A Soft Linen Emulsion Rate Intelligent Control System Based on the Domain Interpolation Algorithm with Self Adjusting

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***Abstract*—A soft linen emulsion rate intelligent control system based on the domain interpolation algorithm with self adjusting is introduced. In the hemp textile industry, soft linen deal processes can directly affect its following process. We take the lead to use the fuzzy control method applied in soft linen emulsion rate of Intelligent Control System. In the research process, the improvement of product quality is not satisfied by basic fuzzy control method. By improving the algorithm, combined advanced interpolation algorithm into fuzzy decision process, that experience rule set has no restriction to access control list, enhanced the flexibility of the method, and obtain fine enough fuzzy control table under the same rules. But as the fuzzy grade classification of fuzzy control input data base on interpolation algorithm can be directly affect the number of control rules, and make more control rules, to affect the realization of deduce speed and storage process, which can not adapt the continence changing ability of soft linen emulsion. We innovate during practice, to combine domain interpolation self adjusting method with fuzzy controller based on intelligent algorithm, to adjust the size of actual measurement and reduce fuzzy control rules, to design a fuzzy controller by domain interpolation algorithm with self adjusting and achieved. After running, the system shows that: 27% Qualified in manual; 48% Qualified by the basic fuzzy control system. 62% Qualified by interpolation algorithm fuzzy control system; 78% Qualified by domain interpolation algorithm with self adjusting fuzzy control system. It proved that, the application of fuzzy control system based on domain interpolation algorithm with self adjusting, can improve control precise which improved production quality.**

***Index Terms*—emulsion rate control, fuzzy control, interpolation algorithm, domain interpolation algorithm with self adjusting**

I. INTRODUCTION

In hemp production, as hemp fibers mixed with dust, dander, linen bone and other impurities, and become hard and brittle during dry state, it must soft first through soft linen machine, remove impurities, and add the appropriate amount of emulsion (also known as oil and water). This preparation process before carding yellow linen and ramie is called as soft linen, including mechanical soft linen, fuel, wet and storage. The purpose is to enable fiber loose, soft, surface lubrication, remove some impurities and then fermented by the heap storage to improve the fiber spin ability, then carding and spinning can be carried out. This process quality has the direct impact on the following process, such as the quality of spinning and weaving.

The references show that the world, especially Southeast Asia, in hemp textile the soft linen processes are used the same fall behind technology model, that is injected emulsion into dry linen, the flow control process operation is completed by hand. During soft linen processes, as the uneven control of emulsion volume, the emulsion rate is difficult to meet the standard, so it has direct impact on product quality and quantity. In addition, it will result the waste of raw materials. To change this backward situation, we take the lead in the fuzzy control method applied to intelligent control system of soft linen emulsion rate[1].

Since L.A.Zaden proposedthe fuzzy set, based on the theory, a new science of fuzzy systems theory has formed, it has been widely used in control, signal processing, pattern recognition, communications and other fields.

General, the core problem of fuzzy control theory is how to improve Fuzzy Control about the stability and robustness analysis , system design methods (including rules access and optimization, and selection of membership functions), control system performance (steady-state accuracy, jitter and saturation points, etc.), it has become the basic problems in the Study of fuzzy controller. Among them, the stability and robustness problem researhes are the most enthusiastic, from the earlydescribing function analysis based on "multi-level relay"equivalent model of fuzzy controller, extended to the phase plane method, relationship matrix analysis method, circle criterion , L yapunov stability theory, super-stability theory, comparative law based on sliding mode controller, fuzzy point - point mapping and numerical stability analysis and other nonlinear theory methods. Design studies have drawn greater attention,

doi:10.4304/jsw.6.8.1429-1436

mainly in the rules of online learning and optimization, optimization amendments of membership function parameters and others applicated with variety ideas,such as optimal control quadratic performance index, adaptive, neural network, genetic algorithms and other ideas.The improvement of steady performance has been always a concern to fuzzy control scholars .

Surrounding several fundamental issues above,emerges multi-variable fuzzy control [2], fuzzy neural network [3], neuro-fuzzy techniques [4], adaptive fuzzy control[5], fuzzy system identification [6] and other hot spots study fields. In the fuzzy control theory and applications, Japanese scholars have made great achievements[7], our scholars in this area have paid tireless efforts and achieved many important results. All these efforts contributed to the theory and application of fuzzy control rapid development.

