STUDY ON PRECISE FEEDING CONTROL OF DAIRY COWS BASED ON WIRELESS COMMUNICATION TECHNOLOGY AND DAIRY COW INFORMATION MANAGEMENT TECHNOLOGY

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基于无线通信技术和奶牛信息管理技术的奶牛精确饲养控制研究

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ABSTRACT

In order to improve the quality of modern dairy industry, it is an inevitable trend to implement intensive control feeding of dairy cows, which is also the development direction in the future. Different feeding methods have different important effects on the health of dairy cows. For example, calves grow and develop rapidly during lactation, their physiological structure changes rapidly, and their digestive function is not perfect. In the production of dairy farms, the scientific feeding mode of calves indirectly affects the overall benefits of dairy farms. Therefore, aiming at the above problems, this paper studies how to accurately control the quality of dairy cows. A cow precise feeding control system based on wireless communication technology and cow information management technology is studied, which solves the problems of wireless information transmission, automatic and accurate cow identification and dual-mode operation of feeder, and ensures the accurate supply of cow concentrate.

摘要

为了提升现代乳品工业质量，实行对奶牛集约化控制饲养是必然的趋势，这也是未来的发展方向。不同的饲养方式对奶牛的健康有着不同的重要影响。比如犊牛在哺乳期身体生长发育快，生理结构变化快，消化功能不完善。在奶牛场生产中，犊牛科学的饲养方式间接影响着奶牛场的整体效益。因此，针对上述问题，本文研究了如何精确控制奶牛质量的问题。研究了一种基于无线通信技术和奶牛信息管理技术的奶牛精确饲养控制系统，解决了无线信息传输、奶牛自动准确识别和喂料机双模运行等问题，保证了奶牛精饲料的准确供应。

INTRODUCTION

Agricultural production is the foundation of national economy in agricultural countries, which is related to the security of national economy and social stability. *(Tian H. et al., 2020)*. The proportion of agriculture as the primary industry in the national economy has gradually declined *(Minakov I. A. and Nikitin A. V., 2019)*. In the modern agricultural industrial structure, dairy industry is the most efficient industry, especially in the agricultural developed countries, the output value of dairy industry accounts for about 20% of the total agricultural output value *(Rosa L. et al., 2020)*. In order to realize the healthy and rapid development of dairy industry, the implementation of dairy fine feeding technology is an inevitable trend, and it is also the main development direction of modern dairy industry *(Pe'Er G. et al., 2019)*. From the perspective of system structure, the dairy industry structure is mainly composed of raw milk production, dairy products processing and marketing *(Dong C. Y. et al., 2020)*. As the dairy industry is a part of the raw milk production system, the development of dairy industry is the basis for the development of dairy industry *(Storm H. et al., 2020)*. The automatic feeding system of dairy cattle is one of the earliest and most effective fields in the application of advanced electronic technology in agricultural production. As the basis of automatic information management, cow automatic number recognition device was successfully developed in the mid-1970s and became a commercial product *(Doss C. R., 2018)*. The reserve group of adult lactating cattle in dairy farm is calves. Different feeding methods of calves not only affect the healthy growth of calves, but also have an important impact on the later growth of calves and the performance of adult milk production. Therefore, it is very important to grow calves for the development of the whole dairy farm and even the whole dairy industry *(Maleko D. et al., 2018)*.

