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Design of the Glass Batching-Material System based Fuzzy-PID Combined Control

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Abstract

According to the traditional control methods of batching-material exists system defects low precision and bad real time, this paper has proposed the combined control algorithm. This paper has designed a Fuzzy-PID control Glass batching-material system by using of combining the traditional PID and the Fuzzy control algorithm. The system uses expert system of online learning and adjusts automatically the control parameters; realize the best combination controlling precision and speed. The actual operation result of the system has proved the feasibility and validity of the Fuzzy-PID combined control.

Keywords*: batching-material, fuzzy -PID combined control, expert system*

1. Introduction

Glass batching system needs sandstone, limestone, dolomite, feldspar, soda ash and other raw materials, then according to the production needs; those materials are transferred, mixed automatically. In fact production, according to the changes in the external environment, the influence of the material properties, and many other uncertainties, which make the entire batching system with nonlinear, time delay, parameters time-varying and other characteristics, because of those problems, it is difficult to establish an accurate mathematical model. Traditional PID controller has a simple structure, easy to implement, and robustness, but in the practical application of control process, not only with so many control parameters, complex, highly non-linear, time-varying uncertainty and time delay characteristics[1][9], but also often need experienced technical staff to adjust the parameters. And fuzzy control is dependent on the experience of expert's, no need to establish an accurate mathematical model has a good ability to control delay, nonlinear and time-varying systems, in the case of variable grading enough, the oscillation phenomena and steady-state error often appear near the equilibrium point. In the batching system, when the controlled process parameters change, fuzzy control performance can not meet the control requirements, by using the expert system online learning to self-tuning control parameters, the control system can always adapt to the changes of the controlled, process environment[10]. Therefore, this paper through Fuzzy-PID control algorithm combined with expert system online adjustment parameters designed glass batch control system based Fuzzy-PID, the system can line judge the state of weighting and control precision, adjust weighing speed and fly quantity control automatically, achieved the best combination of accuracy and speed.

2. Charged object analysis

In the glass batching system, the weighing control of the glass raw material is usually accomplished by using electronic weighing scales system, Figure 1 shows configuration diagram, which is one of a certain raw materials weighing discharge control system, the main devices are hopper, weighing sensor, belt motor and inverter. In order to ensure that the material to fall the same thickness on the unit length of the belt, at the discharge port design a baffle.

In the early feeding, with the actual feeding amount and the set value of the larger deviation, in order to ensure the batching-material speed, the system should be fast feeding;

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when feeding quantity close to the set value, feeding system should be slow to ensure the accuracy of weighing. In fact, using of feed through the process control to achieve the most speed and accuracy optimization,in order to overcome the slow rate of feed is too low result in excessive weighing extended, resulting in reduced efficiency weighing ingredients that can not timely access to mixer mixing of problem[2][8].

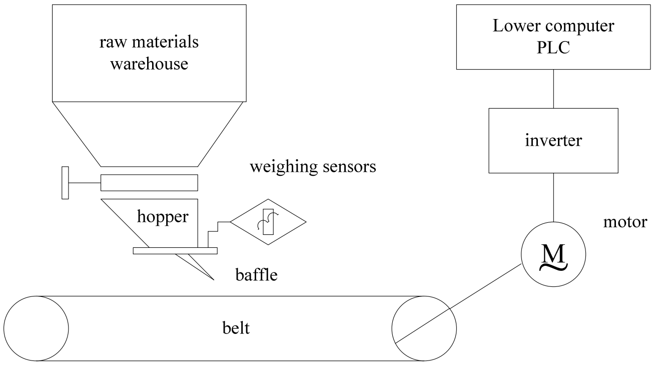

Figure1. Belt Sending Material System Structure

3. Fuzzy-PID composite control algorithm

PID control algorithm is the most widely used in industrial process control, but the matching-material system for material properties in the subject, body mechanical vibration and other factors, its dynamic characteristics is not ideal, and the larger overshoot. For a simple fuzzy control algorithm, when the system error is close to 0, it can not achieve optimal control, and the oscillation will occur and the larger steady state error. In order to achieve the high precision control of the system, the system introduced Fuzzy-PID composite control algorithm, so that the parallel role of the two control modes, shorten system response time, steady state error was eliminated. The design ideas: When the deviation is small, using Fuzzy control, in order to improve control accuracy; when the deviation is large, using PID control, in order to speed up the response speed; Two control modes can realize automatically switching by prior programs in the given deviation range.The Fuzzy-PID control system structure is shown in Figure 2. Amount in advance coefficient K is set to prevent material falling into the hopper feed or fly after the overshoot in Figure 2.