From the mid 60s 20th century, fuzzy control gradually developed into an attractive and fruitful research field, fuzzy control process is mainly to deal with the difficulties caused by those itself due to uncertainty, accuracy, and noise, particularly in dealing with complex systems (such as large time delay, time-varying, nonlinear system) shows its superiority and advanced. We will introduce advanced fuzzy control methods to soft linen emulsion rate control system. In research and implementation process, in order to overcome un-ideal situation of the basic fuzzy controller, we improved the control algorithm, using the fuzzy controller based on interpolation, can be get fine enough fuzzy control table. However, during the operation, the fuzzy controller based on interpolation does not have the ability to adapt to the continuous changing of soft linen emulsion process; the input volume fuzzy level divisions directly affect the control rules number. To ensure the performance of soft linen emulsion rate control system, the fuzzy classification need very small, which bring more control rules to affect of the realization of deduce speed and storage process[8].

The domain controller with self-adjusting, which developed in recent years, can reduce the number of fuzzy control rules. Therefore, we innovate in practice, combine the interpolation fuzzy control method with domain fuzzy control method with self-adjusting, based on the fuzzy controller based on interpolation designed a fuzzy controller based on domain interpolation algorithm, to adjust the actual measuring size, reduce the number of fuzzy control rules, so simplifying the design process and successful applied in the soft linen emulsion rate control system while fuzzy controller can not affect the control characteristics[9].

II. SOFT LINEN PROCESS AND SYSTEM COMPONENTS

Soft linen Process sequence is completed in a soft linen hydraulic machine, including the combination of soft linen roller, hydraulic control system and transmission system. The motor drive of hydraulic control system through transmission system connected the upper and lower rollers of soft linen roller combination, by reversing the hydraulic motor system so that the upper and lower soft linen rollers rotate synchronous, to soft jute or ramie, there is a vent above it, at the same time drop the rolling emulsion on soft jute or ramie, to measure the soft linen by the quasi-emulsion ratio (positive). It shows in Figure 1.

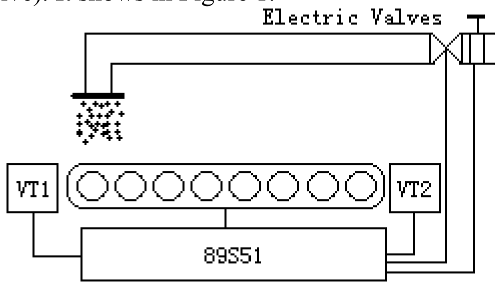

Figure 1. System operation diagram

Figure 1 shows that the system is mainly composed of soft linen machine detection, solenoid valves, flow meters, load sensor installed in the soft linen Machine and microcontroller 89S51. There are four signal in control process: First, the output signal from the weight load sensor which is below the transmission belt at the forward and backward port of soft linen machine: VX1 and VX2, it is direct proportional to dry linen weight and oil linen weight; second is input emulsion volume by flow meter; third is the valve control signal output from the controller, fourth is soft linen machine detection signal. The parameters of given emulsion rate input by keyboard. Thus, the given instantaneous flow (1) and time T, the cumulative flow (2) are get from calculation.

III. SYSTEM HARDWARE CONFIGURATION

The Hardware configuration of the emulsion rate automatic control system which core is microcontroller 89S51 shown in Figure 2, including:

