Design of Fuzzy Control System of the Fast Drying Equipment for Chinese Herbs

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Abstract

Microwave vacuum drying technology has obvious advantages for drying Chinese herbs with relatively lower cost of the equipment and operation. The dryer studied in this paper is based on this technology, and its control system is one of the most important parts that influence greatly the function of the dryer. This paper introduces a fast drying control system for Chinese herbs. Fuzzy control technique is applied in designing the controller. A 8051 single-chip processor is utilized for the hardware system. The temperature sensor model is NJL9103. And the software system is designed with the character of modularized structure and separate functions. Finally, an example is given to explain the advantages of fuzzy control.

Keyword: Chinese herbs fast-drying, fuzzy control, single-chip processor.

I. Introduction

Traditional Chinese herbal medicine has following specialties: (1) four properties of a medicine: cold, hot, mild and cool; (2) five flavors of a medicine: spicy, sweet, sour, bitter and salty. Because of lacking systematic drying technology and scientific manufacture control, those special characters couldn't be well protected during the drying process of the raw material. And this will result in some problems like destroying the structure of the medicine, changing the medicine's functionality, losing the medicine's components or lowering the material's quality. As to the problems exist in the Chinese herbal medicine drying procedure; it is highly required to increase the drying quality, to reduce the energy consuming and to increase the operation validity. So to improve products' quality, to use energy efficiently, to reduce the bad influence to the environment and to use computer to control the operation system become the trend of the development of the drying equipment of Chinese herbal medicine.

Microwave vacuum drying technology uses microwave to work with medium and uses microwave to replace heating source. Medium absorbs the energy from microwave then converts it into thermal energy within itself, which means that the medium itself is the heater. Without thermal conduction and convection procedures, the drying speed of the raw material is greatly improved. On the other hand, in the condition of vacuum, the drying process can be done under relatively low temperature, which can avoid the damage to the raw material due to high temperature; this can help to keep the original quality of the raw material. Microwave drying technology can also sterilize, so it can avoid

using preservative, and the raw material's possibility to be polluted can be reduced. Therefore microwave vacuum drying technology has obvious advantages for the drying of raw materials such as food, medicine and biology's production with relatively lower cost of the equipment and operation. The dryer studied in this paper is based on Microwave vacuum drying technology. And its control system is one of the most important parts that influence greatly the function of the dryer.

Dryers are generally far from being perfect as for their functions and control systems. Now some dryers in the market are even based on mechanical temperature control systems. These systems are usually lack of reliability, and they only have the function of simple measurement and control systems, have the low degree of intelligence and the high loss of power. Therefore it is difficult for them to assure the herbs of a high quality after drying.

Intellectual control is the trend of the development of modern auto-control technology. There are three control methods which are artificial intelligence, fuzzy control and neural network. And fuzzy control is the most practical one. With its nonlinear characters in essence the fuzzy control performs well in all kinds of control systems. A relatively ideal effect can be gained in the complicated control system by applying the technology of fuzzy control. It can adjust those different control targets of controlled objects to the best state. The advantage of fuzzy control is that it doesn't need to know the mathematical model of controlled object. It organizes the control decision table according the artificial control rules. Then the value of control input is based on this table. So the fuzzy control has good flexibility and adaptability.

It is a nonlinear system when the fast dryer is working and it is difficult to build up an accurate mathematic model for it. But the fuzzy rules can be used to represent such a complex object. The fuzzy control system of the fast dryer for herbs designed in this paper utilizes a single-chip processor with low cost and high capability, adopts the technology of software control, and uses the fuzzy control technology according to intellectual control theory. All these features help to improve its intelligence greatly during drying process.

II. Fuzzy control algorithm[1] [2]

This system is a two-dimension fuzzy controller. In this controller, the inputs include the temperature error E and the change of error EC; the output is the controlled quantity U. The temperature error is the difference between preset temperature and inner temperature. The process of fuzzy control algorithm includes three parts: Fuzzification, Fuzzy inference and Defuzzification. They are introduced as follow.

A. Fuzzification part

The main function of this part is to transform the signal detected into a fuzzy value. First, the basic domain must be transformed into domain. Suppose that the basic domain of error is $[-x_e, x_e]$, the basic domain of the change of error is $[-x_c, x_c]$, the domain of error is [-n, n], the domain of the change rate error is [-m, m], the quantization factor of error is:

$$Ke=n/xe\ . \tag{1}$$

And the quantization factor of the change of error is:

$$K_{ec}=m/x_e\ . \tag{2}$$

The parameters K_e and K_{ec} can affect the performances of the controller greatly in practice. The increase of K_e results in the improvement of the system's responding speed and the increase of overshoot. The increase of K_{ec} leads to the decrease of overshoot while it prolongs the transition time.

