Design of Bearing Alloy Intelligent Batching System Based on Electrical Control

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Abstract. In order to realize the optimization and intelligent control of the burden ratio of bearing alloy, the intelligent burden system of bearing alloy based on electrical control was constructed with the minimum error of the formula as the index, in order to complete the work of alloy ratio and intelligent burden independently. The feature of the system is to realize the automatic and accurate batching of bearing alloy by using fuzzy algorithm, and to configure electrical control to supply alloy raw materials quantitatively. Experimental results show that the system can basically control the error of bearing alloy batching within ±1%, which proves that the system can meet the requirements of batching precision.

Keywords: PLC electrical control · Bearing · Alloy batching system · Fuzzy algorithm

1 Introduction

The forming quality of materials is closely related to the accurate proportion of charge composition. It is of great help for lean management of raw material consumption, reducing the difficulty of composition adjustment in front of furnace and improving the casting characteristics of alloy to accurately match the alloy composition and control the charge composition. At present, there are two common matching methods: artificial experience calculation and algorithm optimization derivation. The former has low efficiency and heavy workload, and the proportioning accuracy is affected by subjective factors. With the help of computer algorithm optimization and programming derivation, it is easier to realize the accurate proportion of alloy composition.

High quality sliding bearing alloy should have good antifriction, compressive strength and fatigue resistance. Accurate control of alloy composition is the key to produce high quality bearing materials.

The electrical control system is generally called the secondary control loop of electrical equipment. Different equipment has different control loops, and the control mode of high-voltage electrical equipment and low-voltage electrical equipment is not the same. Specifically, the electrical control system refers to the combination of several electrical components, used to achieve the control of a certain or some objects, so as to ensure the safe and reliable operation of the controlled equipment. Therefore, an intelligent

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batching system for bearing alloys based on electrical control is designed in this study to reduce batching errors through electrical control.

The innovative design process of the system is as follows:

(1) Based on the minimum formula error, the fuzzy algorithm was used to realize the automatic and accurate batching of bearing alloy.
(2) Configuration of electrical control to ration the supply of alloy raw materials.

2 Design Requirements of Intelligent Batching Control System

The design of bearing alloy intelligent batching control system must first meet the actual process requirements, and then design a reasonable technical scheme on this basis, so that the design of the system and customer requirements to achieve the optimal unity. Combined with the project contract and the actual situation of the enterprise, this paper puts forward the following process requirements and technical requirements.

2.1 Process Requirements of Batching Control System

In order to achieve the best effect and requirements of proportioning, the design of proportioning control system has the following process requirements:

(1) The system has comprehensive functions, stable and reliable work, accurate weighing, and can meet the requirements of batching production.
(2) It should be able to adjust the formula data of various raw materials online to achieve higher batching accuracy.
(3) It has monitoring screen to know the running state of the system at any time.
(4) It has good adaptability and can adapt to different requirements of environment and process form.
(5) On the premise of meeting the batching accuracy, the system has clear structure, reliable use, convenient maintenance, high performance and price [1].

2.2 Technical Requirements of Batching Control System

According to the actual situation of bearing production equipment and the experience requirements of bearing proportioning, the following technical requirements are put forward for the bearing proportioning control system.

(1) The system has automatic, automatic and manual functions. No matter in which way, it has a kind of compulsive function. This function can start or stop an operation immediately [2].
(2) The system accurately weighs all kinds of raw materials, and the error value is not more than 0.1%.
(3) The system shall be able to display, store and print the current formula and production report.
(4) The system can display and print the batch, shift, daily and monthly ingredients.

(5) Automatic diagnosis function of the whole system.
(6) The system has good man-machine interface function.
(7) Out of tolerance alarm and fault printing function.
(8) The system has good communication function.

3 Framework of Bearing Alloy Intelligent Batching System

A complete batching control system is mainly composed of feeding system, weighing system, mixing system and control system [3].

(1) Feeding System

For weighing bulk materials, often use solenoid valve feeding, screw feeding, material door feeding, electromagnetic vibration feeding, belt feeding and motor vibration feeding and other feeding methods.

In order to accelerate the speed of ingredients, generally choose a slightly larger feed caliber silo, but it will produce a large and unstable drop, so it is difficult to improve the accuracy of ingredients. If in order to solve the precision problem and choose a slightly smaller feed caliber silo, although the ingredients are stable, but the speed of the ingredients can not meet the requirements, so that the production efficiency is low. Therefore, this paper uses double - gate batching method to solve the problem of batching speed and precision.

Double-door batching method is a silo with a raw material, but each silo has two feeding doors, the system determines the switch state of the two feeding doors according to the set value. After starting the batching, the two feeding doors of each bin are opened. In a short time, once the weight value reaches the set value, one of the feeding doors will be closed, and the remaining one will be closed to complete the fine feeding. When the weight value is the rated value, the remaining feeding doors will be closed. Double-gate batching method not only reduces the error caused by unstable drop, solves the problem of batching speed and precision, but also makes the control system more flexible.

(2) Weighing System

The key of the batching control system is the weighing system, and the weighing mode quickly transits from the mechanical scale stage to the electromechanical electronic scale stage and the sensor electronic scale stage.

The mechanical scale composed of scale bucket and lever system has slow weighing speed and low efficiency, so it is not suitable for automatic production. The electronic scale is mainly composed of load-bearing, force transmission reset system and load cell. Among them, the load-bearing and force transfer reset system is the mechanical connection between the measured object and the conversion element. Because of the good sealing of the load cell, the sensor electronic scale can replace the mechanical scale and the electromechanical scale to complete the work under bad conditions. The development of electronic scale is a process from simple to complex, from rough to precise, from mechanical to mechanical and electrical integration, and finally to full electronic, from single function to multi-function.