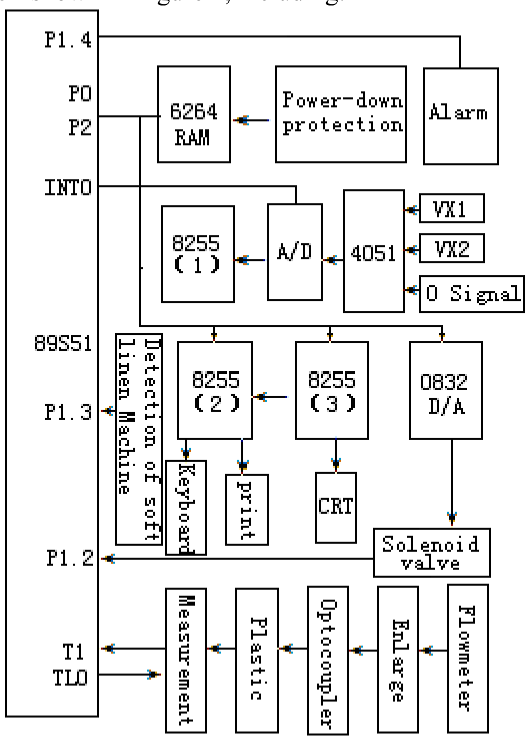

Figure 2. Hardware configuration diagram

A. Control section

Control section part is the core of the whole control system. Its task is to complete data processing, computing, storage, control, display and print. The EEPROM of Microcontroller 89S51 is a program memory and storage of self-edit Chinese character library information of the control system. A static RAM6264 is for data storage. Extended I / O interface circuits 8255 (1) PA port control 14433 is used to capture analog voltage signal of the load sensor; the lower three of PC port is the 4051 control port. The PA port of 8255 (2) put the keyboard, and the PA, PB, PC of 8255 (3) put CRT linked to 8031, to form a human computer channel. PP40 printer connected with PB port, PC port of 8255 (2) and print out the results as required.

B. Input channels

output from Weight Sensor Vx1 (Vx2), the voltage signal through 4051 eight-way select signals sent to the strobe A, D converter 14433, microcontroller 89S51 through the PA port of 8255 to read the results. IN7 ground is zero potential correction, which is to make the PC0 ~ PC2 of 8255 output high voltage, allowing INT7 input, but IN7 ground, that is, helium mode switch put the input port into analog in short circuit, the result as "0" signal, then the PC4 ~ PC5 strobe IN0 (IN4), then the load sensor output signal, by 14433 to A / D conversion, in this A / D conversion, reduce the value of"0" signal as the sample data of the analog signal, so the device can eliminate the errors caused by drift. Meanwhile, the load sensor power and reference voltage power supply of 14433, generated by the same standard power1403, to eliminate the impact on accuracy from power drift.

C. Input circuit of flow

When the emulsion flows through flow meter, the impeller by means of the kinetic energy of liquid to produce rotation, the impeller is the magnetic reluctance values in magnetic sensor system changed periodically, so the magnetic flux of the coil changes to product about 1V pulse signal. This signal is sent via optical coupling circuit to operational amplifier LM324 and converted to 5V signal voltage. CD4013 compose a pulse measurement circuit. When the pulse comes, the Q-side of CD4013 (1) make T1 interrupt and start counting, and continue to test P1. 0, when the P1.0 detected the Q terminal of CD4013 (2) is high, a pulse period detection is end, which achieve flow rate input.

D. current control output circuit

Solenoid valve is a simple and feasible and very reliable instillation implementing agencies, the establishment between solenoid valve conduction ratio and mathematical model of the flow is very difficult, because it is a nonlinear time-varying system. Therefore, we control the P1.2 of microcontroller 89S51 to make the solenoid valve opening time constant, and by using the fuzzy algorithm to control the duty cycle of valve for flow control. Control the adjust volume of flow control valve through current control, which is controlled through different output current, when the current produced by the opening of flow control valve is equal to the control current, the flow control valve stop opening. Thus achieve the flow control of emulsion output. Control current produced by eight D / A circuit 0832, can provided 0 ~ 10mA control current, the output T is, to increase the current output capacity, one grade amplified power. As the D0 ~ D7 of 0832 is three-state data lines, they directly connected to the microcontroller 89S51 bus.

E. Alarm circuit

Alarm circuit generated by the monostable 74LS123, when the system is working normal, P1.4 is low level, so the monostable output Q is high level, and no oscillation pulse, the field speaker silent. When there are unusual circumstances or the CPU is out of control, P1.4 is high level, and monostable output oscillation pulse, so the speaker sounds the alarm.

F. power-down protection circuit

To solve the problem of data loss caused by power-down, add RAM power down protection circuit.

IV. FUZZY CONTROLLER BASED ON SELF-ADJUSTING INTERPOLATION ALGORITHM

A. basic fuzzy controller

1) basic structure of fuzzy controller

Fuzzy controller principle diagram is shown in Figure 3.

In the diagram, e(n) is the actual deviation, K1 is deviation change scale factor, ec (n) is fuzzy quantity obtained through fuzzy matrix operations between deviation change scales; U(n) is output control volume obtained through fuzzy decision, K3 is output scale factor.