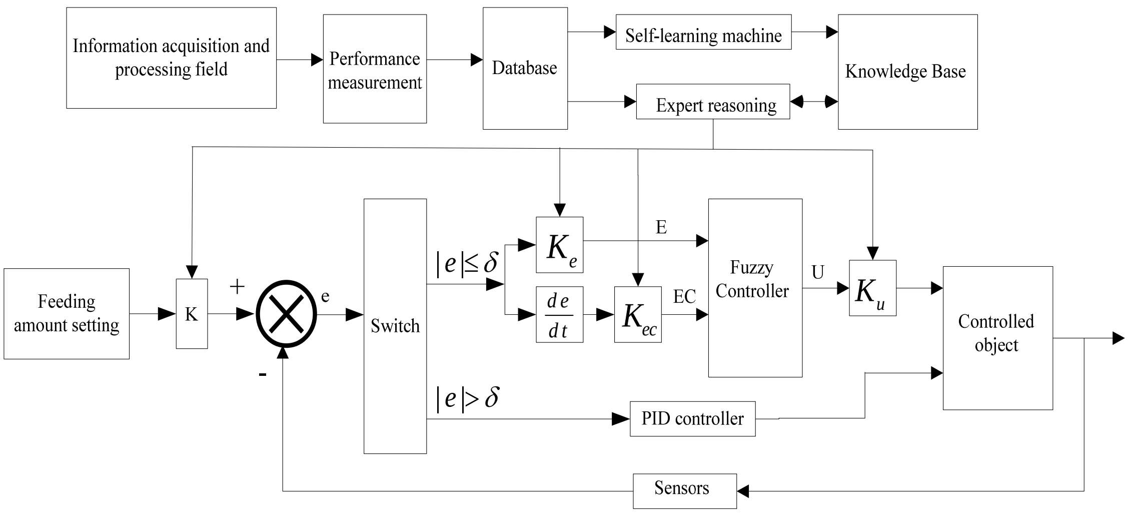

Figure 2. Structure of Fuzzy_PID Control System

3. 1PID Control Algorithm

Based on actual experience,when the amount of deviation $|e|>5Kg$,using PID constant speed control.The system adopts an incremental PID control algorithm[6], that is

$$\Delta u(k) = K_P[e(k)-e(k-1)]+K_I e(k) \\ +K_D[e(k)-2e(k-1)+e(k-2)] \\ u(k) = u(k-1)+\Delta u(k) \tag{1}$$

In the above formula, proportional coefficient Kp is used to generate an output signal and bias proportional for reducing bias and making the system response with smaller overshoot; Integral coefficient $K_I = K_P \frac{T}{T_I}$ is used to eliminate static error and making the system has good steady state performance response; differential coefficient $K_D = K_P \frac{T_D}{T}$ is used to reflect changes in the trend of error, for reducing settling time and making the system response to speed up. T is the sample period, k is the sample sequence number; e(k)、e(k-1)、e(k-2) represent k、k-1、k-2 times sample deviation; u(k)、u(k-1) represent k、k-1 times sample of the control output; Tuning PID control parameters(KP、KI、KD)have done in the field from repeating experiments.

3.2. Fuzzy Control Algorithm

Based on actual experience, using Fuzzy control when the deviation $|e|\le 5Kg$,the system uses a the two-dimensional fuzzy control mechanism model with dual-input single-output, in which the fuzzy controller inputs E and EC, respect for the setting between raw materials and the actual feeding value deviation and the rate change of the deviation, output U represent for plus / discharge speed setting point. The system input and output of the discrete domain are: {0, +1, +2, +3, +4, +5, +6}. For a certain input, it needs to go through transformation of range and quantization to global scope. According to the actual situation, using the non-uniform quantization method in the region which has smaller deviations.

3.2.1. Input and Output Fuzzy Processing

First, the input variable E, the EC and output variable U is converted to the amount of continuous change between [0,6]; Second, makes the exact amount of the continuous discrete, divided into 7 Draw, each file corresponding to a fuzzy subset, Finally the fuzzy processing. This seven-speed is defined as the fuzzy subset {ZO (take 0 near) ,SS (take 1 near), SB (take 2 near), MS (take 3 near), M (take 4 near), BS (take 5 near) , B (taking 6 nearby)}. The membership function of the system using the triangle[3][7], the input and output variables membership function curves shown in Figure 3.