B. Fuzzy inference part

After the domains of the fuzzy variables E, EC and U are ascertained, the definition of the membership function related to language variable should be done. This paper uses a triangular membership function to conduct the fuzzification. And the fuzzy control rules taken by this system

are listed in Table1. In this table the error E is divided into N, O, PS, PM and PB; the change of error EC is divided into NB, NM, NS, OPS, PM and PB; the controlled output quantity U is divided into O, PS, PM and PB.

Table1. the fuzzy control rules taken by this system

E, U, EC	PB	PM	PS	O	NS	NM	NB
PB	PB					PM	PS
PM	PB				PM	PS	0
PS	PB			PM	PS	O	
O	PB	PM	PS	O			
N	O						

The technology of fuzzy control merges human's experiences in the practical controller, so it is flexible comparatively. However the control rules are subjective to some extent, because they are usually dependent on personal experiences, experiences of experts or statistic results from experiment.

C. Defuzzification part

The output of the fuzzy controller is a fuzzy subset. Only after it has been defuzzificated and converted to an accurate quantity, can it be used to control its object. There are three common defuzzification methods: (1) maximum membership degree method (2) weighted average method (3) median method. Among them the first method is simplest while it can't tap the information of fuzzy subset effectively; the other two methods need great amount of calculations while it can achieve a high precision. Since this system is based on a single-chip processor and it doesn't fit for large computation, the first method is chosen. Before it is output the controlled quantity must be transformed from its fuzzy value to practical value in physical domain, namely transition from domain to basic domain.

3 Hardware structure and software designing of control system[3]

The fuzzy controller is realized through digital computer, and its hardware system core is MCU series single-chip 8051. The single-chip is composed of CPU, data memory RAM, program memory EPROM, input/output interface I/O, timer/counter, break system etc. The temperature sensor model is NJL9103, which gets better temperature compensation effect through integrating TD and diode of temperature compensation. The part of display adopts number LED. The conversion of sampling data is realized by I/F converter, and its advantage is to simplify the way of signal input and signal processing. As a result, it simplifies the design of hardware and software. Therefore it is characterized by less circuit links, good ability of resisting interferences. Fig.1 shows the hardware structure of control system.

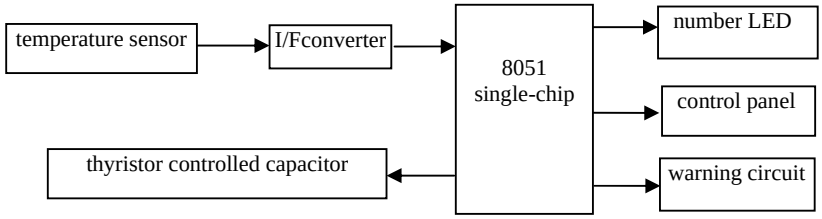

Fig.1. the hardware structure of control system

The working principle of control system is: first the temperature sensor obtains the real temperature of Chinese herbs timely; then it outputs the current in proportion with the real temperature; the current is converted to relevant impulse signal by I/F converter. Afterwards the signal is input to the timer T1 to obtain the value of frequency. Lastly, the value of temperature can be obtained by using the software. In this control system, the temperature output is controlled through the way of combining switch control and fuzzy control. Given E as temperature error, Tr is real value, Tk is preset temperature. There are two conditions:

if Tk-Tr>E, then the drying process goes on with the present power.

if 0<Tk-Tr<E, then the controller starts to control with fuzzy logic. In this process, the system adjusts the error with fuzzy technique, outputs a proper control quantity U, and then changes the power of microwave reactor. The control quantity U controls the angle of thyristor controlled capacitor.

The software system is programmed via MCS51 assembly language. And the control program frames are shown in Fig.2 and Fig.3. The software system is composed of head program and break child program. The task of head program is to perform the setting of the single-chip system parameters and application system parameters. The task of break child program is to perform data sampling, data disposal and data output.

