THE TEMPERATURE FUZZY CONTROL SYSTEM OF BARLEY MALT DRYING BASED ON MICROCONTROLLER

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Abstract: The control strategy of temperature and humidity in the beer barley malt drying chamber based on fuzzy logic control was implemented. Expounded in this paper was the selection of parameters for the structure of the regulatory device, as well as the essential design from control rules based on the existing experience. A temperature fuzzy controller was thus constructed using relevant fuzzy logic, and humidity control was achieved by relay, ensured the situation of the humidity to control the temperature. The temperature's fuzzy control and the humidity real-time control were all processed by single chip microcomputer with assembly program. The experimental results showed that the temperature control performance of this fuzzy regulatory system, especially in the ways of working stability and responding speed and so on, was better than normal used PID control. The cost of real-time system was in quite competitive position. It was demonstrated that the system have a promising prospect of extensive application.

Keywords: fuzzy control, single chip microcomputer, barley malt drying, temperature control system.

1. INTRODUCTION

With the higher up of living standard of China, beer consumption is increasing greatly in recently ten years. Nowadays the main barley suppliers are European, North American, Australia. In the world, the total yield of barley was about 152.39 million tons in 2004 (Ju Fang, et al.2007), and planting areas were 61.6 million hm^2 in 1990s (Gu Zifen, el al. 2001). The Asian barley malt is about 21% of the global production, and the production of Northwestern areas is more than 1/3 of China (Gu Zifen, el al. 2001). Because of good irrigation farming condition and longer sunlight period, more and more farmers began to plant barley, the original materials of beer brewing, especially with the field planting plan changed for agricultural economic effects in Hexi Corridor of Gansu (Chen Bin. 2006). As the most population country of the world and half of barley import from aboard, therefore it is necessary for China's local barley malt enterprises to consider how to develop a kind of suitable high technology process in barley malt drying and also is urgent to control their product quality (Industry standard of P. R. of China-beer barley malt, 2003; Industry standard of P. R. of China-beer barley malt, 2003). At present most drying control measurement system used PID or relay circuits even few by hands, with the development of advanced control and microcomputer technology, several control systems were developed and got application in staple grain drying (Marchant J A. 1985; Courtois F., el al. 1995). This article will present the drying control experimental system based on fuzzy logical control strategy in the temperature and humidity control process of the columned barley malt drying chamber. It is beneficial for intelligentization and automatization of agricultural equipment.

2. MATERIALS AND METHODS

2.1 Devices of drying control system

Based on the further processing demand situation of Gansu agricultural products, and cooperated with Lanzhou Zhongchuan Barley Malt Corporation Limited, our research group selected the columned barley malt drying chamber as the temperature and humidity control implemental equipment of the national project of spark plan No.2006EA860002, supported by the Ministry of Science and Technology of the People's Republic of China. With the availability and reliability of the MCS-51 serial microcontroller and its abundant developmental compiler, the experimental

apparatus is constructed and shown in Fig. 1. It is composed of blower1, adjuster 2, speeder of VVVF, that is variable voltage and variable frequency inverter 3, electric motor 4, single chip microcontroller and its control circuits 5, temperature sensors 6, humidity transmitter 7, drying chamber 8, solid state relay 9, exhaust fan 10 (Liu Xueqiang, el al.2002) .

The figure 2 shows the all data acquisition and control system of drying experimental system. It is made up of AT89C51 microcontroller, temperature transmitters, humidity transmitters, amplifying and conditioning circuits, A/D converter, D/A converter, and power executive circuit.

