual cow is shown in Fig. 6.

3.   RESULT

The intelligent multi-concentrates feeding system for dairy cow has been developed and used in the experimental dairy cow farm of Shandong Agriculture University. The data presented below were collected in the experimental farm on the trial period.

Fig. 7 shows the influence of the flute number on the discharge accuracy of the concentrate with great discharge capacity when the large pellet feed was delivered. The results indicated that the discharge accuracy and the stability of the flute-wheel with 16 flutes is higher than that of the flute-wheel with 12 flutes, even thouth the number of flute does not have significant difference on the measurement accuracy ($p>0.05$). The discharge error of the flute-wheel with 16 flutes is less than 1.5% in this case.
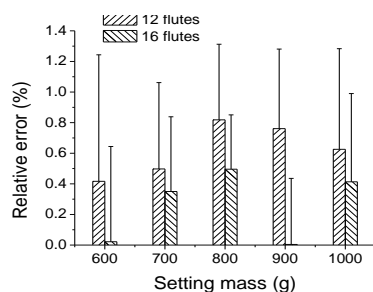

Figure.7: Large pellet and high displacement

Fig. 8 shows the relationship between the different flute number and the discharge accuracy under the conditions of discharge large or small pellet and low discharge capacity. The results indicated that the discharge accuracy of the flute-wheel with 16 flutes is nearly the same as the flute-wheel with

12 flutes, but the discharge stability is better than the flute-wheel with 12
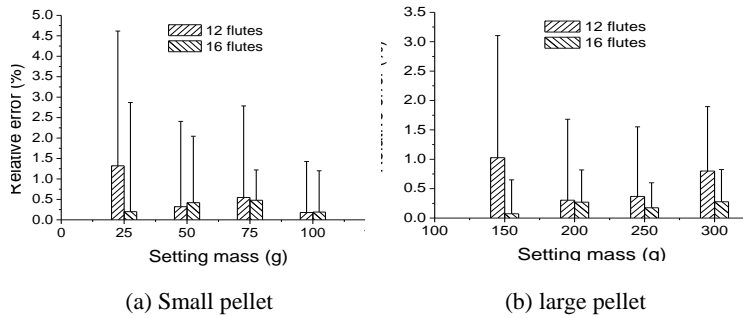flutes. The discharge error of the flute-wheel with 16 flutes is less than 1.5%.

(a) Small pellet   (b) large pellet

Figure.8: Low displacement

According to the experiment results, the total error of the concentrate
discharging is less than 5%.

4.   CONCLUSION

The intelligent multi-concentrates feeding system for dairy cow has been
designed and implemented. According to the individual cow food intake
recipe and the feeding times as well as the feeding interval, the feeding
system can discharge 4 kinds of concentrates by the cow indentification with
RFID technique. Moreover, the system can online record cow's feeding
information such as each concentrate weight, the intake times and the intake
time. Because of the friendly graph user interface and easy update in system,
the feeding system developed in our research is different from the previous
feeding systems based on PLC and the single chip microprocessor. In
addition, the system is cheaper than the similar system, and has easy
maintenance, reliability. The system is suitable for the small cow farm short
of funds.

The flute-wheel with taper arc flutes was used on the discharger, and the
results indicated that the discharger has well pellet discharge accurancy and
discharge stability. The mechanism has the characteristic of simple structure
and manufacturing technology. The discharge accuracy can be satisfied with
this mechanism.

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