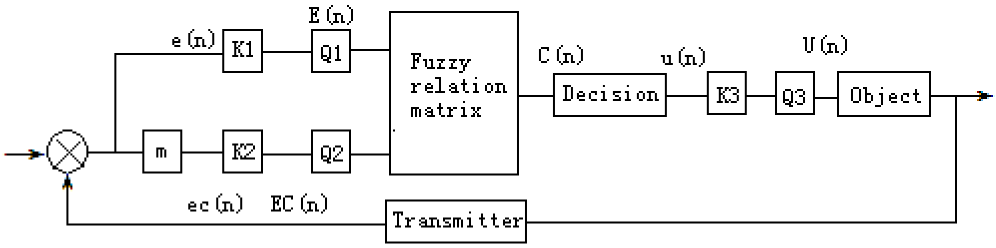

Figure 3. Fuzzy controller principle diagram

2) Control rules of fuzzy controllers

Soft linen emulsion rate intelligent control system is based on the flow changes in single-input, single output system, fuzzy controller uses two-dimensional basic form, control rules can be expressed as follows:

if E is A and Ec is Bj,

then U is Cij (i=1,2,⋯,m. j=1,2,⋯,n.) (1)

Among this, input E , E_c ,and U, which error is $e(k)$, error change rate is $\Delta e(k)$ and control capacity is $u(k)$; A_i , B_j and C_{ij} is fuzzy linguistic variables defined on the domain x as well as z . According to this rule, fuzzy relation can be drawn.

$$R = \bigcup_{I=1,J=1} R_{ij} \tag{2}$$

$$R_{ij} = A_i \times B_j \times C_{ij} \tag{3}$$

$$\mu R_{IJ}(X,Y,Z) = \mu A_i(x) \wedge \mu B_J(y) \wedge \mu C_{IJ}(z) \tag{4}$$

In the formula: μ is the membership function; $\wedge$ means operate with small value; $\times$ is Cartesian product. R_{IJ} means operate with large value. Then according to the above formula, calculate relationship matrix R_{IJ} corresponds to each control rule, then calculate all R_{IJ} to a set, and get general fuzzy relation matrix by the large operation, and form a fuzzy rules subset.

a) Determine fuzzy state of input and output variables and its corresponding fuzzy sets

Basic fuzzy controller uses 8 fuzzy state to describe the deviation E: negative large (NL), negative middle (NM), negative small (NS), negative zero (N0), is zero (P0), positive small (PS), positive middle (PM), positive large (PL), the corresponding domain E={E}={-6,-5,-4,-3,-2,-1,-0,+0,+1,+2,+3,+4,+5,+6}, then deviation E values show in table 1.

TABLE I. DEVIATION E ASSIGNMENT

	-6	-5	-4	-3	-2	-1	-0	+0	+1	+2	+3	+4	+5	+6
PLe	0	0	0	0	0	0	0	0	0	0	0.1	0.4	0.8	1.0
PMe	0	0	0	0	0	0	0	0	0	0.2	0.7	1.0	0.7	0.2
PSe	0	0	0	0	0	0	0	0.3	0.8	1.0	0.5	0.1	0	0
POe	0	0	0	0	0	0	0	1.0	0.6	0.5	0	0	0	0
NOe	0	0	0	0	0.1	0.6	1.0	0	0	0	0	0	0	0
NSe	0	0	0.1	0.5	1.0	0.8	0.3	0	0	0	0	0	0	0
NMe	0.2	0.7	1.0	0.7	0.2	0	0	0	0	0	0	0	0	0
NLe	1.0	0.8	0.4	0.1	0	0	0	0	0	0	0	0	0	0

TABLE II. DEVIATION CHANGE EC ASSIGNMENT

	-6	-5	-4	-3	-2	-1	-0	+0	+1	+2	+3	+4	+5	+6
PLec	0	0	0	0	0	0	0	0	0	0	0.1	0.4	0.8	1.0
PMec	0	0	0	0	0	0	0	0	0	0.2	0.7	1.0	0.7	0.2
PSec	0	0	0	0	0	0	0	0	0.9	1.0	0.7	0.2	0	0
Oec	0	0	0	0	0	0.5	1.0	1.0	0.5	0	0	0	0	0
NSec	0	0	0.2	0.7	1.0	0.9	0.3	0	0	0	0	0	0	0
NMec	0.2	0.7	1.0	0.7	0.2	0	0	0	0	0	0	0	0	0
NLec	1.0	0.8	0.4	0.1	0	0	0	0	0	0	0	0	0	0

TABLE III. OUTPUT C ASSIGNMENT

	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	-7
PLc	0	0	0	0	0	0	0	0	0	0	0	0.1	0.4	0.8	1.0
PMc	0	0	0	0	0	0	0	0	0	0.2	0.7	1.0	0.7	0.2	0
PSc	0	0	0	0	0	0	0	0.4	1.0	0.8	0.4	0.1	0	0	0
Oc	-	0	0	0	0	0	0.5	1.0	0.5	0	0	0	0	0	0
NSc	0	0	0	0.1	0.4	0.8	1.0	0.4	0	0	0	0	0	0	0
NMc	0	0.2	0.7	1.0	0.7	0.2	0	0	0	0	0	0	0	0	0
NLc	1.0	0.8	0.4	0.1	0	0	0	0	0	0	0	0	0	0	01

uses 7 fuzzy state to describe the deviation EC: negative large (NL), negative middle (NM), negative small (NS), zero (0), positive small (PS), positive middle (PM), positive large (PL), its corresponding domain EC={EC}={-6,-5,-4,-3,-2,-1,-,+0,+1,+2,+3,+4,+5,+6} , then deviation E values show in table 2.