With the development of agricultural science and technology, precision agriculture will become the development direction of modern agriculture. The per unit area yield of dairy cows has not increased significantly, and the development of dairy industry is still in the initial stage of extensive quantitative expansion *(Igliński B. et al., 2020)*. Calves in the lactation stage have rapid growth and development, rapid changes in physiological structure, strong plasticity, and incomplete digestive function *(Van Damme M. et al., 2018)*. With the rapid development of breeding industry, the feeding mode of calves is too simplistic, which affects the growth and development of calves *(Qin Y. et al., 2020)*. The reserve group of adult lactating cattle in dairy farm is calves. Different feeding methods of calves not only affect the healthy growth of calves, but also have an important impact on the later growth of calves and the performance of adult milk production *(Costa J. H. C. et al., 2021)*. Because the healthy growth of calves and low calf mortality can lay a solid foundation for the growth and development of dairy cows, calf feeding has become the primary task of dairy cattle production, and it is also an important link to create a high yield of cattle *(Goulart R. S. et al., 2020)*. For a long time, with the development of animal husbandry and beef cattle industry, people did not adopt a relatively strict calf culture method, which was more random and affected the normal growth and development of calves *(Humer E. et al., 2018)*. There is a large space for the development of dairy industry. Under the new situation of vigorously developing dairy industry, especially in the process of large-scale dairy farming, fine breeding based on individual information of dairy cows is the main research direction of modern dairy scientific breeding *(Jensen M. B. et al., 2017)*.

There is a large space for the development of dairy industry. In the new situation of vigorously developing dairy industry, especially in the process of large-scale dairy farming, fine feeding based on individual information of dairy cows is the main research direction of modern dairy scientific feeding. It is difficult to develop dairy farm automation equipment and computer integrated management system. At present, the development and application personnel of dairy automatic identification system pay less attention. Dairy farm equipment generally has the problems of single function, low efficiency and high failure rate. Most of the dairy farm management is still at the level of manual management. The self-propelled cow precise feeding technology provides the feed needed by individual cows according to the physiological characteristics of cows, implements the "distribution according to demand and quantitative milk" of cow feeding, and realizes the automation, refinement and intellectualization of cow breeding. With the rapid development of Internet of things technology, its application fields are penetrating into all fields of social life including agriculture. Internet of things technology refers to the use of local network or Internet and other communication technologies to connect sensors, controllers, machines, people and things together in a new way, forming a network of people and things, things and things, realizing informatisation, remote management and control and intelligence. This paper studies a self-propelled precision feeding control system based on wireless communication technology and cow information management technology, which solves the problems of wireless information transmission, automatic and accurate identification of individual cows and dual-mode movement of feeding machine in precision feeding technology of cows, and ensures the accurate supply of concentrate for cows.

Literature suggested that due to the improvement of internal nutrients and physical processing characteristics, and combined with the implementation of group feeding mode, the total mixed ration (TMR) feeding mode promoted the increase of per unit area yield of dairy cows in different degrees. However, the characteristics of feeding behaviour still adapt to the new feeding mode and management concept needs to carry out behavioural observation and research after the change of conditions in order to explore the new rules of feeding. In reference, a new design method is proposed. The intelligent precise feeding system of dairy cattle, combined with the corresponding mechanical structure, becomes a feeding robot, which is hung on the track, runs according to the designed program, runs along the track, automatically identifies the dairy cows, accurately proportions and mixes the feed for each dairy cow, realizes regular feeding for many times every day, and can change the feeding curve, memorize and download the delivery records. In reference, a self-propelled accurate feeding control system for dairy cows was proposed, which solved the problem of automatic identification of individual dairy cows, and the measurement error was controlled at about 2%. The measurement error of the latter has been improved obviously, but it is not enough to identify individual cows and record feed intake for further study of the feeding behaviour of cows. Under the automatic control of computer technology, calf feeding machine can accurately feed many calves. It can not only ensure the nutritional needs of different individual calves, but also find out the abnormal condition of calves in time, saving a lot of labour. In large-scale dairy farms with increasing workload and rising labour costs, such automatic calf feeding machinery is needed to ensure the operation and expansion of the pasture.