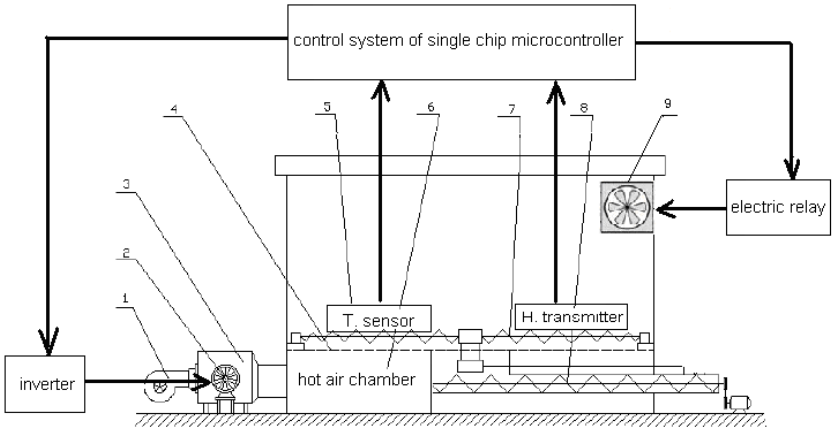

Figure 1. Schematic diagram of drying experimental apparatus

Where ADC0809 from National Instruments was selected as A/D converter, its function includes a 8 channels of analog input and 8 lines of digital output, and it is convenient to interface with microcontroller. You can program each channel with a different address control to maximize 8-bit analog-to-digit converter (ADC) resolution and measure the input signal. In this article, we selected the reference voltage to 5V, so the input range is from 0 to 5 voltage, and the measured precision is 19.53 mV. Channel 0~5 are configured to acquire the temperature and humidity and digital output is configured to interface with the microcontroller.

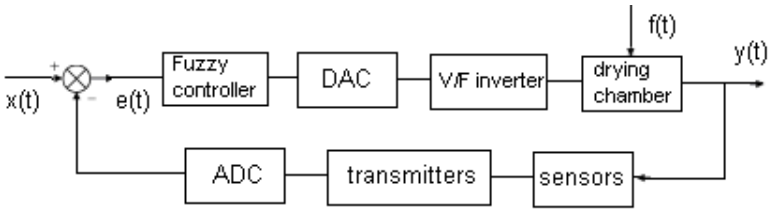

Figure 2. Flowchart of control system

AD590 two-terminal integrated circuit temperature transducers are used to measure heated medium, waste steam and surrounding, which produce an output current proportional to absolute temperature. For supply voltages between 4 V and 30 V the device acts as a high impedance, constant current regulator passing 1 μA/K. Laser trimming of the chip's thin-film resistors is used to calibrate the device to 298.2 μA output at 298.2K (25°C).

Chamber humidity is acquired by HS1101 relative humidity transmitters, its configuration features are suitable for linear voltage or frequency output circuitry separately, and measurement range is from 0 to 99%, while the typical frequency output is 7351-6033 Hz and voltage up to 3.55 V. V/F inverter is used for blower motor speeder controlling hot steam velocity of drying.

2.2 Drying control method and fuzzy controller design

During the drying experiment, we must keep the drying temperature invariably to meet the process demand of experiment（Liu Ying, el al., 2004）. The precise model of nonlinear and time-varying control object is difficult to establish, so the fuzzy control algorithm is applied in this paper in order to implement the precise control goal (Li Guofang, el al., 2007; Li Changyou, Ban Hua.,2008). The controlled temperature fluctuation-residuum between initiation and measured value, residuum changing rate and output control parameter must be processed in fuzzy logical language, its discretized classifications of universe range are set in 13 quantization steps and fuzzy sets are 7. With the benefit of the MCS-51 serial microcontroller, the basic fuzzy system is constructed to realize the fuzzy logic control. The key points of fuzzy controller are how to decide the favorite input and output fuzzy membership functions. In this paper, with the consideration of the system stability, the continuous Gauss Function is selected for input membership function. Fuzzy logical consequence is deduced by Mamdani comprehensive implication rules. Weighted arithmetic mean method of fuzzy decision is used to get precise output control value (Li Shiyong., 1998).

So drying fuzzy logic control was applied to control the motor speed in this paper. The single-chip microcontroller calculates and sorts the output control value using fuzzy algorithm program according to the input signal values which are acquired by transducers and amplifying and conditioning circuits. The amplitude of inverter output can be controlled by the on-time digit-to-analog converter during controlling periods, which proportionally decides the output frequency of V/F inverter and the voltage supplied to motor.

2.3 Drying control system program

Assembly language is one of programming language that instruction of memory help symbol and operation data determines how to create application. In contrast to the advance programming languages, its storage spaces of responding machine codes are quite saving and its program execution is especial accurate（Zhang Yigang, el al.,1998）.