Also, uses 7 fuzzy state to describe output C: negative large (NL), negative middle (NM), negative small (NS), zero (0), positive small (PS), positive middle (PM), positive large (PL), its corresponding domain C={C}={-7,-6,-5,-4,-3,-2,-1,0,+1,+2,+3,+4,+5,+6,+7}, then output C values show in table 2.

The actual change amount of e and ec, for basic fuzzy controller, we only take an integer between -6 to +6, if the continuous change amount is not an integer, it is classified to the nearest integer, such as 5.8 → 6,3.2 → 3, -1.4 → 1.

In addition, the actual changes of e and ec are not necessarily between the -6 and +6, by the following formula transform them into the interval [-6, +6].

$$y = \frac{12}{\beta - \alpha}[x - \frac{\alpha + \beta}{2}] \quad (5)$$

b) Determine fuzzy control rules

For dual-input single-output control system, generally used "if A and B then C" to describe the actual control of the controller to the strategy summarized in 17 control rules, and made as shown in control rule table 4, , This is a qualitative control rule, its the key to achieve the fuzzy algorithm.

TABLE IV. CONTROL RULE TABLE

Deviation e / Output c / Deviation Change ec	NLe	NMe	Nse	N0e	P0e	PSe	PMe	PLe
Plec	PLc	PMc	NLc	NLc	NLc	NLc	*	*
Pmec	PLc	PMc	NMc	NSSc	NSc	NSc	*	*
PSec	PLc	PMc	NSc	NSc	NSc	NSc	NMc	NLc
0ec	PLc	PMc	PSc	0c	0c	NSc	NMc	NLc
Nsec	PLc	PMc	PSc	PSc	PSc	PSc	NMc	NLc
Nmec	*	*	PSc	PMc	PMc	PMc	NMc	NLc
NLec	*	*	PLc	PLc	PLc	PLc	NMc	NLc

Get c=NM from e=PM ec=ps which get from the table, means when deviation change e is positive middle, and deviation change rate is positive small, then the control decision-making should be negative middle. In the table, "*" indicates that in the control process the situation is impossible to happen, for example $e = PL$, can not happen simultaneously, which is called "dead zone."

c) Relationship matrix and fuzzy decision-making

As multi-input single-output control system use "if A and B then C" to describe, therefore, fuzzy relationship R as R = A × B×C, then at time FC the output C as $C = [E(n) \times Ec(n)] \bullet R$.

We can see from the front, R is a 14 × 13 × 15 matrix, we must deal with such a constant matrix accounted 3.1K bytes of storage capacity. Therefore, the direct use of microcontroller in real time to solve such a matrix is impractical. Generally calculated matrix R in advance, and then according to fuzzy decision-making (using the "select a subordinate degree" rule), the calculated fuzzy amount converted into the corresponding output control value (the exact amount).

B. Fuzzy controller based on interpolation

Fuzzy decision based on fuzzy controller is carried out according to the preset table. Experiments show that the steady-state quality is not ideal, steady-state accuracy is not high. The main reason causing the above results is rough quantify sub-file calculated by error E and error change rate Ec caused adjustment dead zone of controller, the form of controller output cause the classification regulation too rough. In addition, this algorithm is essentially a discrete variable parameter PD adjustment algorithm. As there has no part of the integral control, theoretically it's impossible to eliminate steady state error.

For these reasons above, the control algorithm is improved. Under the circumstance that not to increasing the complexity of the controller, through the interpolation algorithm and output transformation, to solve the problem in essence. The improved control system shows in Figure 4.