MATERIALS AND METHODS

With the transformation of dairy industry from scale and quantity type to quality type, it has become the development direction of cattle owners to improve individual milk yield and overall economic benefits of cattle, and it has become an inevitable trend for dairy farms to introduce computer management. The MCU control system receives the data sent by the information management software and stores the data in the external memory. When feeding, the SCM control system controls the dual-mode traveling mechanism to move forward. When the RFID card reader of the feeder identifies the tag installed on the cow's ear, the SCM control system receives the cow tag number sent by the card reader and controls the feeder to stop traveling. A PC is installed in the operator management office to realize the functions of man-machine conversation, data storage and processing, and given control commands. The feeding station includes milk storage tank, milk box, milk tank, electromagnetic valve, heater, ear tag reader, weighing scale, single chip microcomputer control box, etc. Single-chip microcomputer integrates microprocessor, random access memory, read-only memory, various I/O ports, interrupt systems and other input and output interfaces, and has been widely used in the field of industrial control, with strong functions, fast processing speed and low power consumption.

The designed MCU is the core part of the lower computer of calf feeding control system, which is responsible for communicating with the upper computer and controlling the action of the actuator and even the whole feeding process. Its performance stability, application field, self-contained resources, scalability, cost and compilation complexity, development environment and so on are several conditions that must be considered in the selection process. As shown in Figure 1, the whole feeding control system consists of six modules or systems: identification system, feeding console, weighing quality system, feeding system, feeding behaviour data cache system and data storage management and analysis system.

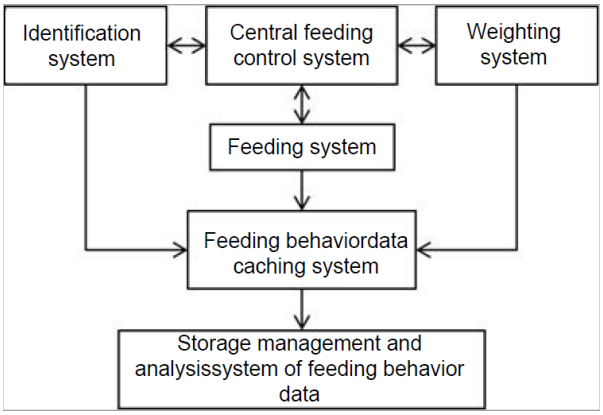


Fig. 1 - Feeding control and data acquisition system structure

Before feeding, the upper computer runs the cow information management software, and uses the software to call the physiological characteristic information data of the cow and process the information. The processed feeding data and the cow ID are sent to the MCU system through wireless transmission, and the MCU system receives and saves the data. The single chip microcomputer control system analyses the identified tag number to determine whether to feed. If the received tag number is a valid tag number, the single chip microcomputer control system controls the accurate feeding device to feed the cow through the stepping motor. When a calf with an ear tag comes to the milk trough to eat milk, the card reader in the feeding station recognizes the electronic ear tag worn by the calf, and transmits the electronic tag to the microcontroller. At the same time, the electronic scale begins to weigh the calf, and transmits the obtained ID number of the calf identification and the data of the weighing sensor to the upper computer through the RS-485 bus. The calf feeding control system is mainly composed of identification system, temperature control system, upper computer control system, peristaltic pump precise feeding system and communication system. When calves wearing ear tags approach the identification system, the machine matches the information of calves imported into the control system by identifying the ear tag ID, calculates the feeding amount, and sends the feeding amount to the MCU, which converts the feeding amount into pulses and transmits them to the servo motor driver to drive the peristaltic pump to feed accurately. The overall schematic diagram of the system is shown in Figure 2.