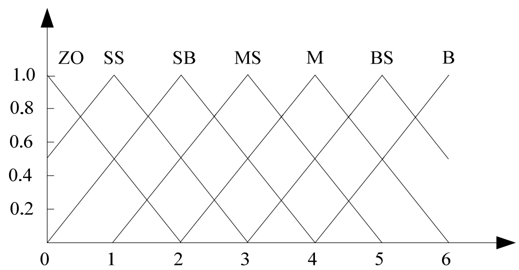

Figure 3. Input and Output Subordinate Function

3.2.2. Fuzzy Rules and Fuzzy Reasoning

In order to realize the fuzzy inference control system, the glass batching-material system by summing up the experience of actual control, fuzzy rule table is established as shown in Table 1. The total of 49 fuzzy control rules, using the logical form: If A and B then C, that is if EC=Ai and if E=Bj then U=Cij(i=1,2,…,7;j=1,2,…,7).

Table 1. Rules of Fuzzy Control

EC \ U \ E	ZO	SS	SB	MS	M	BS	B
ZO	ZO	SS	MB	M	B	B	B
SS	ZO	SS	SB	MS	M	BS	B
SB	ZO	SS	MB	M	B	B	B
MS	ZO	SS	MB	M	BS	B	B
M	ZO	SS	SB	MS	M	BS	B
B	ZO	SS	SB	MS	M	BS	BS
BS	ZO	SS	SB	SB	MS	MS	BS

In order to improve the real-time of the control and reduce the computational complexity, the system calculate discrete fuzzy control query table for each scale, and stored in the platform scale data block, in order to convince for PLC when query the corresponding control in operation. Since the precise amount of control used in the actual operation, and therefore the amount of blur by the fuzzy reasoning is needed convert to a precise amount, take the largest domain degree of membership which is corresponding output by fuzzy sets as the output. The calculated formula is;

$$\mu_C(\mu_C^*) = \max(\mu_C(\mu)) \tag{2}$$

In the above formula, C is the output fuzzy set; μ is the output of domain elements.For example, in a known case of Ei and ECj, Uij can be obtained through table look, the actual control quantity u is calculated as

$$u = K_u \times U_{ij} \tag{3}$$

In the above formula, Ku is a scaling factor for the amount of output control.

3.3. Complex Control Algorithm Process

PLC will compare the collected weighing difference e with 5Kg in the actual batching-material control process. If $|e|> 5Kg$,the system will use PID control algorithm, its current time of Kp、Ki and Kd values according to equation (1) obtained,then get the output control quantity u (k); If $|e|\leq 5Kg$, the system will use Fuzzy control algorithm, e and ec are collected by PLC will respectively multiplied Ke and Kec,then will get the quantization factor and E and EC , by calling the fuzzy controller lookup table, you can control of the amount of output change in U, again multiply factor can get feed speed control quantity u, if u meet the control requirements for output control, it will be output, otherwise required by the expert system based on field information online adjustment coefficient K and the quantum factor Ke、Kec and Ku,until the control u meet the requirements. The design program uses a modular structure, two control mode switch is determined by the prior given deviation range[4] [5]. Figure 4 is a flowchart of the software within a sampling period.

4. Glass Batching-material System Hardware Design

The system hardware design block diagram is shown in Figure 5. In system, the material weight signal by the weighing sensor is converted into an electrical signal, then by amplifying transformation and filtering processing, and after the A/D converter into the PLC, the PLC will process the acquisition of the relevant data and parameters, via a serial communication module or Ether network and host computer communication, the host computer will compare the on-site parameters and set parameters, ordering PLC control feeder, belt conveyor, mixer and other power equipment, achieving automatic control of the batching system.