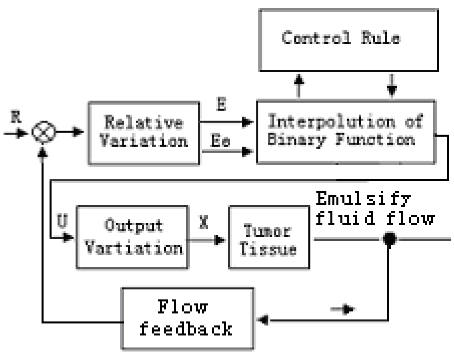

Figure 4. fuzzy controller diagram based on interpolation

the role of the relative change part is, when the actual error and the given value changes, the controller still operate fuzzy algorithm in full domain areas, to ensure the system's output characteristics, and get no impact from the given value changes.

The role of the output transformation is t of interpolation output U converts to input X needed in process. Their outputs take place type while has larger error; when the error is small, take incremental 5.

$$X_n = \begin{cases} K_P U(n) & |E|>\delta \\ K_P U(n)+K_I x(N-1) & |E|<\delta \end{cases} \quad (6)$$

As fuzzy control rule is not determine the function itself, it has low accuracy to fuzzy control table when interpolation. Considered from the realization of ARM microprocessor, choose the dual function linear interpolation algorithm. The control table function relationships is

$$U_{ij} = f(E_i, E_{C_i}) \quad (7)$$

When $E_I < E < E_{i+1}$, $C_I < E_C < E_{C_i+1}$ (8)

$$U \approx f(E_{i,}E_{c_i}) + (\partial(E_{i,}E_{c_i})/\partial E)dE + (\partial(E_{i,}E_{c_i})/\partial C)dc \quad (9)$$

$$U \approx U_{ij} + ((U_{i+1,j} - U_{ij})/(E_{i+1} - E_i))(E - E_j) + ((U_{i,j+1} - U_{ij})/(E_{C_j+1} - E_c))(E - E_j) \quad (10)$$

$$U \approx f(E_i, E_{C_i}) + f((E_{i+1}, E_c) - f(E_i, E_{c_i}))/(E_{i+1} - E_i) + f((E_i, E_{i+1}) - f((E_i - E_{c_i}))/(E_{c_j+1} - E_{c_i}))(E_c - E_q) \quad (11)$$

C. fuzzy controller based on self-adjusting interpolation algorithm

- The standard domain of e, eu, and u is [-6, 6], the maximum value of standard domain is Nmax, means Nmax = 6, then has the following self-tuning fuzzy control algorithm.
- Calculate domain scaling factor a_e、 a_{ec} and a_u

After adding interpolated, the real universe of e, ec and u are $[-E_e, E_e]$ $[-E_{ec}, E_{ec}]$ and $[-E_u, E_u]$, expressed as U_e, U_{ec} and U_u respectively, there initialization domain are $[-E_{e0}, E_{e0}]$, $[-E_{ec0}, E_{ec0}]$ and $[-E_{u0}, E_{u0}]$, expressed as U_{e0}, U_{ec0} and U_{u0} respectively.

the domain extension domain reduction factor of Error e and error change ec is:

$$a_e(ec) = 1 - \lambda e^{-k(e/Ee0)^2} \quad (12)$$

$$a_e(ec) = 1 - \lambda ec^{-k(ec/Eec0)^2} \quad (13)$$

According to the control precision of soft linen System, taking λ = 0.96, λ is the minimum domain range coefficients.

In the control process, when e, ec has domain scaling factor a_e and a_{ec}, then

$$\begin{cases} U_e = a_e U_{e0} \\ U_{ec} = a_{ec} U_{ec0} \end{cases} \quad (14)$$

a_e, a_{ec} is the adjustment role to U_{ec0}, U_{u0}, meanwhile take the corresponding adjustment to U_u, means:

$$U_u = a_u U_{u0} \quad (15)$$

In which, a_u is domain expansion factor of u, and with, and a_u with a_e, a_{ec} has the following relationship

$$a_u = f(a_e、 a_{ec}) \quad (16)$$

For the fuzzy control system is difficult to obtain accurate mathematical description of formula (16), according to the dynamic response process of controlled system to qualitative analyze the variation, which are:

$$a_u = \begin{cases} a_e & a_e >> a_{ec} \\ \sqrt{(a_e^2 + a_{ec}^2)/2} & e < 0, ec > 0 \\ (a_e + a_{ec})/2 & a_e \text{ and } a_{ec} \text{ equal} \\ & \text{other} \end{cases} \quad (17)$$

- Adjust the domain size of $e(n)$, $ec(n)$ and $u(n)$;

$$\begin{cases} Ee = E_{e0} \bullet a_e \\ Eec = E_{ec0} \bullet a_{ec} \\ Eu = E_{u0} \bullet a_u \end{cases} \quad (18)$$