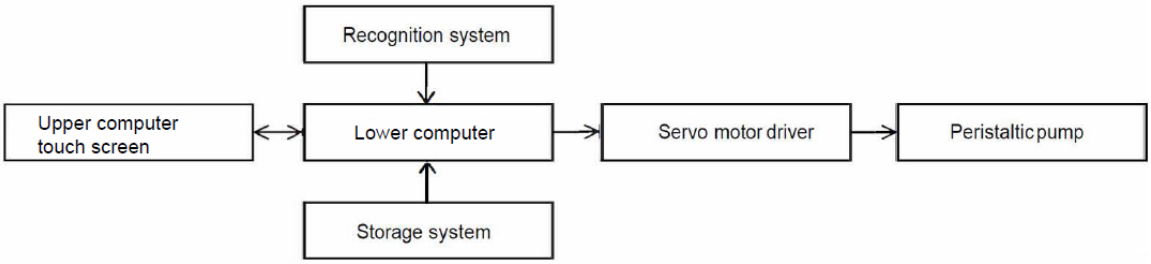


Fig. 2 - Feeding control system

Reader, i.e. radio frequency tag reading and writing equipment, is one of the two important components of radio frequency identification system. Generally speaking, the reading and writing equipment of radio frequency tags should be designed according to the reading and writing requirements and application requirements of radio frequency tags. When feeding, adjust the feeder to the manual control mode, manually operate the feeder to the tower of the cattle farm for feeding, and then drive the feeder to the pen to be fed, and adjust the feeder to the automatic control mode. Calves are sensitive to the changes of external feeding environment, and the most suitable temperature for feeding is 39°C. Too high or too low temperature is not conducive to the digestion and absorption of nutrients by calves. Excessive milk temperature will damage the intestinal mucosa of calves, reduce absorption capacity, cause nutritional diarrhoea and anorexia. If the temperature of milk is too low, the milk will be discharged in intestines and stomach, and the nutrition will not be absorbed completely, which cannot meet the needs of calf growth. With the development of radio frequency identification technology, some typical system realization modes have been formed for radio frequency tag reading and writing equipment. From the most basic principle point of view, radio frequency tag reading and writing equipment generally follows the basic mode. The main factor affecting the communication between the electronic tag and the reader is the working frequency, so the working frequency is determined according to the application requirements and the standards of various countries and regions.

The upper computer software control system calculates the milk feeding amount according to the formula of calf milk feeding amount, and converts the milk feeding amount into the required milk height in the milk box. The actual driving process of the automatic electromechanical control system is analysed, and a unified visual and behavioural model is formed, as shown in Figure 3.

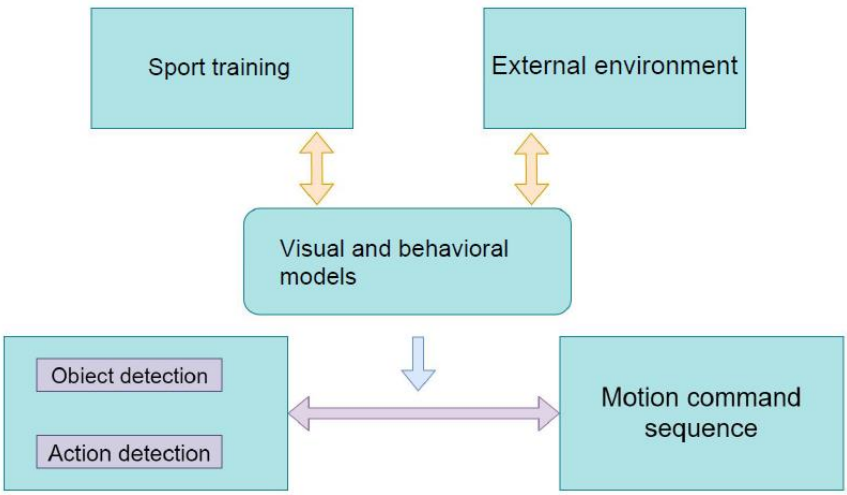


Fig. 3 - Vision and behaviour model

As the upper computer, PC stores, processes and analyses the data transmitted from the lower computer, and transmits various control commands to the lower computer through RS232/485 bus structure to realize centralized management and optimal control. Figure 4 is the flow chart of control system fault diagnosis algorithm.