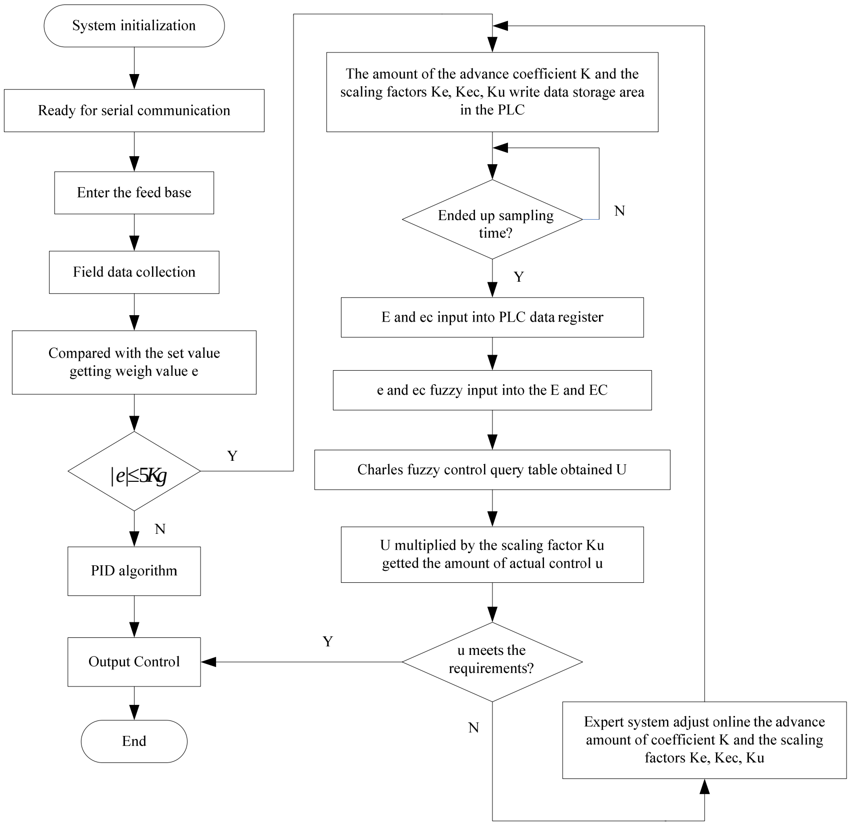

Figure 4. Complex Control Algorithm Flow Chart

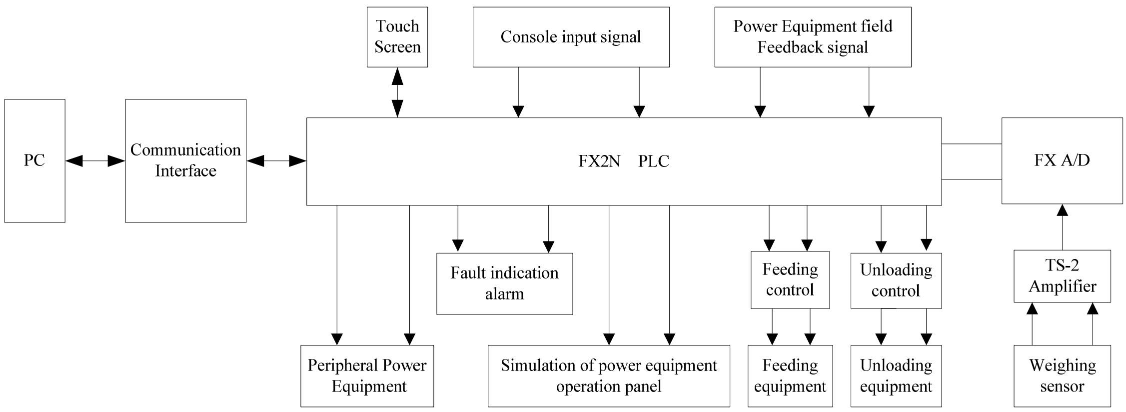

Figure 5. System Hardware Block Diagram

5. Test results

In order to verify the correctness the control algorithms of Fuzzy-PID composite, the software and hardware design, testing on the glass batch experimental apparatus which is based on Fuzzy-PID control. Table 2 gives some experimental data which are about using the algorithm to weight # 1 silica sand.

Table 2. Record form part of the experimental data

Sampling time	Set value/Kg	Actual value/Kg	Error/Kg	Accuracy/%
2012-5-8 10:15	500.3	500.5	0.2	0.04
2012-5-8 10:20	500.3	500.4	0.1	0.02
2012-5-8 10:25	500.3	500.4	0.1	0.02
2012-5-8 10:30	500.3	500.7	0.3	0.06
2012-5-8 10:35	500.3	500.5	0.2	0.04
2012-5-8 18:20	488	488.0	0.0	0
2012-5-8 18:25	488	488.1	0.1	0.02
2012-5-8 18:30	488	488.3	0.3	0.06

6. Conclusion

From the table, the maximum error in the test is 0.3Kg. The description of the system software, hardware design correctness, but also proved using Fuzzy-PID composite control algorithm can effectively improve the control accuracy of the ingredients, shorten the ingredients time and improve the efficiency of the production .In addition, the combination of expert system online learning to adjust the control parameters, achieving accuracy and speed to the best fit. The entire control system is simple and reliable, with high control accuracy to meet the requirements of various ingredients production. The control method has been used in glass production company in a high-tech industrial zone, the actual operating results show that using Fuzzy-PID composite control mode can improve the pass rate, reducing operator workload.

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