- Adjust the quantization factor q_e, q_{ec}, and the scale factor q_u

$$\begin{cases} q_{ec} = N_{max} / E_{ec} \\ q_{ec} = E_u / N_{max} \\ q_e = N_{max} / E_e \end{cases} \quad (19)$$

- Quantify $e(n)$ and $ec(n)$

$$\begin{cases} e = q_e \bullet e(n) \\ ec = q_{ec} \bullet ec(n) \end{cases} \quad (20)$$

- Use plot - and gravity center method to calculate control amount u, and ratio adjustment;

$$u(n) = q_u u \quad (21)$$

- output control amount $u(n)$, and calculate the response results of the controlled object

D. Simulation Debugging

In the simulation, the basic parameters of the controlled object is ks = 1, T m = 20s, S = 10s, T = 5s, the basic parameters of the control system is Ee0 = 113, Eec0 = 110, Eu0 = 012, simulation results shown in Figure 5, ITA E indicators shown in Table 1. Increase system delay time constant S = 20s, the other parameters are still, the simulation results shown in Figure 6, the figure MF5 and MF7 represent fuzzy classification of the domain self-tuning fuzzy control are 5 and 7.

Simulation results show that:

As Figure 5 and Figure 6 shows: the simplified Fuzzy level of Fuzzy control has better effect than previous;

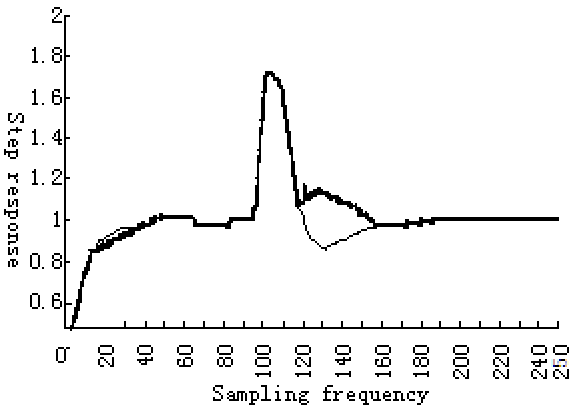

Figure 5. T=10s domain self-adjusting fuzzy control

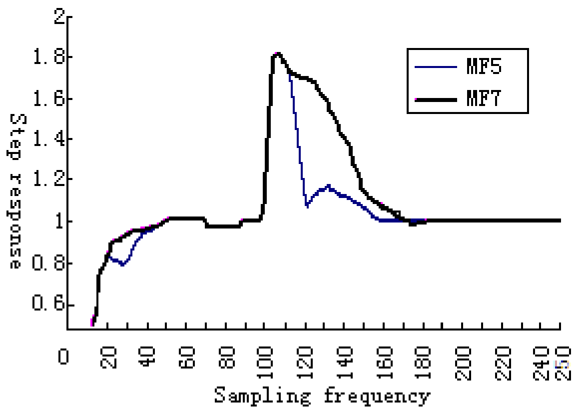

Figure 6. T=20s domain self-adjusting fuzzy control

- Before, the number of control rules are 49, then simplified to 25, therefore, after simplified, the control rule number is not only reduced by half, but the computation are also greatly reduced.
- After the fuzzy class simplification of fuzzy quantity, the ITA E indicators are smaller than former, so the control effect is good. It can be seen, the fuzzy level simplification of fuzzy quantity is reasonable and feasible.

V. Software Design

Software design is the key to the system design. In order to improve program reliability and understandability, using modular program design, that is to design the program be a relatively independent subroutine program, it is good for program modify and transplant. The main function of control system software is to accept orders from control center or open key on the controller; accept the valve opening feedback signal, calculate in certain algorithm to output control signals: feedback information to the control center; real-time display valve opening; fault alarm, fault handling.

Software is divided into the main, interrupt service program and subroutine program three parts. The main program use modular structure, which includes system initialization module, date enter module, time enter module, input parameter module, system test module, running module and print module.

VI. Running Result and Analysis

Based on the simulation debugged, and put into operation, well improved the control precision. Figure 5 shows the comparison of different fuzzy controller.

Practical operation shows that the system is stable, the control precision meet the product requirements. Relevant organization experts identified, that the system function is full, operation is convenient, after the application of fuzzy control technique by interpolation algorithm, the control accuracy is higher than the actual production requirements.