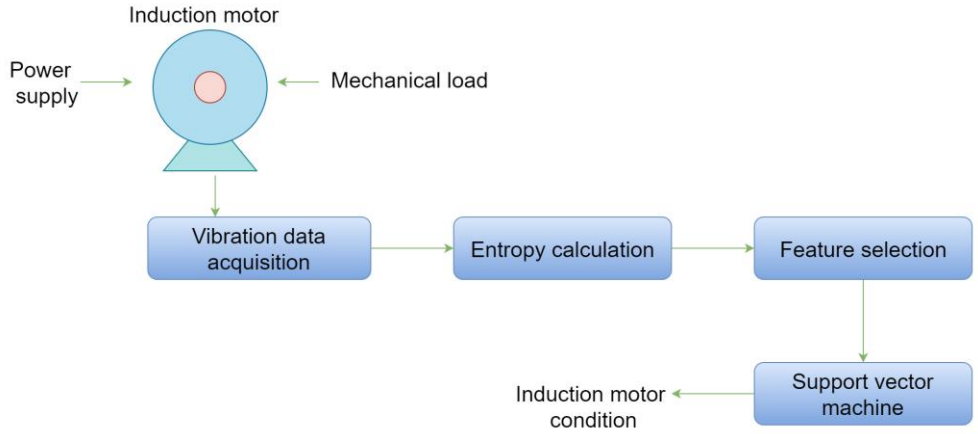


Fig. 4 - Control system fault diagnosis algorithm flow

The upper computer transmits the required milk height to the lower computer through the serial port, and starts the MCU control system to control the opening and closing of the solenoid valve and heater, thus realizing the scientific control of the temperature and milk quantity of feeding calf milk. When cows wearing electronic tags enter the reading range of reading and writing equipment, the recognition system can recognize that many cows wear electronic tags, but for cows, in order to ensure the correct supplementary feeding amount, the reader-writer is set in the fence of the channel, and the channel within the setting range in this direction is determined. The channel can only accommodate a single cow to eat, and the identification system can identify the information data of individual cows, thus avoiding confusion caused by multiple cows wearing electronic tags eating at the same time within the reading and writing range of the reader. In order to ensure the cleanness and hygiene of the normal milk processed by the equipment, water bath heating is designed, but there is a delay when the energy is transferred from water to the normal milk during heating, so the temperature control equipment system has great lag, the temperature is too high or too low to be accurately controlled, and even the pasteurization process is changed. The feeder automatically travels along the feeding trough under the control of the single chip microcomputer. When the feeder travels to the feeding area of dairy cows, the wireless radio frequency card reader identifies the tags worn on the ears of dairy cows in advance, and sends the identified tag numbers to the single chip microcomputer control system.

RESULTS

System function analysis

The foundation and key of the research and development of precision feeding control system for dairy cows is to identify individual dairy cows accurately and quickly. Only after accurately and quickly identifying the individual dairy cows who are taking food can the reasonable feeding amount of the individual dairy cows be determined according to the preset feeding strategy, and the feeding control of concentrated feed can be carried out on this basis. There are strict rules on the feeding amount of calves. At this stage, overeating calves will lead to over nutrition and diarrhoea, and in severe cases, the calves will suffer from diseases and die. If calves eat too little, they will not develop well, which will affect their later growth and development. In the case of a small number of animals, it is relatively easy to identify individual animals by these methods, and the identification process is relatively effective and intuitive. However, many of these traditional animal identification methods have shortcomings, which will cause discomfort or damage to individual animals, so these methods are difficult to be widely used in automatic management, so it is difficult to realize the scale of animal production. The MCU control system controls the feeder to stop moving forward, compares the identified tag number with the ID number in the memory, and after finding the corresponding ID number, calls the feeding data of dairy cows, starts the spiral feeding device, and puts the concentrated feed needed by dairy cows.