A barley malt drying experimental system based on assembly language was developed in this paper. Under the MCS-51 programming surrounding, the system control module and flowchart of drying experimental system is shown in figure 3. When the last step that is key process and parameter display is fulfilled, the program will return to the second step. In this way, a recycle testing and control program is realized and executed (Ding Yuanjie, el al., 2002).

The system is made up of system auto-diagnosis and initiation values given module, temperature and humidity A/D acquisition module, input signal data storage and processing module, keyboard process and temperature as well as humidity display module, fuzzy algorithm module, D/A output control module, error and annunciator module (He Limin, el al., 2007). Every module is programmed as a subprogram. Temperature and humidity A/D acquisition module acquires the experimental temperature and humidity through one of the analog input channels in ADC 0809 chip and

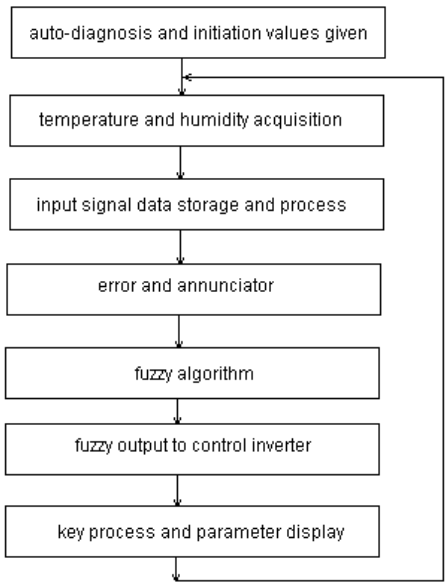

Figure 3. System control module and flowchart of drying experimental system

gives the measured results to other module for storage, diagnosis, control and display. Input signal data storage and processing module filters and stores data onto given register units of internal RAM of microcontroller for further fuzzy control and display. Keyboard process and temperature as well as humidity display module acquires key operation command or signal in interrupt way and displays surrounding sampled parameters according to the relation between the moisture and change of barley moisture removal rate. Figure 4 is the block diagram of this fuzzy algorithm module applies the fuzzy algorithm to deduce the output control value which is sorted by the table of control set strategy. D/A output control module outputs the analog voltage converted by ADC0832 to control the motor inverter to meet the need of the barley malt drying experiment. Error and annunciator module calculates the experimental measured error and gives an alarm if measured value surpasses the given temperature.

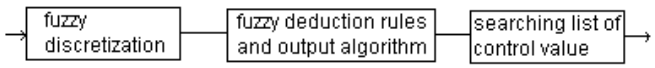

Figure 4. Block diagram of this fuzzy algorithm module

3. FUZZY CONTROL SYSTEM APPLICATION OF SIMULATION

This experimental system was configured and applied to make experimental study of barley malt drying process. The interval is 10 minutes for measuring mass change in the experiment. The simulation application shows that the operation of this experimental system is convenient and reduces the upper workload of drying measurement and shortens the period of drying process (Liu Jinkun., 2004). The procedure is comparatively precise and the precision of temperature control is ±0.5℃ which meets the requirement of the barley malt drying process. During the experiment of the experimental process simulation, the control results meet the experimental drying process while the parameters of control are modified. This system is applied to the experimental drying process and acquires data in the study of the barley malt drying control system design, which will be used in the plant in the near future.

4. CONCLUSIONS

In this paper, using MCS-51 assembly language, fuzzy logical control algorithm and weighted arithmetic mean output control method, a unique experimental control system is developed for drying process and regulation studies. This fuzzy experimental system has been put into use and provides reliable and precise. The simulation results showed that the fuzzy control drying system has a better control precision of temperature and humidity and quick discriminating quality with powerful data processing and analyzing functions. The specific conclusions are as follows.

1. Under the general and flexible MCS-51 programming situation, fuzzy logical control and data acquisition software can be developed conveniently.
2. Using fuzzy logical control algorithm and weighted arithmetic mean output control method, this system is precise and reliable in automatic data acquisition and experimental processing control.
3. Compared with the traditional drying system, this fuzzy experimental drying system, which is a key unit of drying process, is simple in construction. The structure and functions can be expanded easily.
4. Automatic fuzzy control system will enhance the labor productivity, and its performance directly affects the product quality and benefits of the whole barley malt processing plant.

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