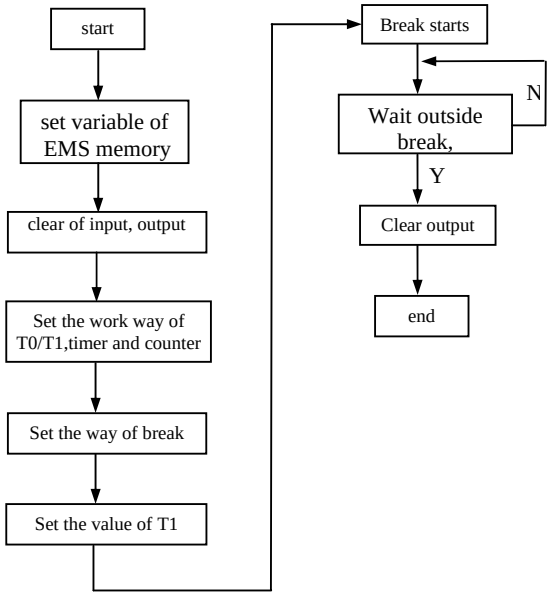

Fig.2 the frame of head program

4 System function

The control circuit of fast dryer in this paper is equipped with MCU single-chip and I/O interface. The single-chip is integrated highly, and the I/O interface samples the input data such as the power, temperature, etc. With the two input data, the error of temperature and variance ratio of temperature error, the fuzzy control adjusts the output power of microwave instrument automatically. Thus the excessive rising of temperature is avoided. Through this function, the system can control the precision of temperature. The primary function includes: temperature initialization and warning system.

Temperature initialization: the system's preset temperature can be continuously adjusted. As for the presetting of temperature, the best drying temperature of Chinese herbs is generally set as the preset temperature. Then the preset temperature is input into the fuzzy controller together with the real temperature of Chinese herbs which is measured by temperature sensor. After the inputs are finished, the fuzzy control starts, and the controlled quantity U is output.

Warning system: when the real temperature is higher than the preset temperature, the control system will cut off automatically the power of microwave instrument. At the same time, the Number LED shows the warning signal "HI".

[1] Example about fuzzy controller and simulation

Now, the transfer function of controlled subject is considered as $1/(S^2+5S+1)$. And the output data is obtained through fuzzy control. In MATLAB, the fuzzy controller adopts Mamdani model. In the MATLAB window, the command "FUZZY" is input and the fuzzy logic toolbox is entered, then the membership function of input and output parameters are figured out. These are represented in

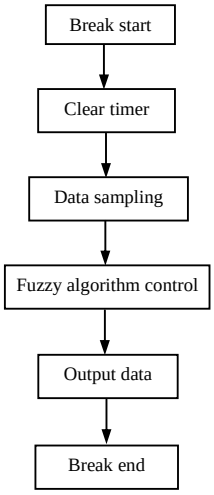

Fig.3. the frame of break program

Fig.4. In this example, all membership functions of the three parameters adopt triangular membership function[4]. Fig.5 shows the surface viewer of the fuzzy control rule. And Fig.6 shows the fuzzy control system structure frame. The result of simulation is shown in Fig.7.

From the simulation result, when the system comes to about 3 second, it inclines to the condition of stabilization.