When working, the host computer circularly scans all data collectors to collect data, circularly scans the control mechanism to collect real-time feeding amount, displays timely data on the console, and sends information to the management platform to run the management software in real time. Figure 5 is the structure of the control system agent node.

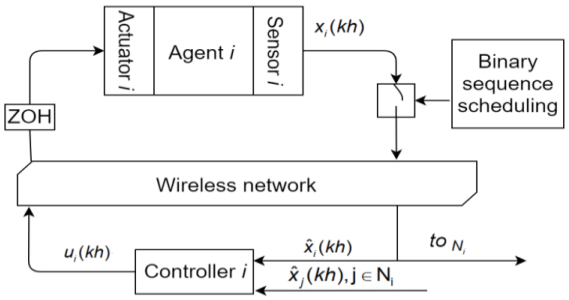


Fig. 5 - The structure of the intelligent body node of the automatic electromechanical control system

Data acquisition, visual positioning and data receiving modules transmit data through interfaces. The data format is shown in Table 1.

Table 1

Data format

Name	Length
Start flag	4
Data length	6
Command word	7
Data part	12
Termination code	7

In the working environment of RFID system, if there are a lot of metals, water and other substances, the identification accuracy of electronic tags will be affected. Figure 6 shows the consistent distributed control state of agents.

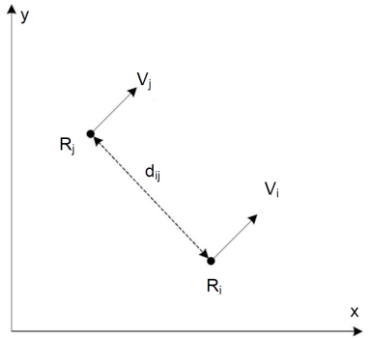


Fig. 6 - The state of consistent distributed control of the agent

Choose a 3-layer 5-input 5-output BP network controller, including 5 input nodes, 5 output nodes, and 1 hidden layer.

The calculation formula for the error of the p-th sample:

$$E_p = \left[\sum_i \left(t_{pi} - O_{pi}\right)^2\right] / 2 \tag{1}$$

In the formula, t_{pi} is the expected output value, and O_{pi} is the actual network output value. The input of the input node is x_j, and the output of the hidden node is:

$$y_i = f\left(\sum W_{ij} x_j - \theta_i\right) \tag{2}$$

In the formula, W_{ij} is the connection weight, and θ_i is the node threshold. The output node output O_l is:

$$O_l = f\left(\sum_i T_{ij} y_i - \theta_l\right) \tag{3}$$

In the formula, T_{ij} is the connection weight, and θ_l is the node threshold.

The speed response of the motor in the dynamic process is an oblique straight line, which shows that the motor is basically started with the maximum torque. When the speed reaches the target speed of 200rad/s, it stabilizes, and the motor torque stabilizes accordingly. The motor torque waveform is shown in Figure 7.

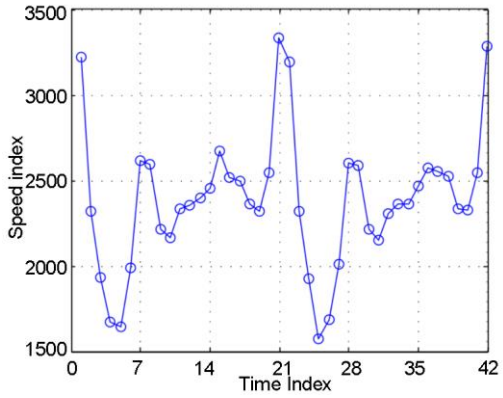


Fig. 7 - Motor torque waveform

The system administrator can run the management software from the management platform to input the basic information and various parameters of cows, and the computer can automatically calculate the concentrate feeding amount and feeding times according to the weight, stage, parity, pregnancy, physiological cycle, milk yield, milk quality and environmental factors of cows. The system uses PC as the feeding management platform to run the information management software. The information management software collects the physiological characteristic data of cows by calling the cow farm database, analyses and calculates these data, and finally sends the valid data to the MCU control system through the wireless transmission device. When working, all kinds of electrical equipment will radiate electromagnetic waves with different frequencies, and the RFID module will be interfered by electromagnetic waves, thus affecting the normal reading and writing recognition rate. In addition, other radio equipment will send out the same frequency wireless signals in the working environment, which will occupy the bandwidth of the radio frequency identification communication module, seriously affect the radio frequency identification module, and may even cause the system to fail to work normally.