In manual control, there is 27% qualified products; using basic fuzzy controller design system, qualification is 48%; using the fuzzy controller by interpolation algorithm design system, qualification is 62%. Based on self-adjustment interpolation Fuzzy controller design system, qualification is 78%. Figure 7 shows the actual obtained results curve. It can be seen from the curves, the application of fuzzy controller by interpolation algorithm has better control effect.

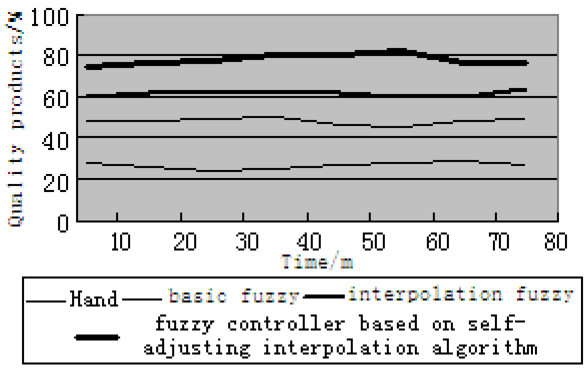

Figure 7. Effect comparison chart

VII. INNOVATIONS AND KEY TECHNOLOGIES

A. innovations

By experts from novelty and project evaluation, that the system has the following innovations:

- China first application the fuzzy control method into soft linen emulsion rate intelligent control system, which provides product quality.
- In China, the interpolation fuzzy control method combine with domain fuzzy control method with self adjusting, based on the fuzzy controller based on, designed a domain interpolation algorithm fuzzy controller with self-adjusting, to adjust the size of actual measurement, reduce fuzzy control rule numbers, so with no affect to control characteristics, simplifying fuzzy controller design process and successful application in soft linen emulsion control system.
- By using the interpolation algorithm, solved the soft valve switches, valve limit position judgments, motor protection, precise positioning, analog signal isolation and other key technology, can achieve good control effect.

B. Key technologies analysis

1) Soft valve switch

Digital signal processor in the system according to the measured inverter output voltage and current, through precision calculation, get output torque. Once the output torque equals or larger than the set torque, automatically reduce speed to avoid over hit inside the valve, then achieve optimal, realize the over torque protection. Ensure that when the valve is closed or fully open, to prevent the valve from stuck or injured.

2) Valve limit position determination

compared the detected location signal this time to the last detected location signal, if no changes or small changes, considered it have reached its limit position (fully open and fully closed), and immediately cut off the induction motor's power supply, to ensure valve is closed or fully open safety.

3) Motor protection realization

Temperature sensor built inside the motor, through temperature sensors continuously detect the actual motor operating temperature, if the temperature sensor detect the temperature too high, then automatically cut off power supply , to prevent the motor from overheating and burning.

4) Precise positioning

The traditional electric executive mechanisms will soon reach its rated operating speed after the asynchronous motor powered, when approaching the stop position, the motor power down, due to mechanical inertia, its valve can not stop immediately, there will be varying degrees of over travel, this over travel usually correct by control the motor to reverse rotation. Based on the difference between the current position and a given position and running speed to determine speed deceleration location and change rate K_i in deceleration section, make the valve at lower speeds to achieve precise fine-tuning and positioning, and thus minimize the over travel.

5) Analog signal isolation

As DC voltage of inverter and its output phase voltage, the address inconsistencies between them, it is a high common-mode voltage, in order to ensure the security of the system, they must be isolated from each other. To form an isolated linear amplified circuit by using LM358 and 4N25, with ± 15 V and ± 12 V two separate sets positive and negative powers. If the inverting terminal potential of op amp A positive deviation from the virtual ground by disturbing, then the output potential of op amp A will be reduced, thus the luminescence intensity of opt coupler will be enhanced, so its sets emitter voltage decreases, at last inverting potential of op amp A is lower, and back to normal. If the reverse side if inverting potential of A negatively deviation from the virtual ground, it can also go back to normal. Therefore the immunity of the system is enhanced .

VIII. CONCLUSION

Through the improvement of fuzzy control output, essentially cleared the adjustment dead zone, and largely reduces the requirements on the output scale factor, it has the capacity to adapt the continuous change of soft linen emulsion process, speed up the reasoning speed and storage process implementation, then improve the control quality, in particular, steady quality. As the improvements of controller implementation itself with no other structures, it is stable and reliable. The practical application results have solved the soft valve switches, valve limit position judgments, motor protection, precise positioning, analog signal isolation and other key technologies, it can achieve good control effect. This method can be applied to the similar control system.

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