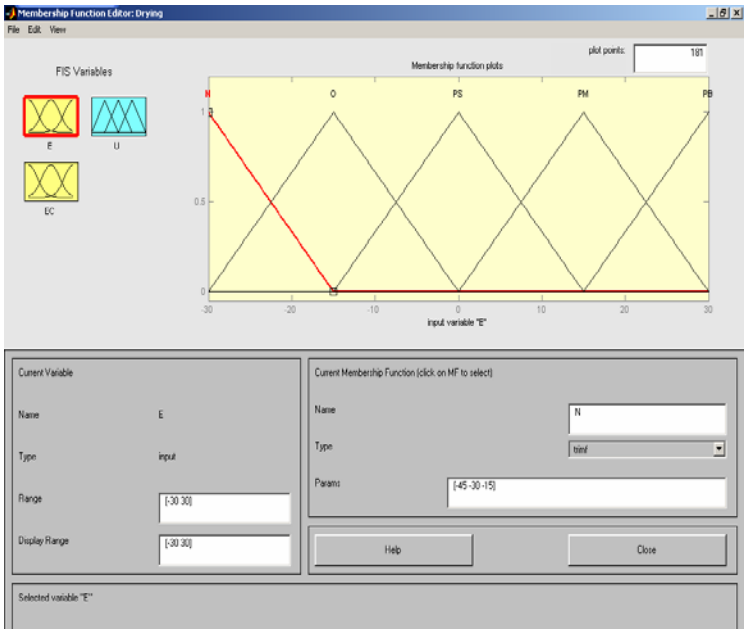

Fig.4. membership function editor

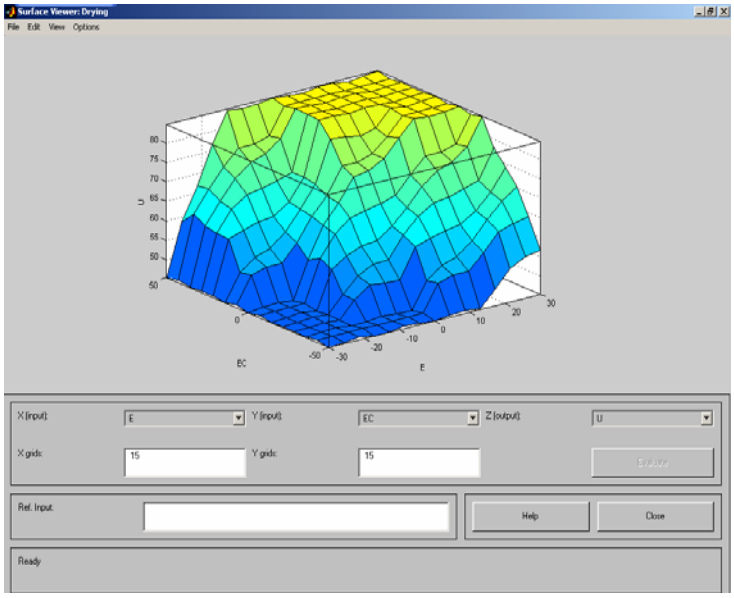

Fig.5. surface viewer

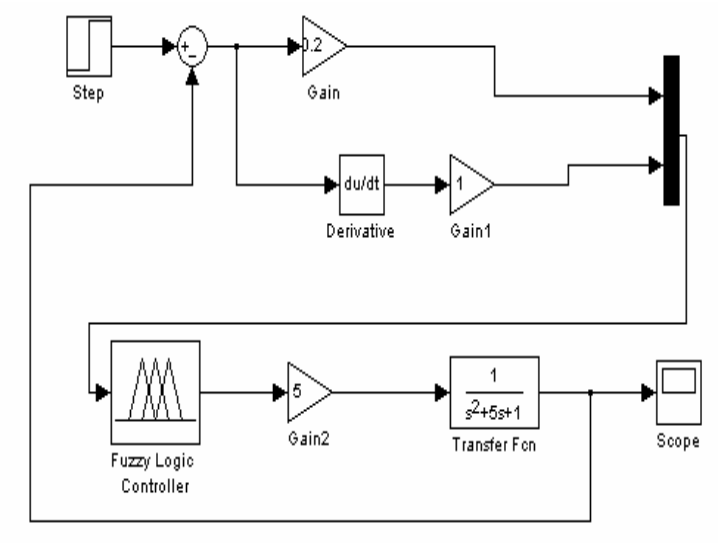

Fig.6. fuzzy control system structure frame

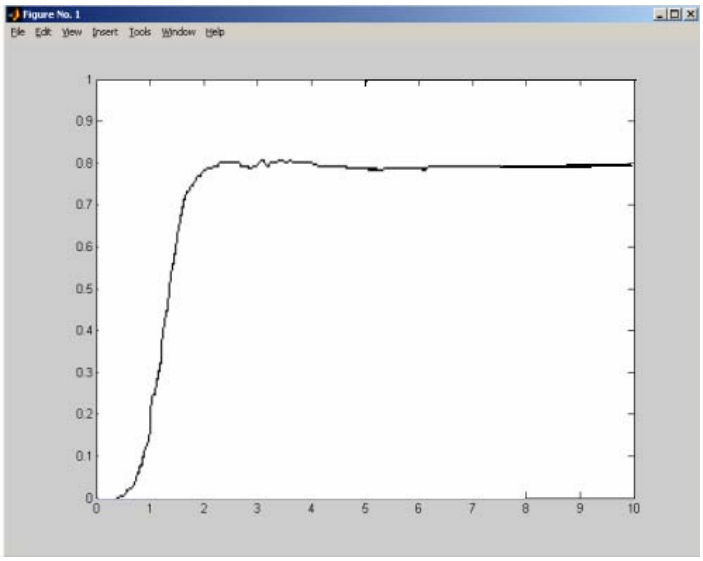

Fig.7. simulation result

III. Conclusion

This article introduces a fast drying control system for Chinese herbs based on the technology of fuzzy control. With the application of fuzzy control technology, the drying system possesses some advantages such as the intellectualized level and the small power. Furthermore, the hardware of system adopts single-chip controlling which achieves a cheap price. To the some extent, it has the possibility of extensive application.

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