System structure analysis

When in the state of system debugging, setting and correcting control parameters, and sending commands by the upper computer, the upper computer is always in the state of active communication, and the method used is query method, with sending before receiving. In practical work, with the application of radio frequency technology, it will be greatly affected when absorbing electromagnetic waves or hindering the transmission of electromagnetic waves. When the cow approaches the concentrate feeding trough, the cow identity automatic recognizer recognizes the identity of the cow and sends the information to the computer management system. After the computer processes the information, it sends a control command to the automatic feeder according to the preset value, and the automatic feeder accurately feeds according to the command. When feeding, the SCM control system controls the dual-mode traveling mechanism to move forward. When the RFID card reader of the feeder identifies the tag installed on the cow's ear, the SCM control system receives the cow tag number sent by the card reader and controls the feeder to stop traveling. Figure 8 shows the automatic feeding system of dairy farm.

Fig. 8 - Fully automatic feeding system for dairy farms

The whole communication process is in the form of polling, and the slave machine can send out a reply signal only when the PC accesses it. The slave is always waiting for the serial interrupt, and as soon as it receives the data, it immediately enters the serial interrupt to process the data. Establish a multi-mode cooperative working environment by using the existing technology. Collaborative work support platform with integrated multimedia mode. The operation flow of cooperative design is shown in Figure 9.

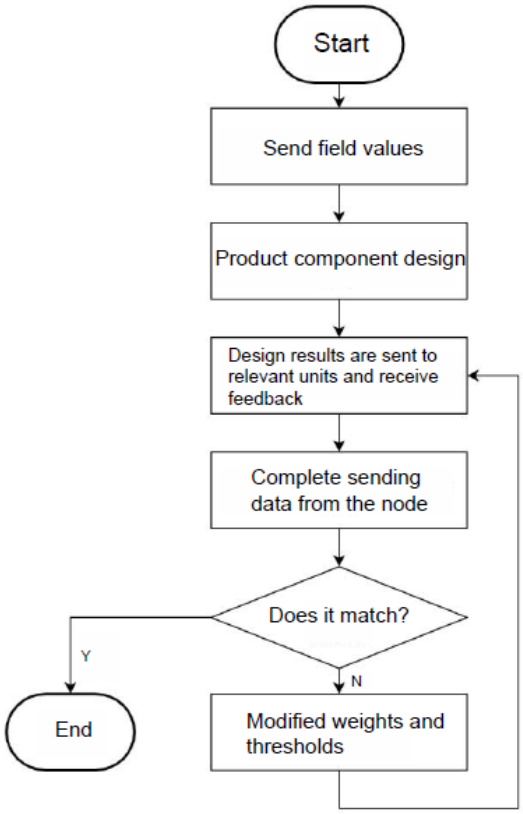
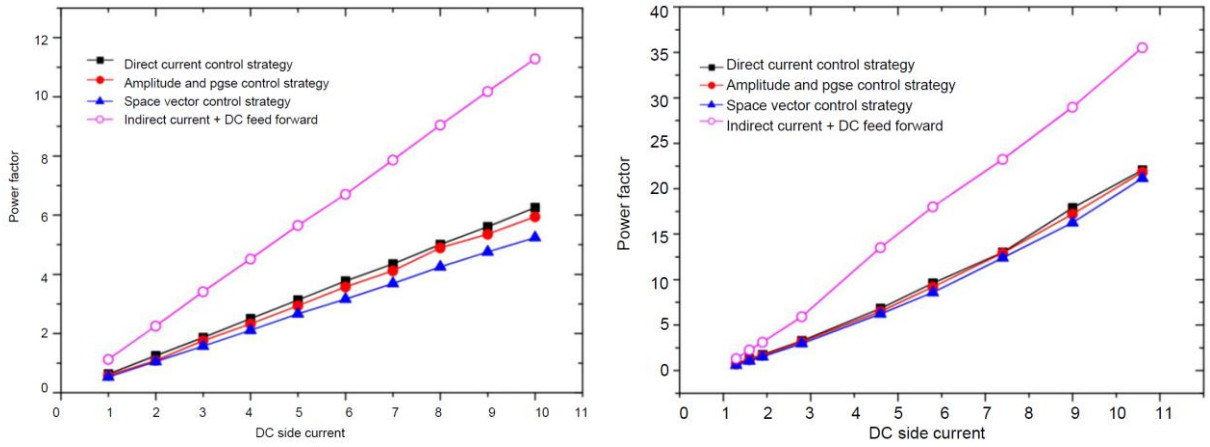


Fig. 9 - The operation process of mechanical processing cooperative design

According to the operational capability of power factor, each control strategy is different. Under the condition of constant resistance load resistance, the simulation results of each control strategy are shown in Figure 10(a). The simulation result curve under the condition of constant power load resistance is shown in Figure 10(b).



(a) constant resistance load resistance (b) constant power load resistance

Fig. 10 - The power factor operation capability of each control strategy

When transmitting data, the ports of each MCU are inquired by the PC, and all the lower computers are always in the monitoring state, waiting for the upper PC to send instructions. The single chip microcomputer control system analyses the identified tag number to determine whether to feed.

If the received tag number is a valid tag number, the single chip microcomputer control system controls the accurate feeding device to feed the cow through the stepping motor.

In practical work, we should consider as much as possible to ensure the accessibility of reading and writing equipment and electronic tags, adjust the reader-writer distance, reader-writer power parameters and reduce the influence of working environment on the normal work of RFID module. The basic function of the system is to automatically identify the cow's identity, and automatically feed each cow with concentrated feed several times according to the set value. In addition, it can also realize the functions of milk cow yield monitoring, milk cow weight monitoring, milk cow activity monitoring, oestrus monitoring, output of various reports, analysis of milk cow conditions, etc., or expand other functions as required. When the upper PC sends instructions, all the lower PCs can receive and compare their addresses with the received address frames. If the two addresses are the same, the instructions or data will continue to be received, and if they are different, they will be ignored. After receiving the reply from the lower computer, the upper computer starts to prepare for receiving data, otherwise, it interrupts the line and continues to query the port of the next single-chip microcomputer until the end of receiving.

CONCLUSIONS

Self-propelled precise feeding technology for dairy cows is an advanced feeding technology for feeding dairy cows according to individual physiological information of dairy cows, and the corresponding feeding equipment has the characteristics of simple operation and high automation. The system uses PC as the feeding management platform to run the information management software. The information management software collects the physiological characteristic data of cows by calling the cow farm database, analyses and calculates these data, and finally sends the effective data to the MCU control system through the wireless transmission device. When transmitting data, the ports of each MCU are inquired by the PC, and all the lower computers are always in the monitoring state, waiting for the upper PC to send instructions. When working, all kinds of electrical equipment will radiate electromagnetic waves with different frequencies, and the RFID module will be interfered by electromagnetic waves, thus affecting the normal reading and writing recognition rate. On the basis of large-scale data analysis, we can obtain more general rules of dairy cows' feeding behaviour, and even refine the feeding behaviour characteristics of different lactation stages. With the continuous development of agricultural refinement, dairy cattle precision feeding technology will continue to promote the application in modern dairy farming.

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