(3) Hybrid System

At present, the domestic mixer design technology is very mature, such as the horizontal screw belt mixer used by most manufacturers. Horizontal screw belt mixer is a new type of mixing equipment with high efficiency, high uniformity, high loading coefficient, low energy consumption, low pollution and low crushing. In this paper, the motor and inverter are selected for simulation experiment.

(4) Control System

The main function of the control system is to make the field equipment complete all the batching work according to the preset formula proportion.

Nowadays, most batching control systems adopt computer control method, because this control method not only makes the whole process automatic and improves the productivity, but also provides users with a large number of ratios that can be easily called and modified. At the same time, the computer can carry out real-time online monitoring on the field control system, and realize the function of storing and viewing historical data, so as to achieve the purpose of scientific management.

Based on the composition of the above batching control system, the framework of bearing alloy intelligent batching system is designed, which consists of user, controller and equipment. The control computer and touch screen are oriented to the technologists, and it is convenient to set the bearing alloy grade, mass, element mass fraction, etc. The controller includes industrial computer and programmable logic controller (PLC). The industrial computer participates in the alloy proportioning optimization and sends the proportioning parameters to PLC module through industrial Ethernet.

PLC is responsible for the process control of the batching machine. The field equipment communicates with PLC through CC link to complete a series of actions such as weighing, lifting, transferring and charging according to the alloy proportion. The alloy proportioning is a semi-automatic process, which requires the participation of the technologists: PLC displays the proportioning processed by the industrial computer on the touch screen, and the technologists place the burden in the weighing area of two stations in order. When the quality and weight meet the proportioning requirements, the carrier rises, and the frequency conversion speed regulating conveyor belt loads the raw material into the furnace.

4 System Hardware Design

4.1 Electrical Control Hardware—PLC

PLC is a programmable memory which can realize the functions of logic operation, sequence control, timing and counting. It is also a kind of digital or analog input and output to control various production processes.

In the running process, the CPU of the programmable controller repeatedly executes three working stages of input sampling, user program execution and output refresh in a single scanning cycle according to a certain scanning speed [4, 5]. PLC has the following advantages:

The hardware is complete and adaptable;
Programming is simple and easy to use;
The control program can be changed with good flexibility;
It has high reliability and strong anti-interference ability;
Abundant input/output interface modules;
The workload of system design, installation and debugging is less.

In modern control engineering, Siemens 57-200 series PLC is used as the ideal controller. Because of its compact structure, good expansibility, powerful command function and low price, it can fully meet the system requirements.

4.2 Load Cell

The Weighing Sensor

Load cell is a kind of force sensor, which measures the mass by converting the measured mass into another one. The load cell is an important part of the electronic scale, which converts the weight of the weighed object into electrical signal and indicates it after processing [6]. Therefore, its advantages and disadvantages largely determine the accuracy of the electronic scale.

Combined with the structural characteristics and working principle of the hopper, the resistance strain type tension weighing sensor is selected. The resistance strain type tensile load cell mainly has the following characteristics:

(1) High precision and wide measuring range.
(2) Good frequency response.
(3) The utility model has the advantages of simple structure, small size, light weight and simple installation.
(4) It can work under high temperature, low temperature, high pressure, strong vibration, strong magnetic field and nuclear radiation.

The resistance strain gauge is made of resistance wires with a diameter of 0.025 mm and a high resistance string. In order to obtain high resistance, the resistance wires are arranged into a grid network, called sensitive grid, and pasted on the insulating substrate. The two ends of the resistance wire are welded with leads. A protective covering layer is pasted on the sensitive grating. When measuring with strain gauge, paste it on the surface of the object to be measured. When the measured object is deformed by force, the sensitive gate of the strain gauge is also deformed, and its resistance value changes accordingly. It is converted into the change of voltage or current through the conversion circuit, which is used to directly measure the strain.

Weighing Indicator

Panther weighing terminal is a high quality weighing terminal product designed by METTLER TOLEDO company for chemical industry, pharmaceutical industry, food industry and other process industry applications. Panther uses sigma delta analog-to-digital converter (ADC) and digital processing technology to provide a variety of applications for

industrial weighing demand: weighing display, weight checking, sorting, setting control, etc.

The other weighing terminal adopts traxdsp digital filtering patent technology, which can obtain stable weight value in real time. Even if there is motion equipment on the connected weighing body, the real weight data can be obtained by adjusting the parameters of the weighing terminal.

(1) Easy to install Panther can choose different voltage power supply. Optional AC voltage is 100 V AC, 120 V AC, 230 V AC. The panel instrument can be fixed on the control cabinet only by opening a rectangular port on the control cabinet. Sealed (desktop/wall type) instrument wiring harness connection adopts sealed joint, which has dust-proof and waterproof effect (in line with IP65 standard). With bracket structure, Panther can be placed on the platform or installed on the wall with adjustable angle.
(2) Easy to use, fluorescent display, high brightness, touch film keyboard, durable resin panel, anti physical and chemical damage.
(3) The flexibility adopts modular tree structure parameter setting, which is convenient for users to find setting parameters.
(4) Panther is designed, manufactured and tested in Mettler Toledo's IS09001 certified factory. All parts (including options) of panther are installed and debugged in the factory. Built in diagnostic program, easy to find and solve problems. The design of standard Panther conforms to relevant international standards of metrology, electrical safety and electromagnetic compatibility.

Panther weighing terminal function the functions of panther instrument are as follows:

(1) The Panther meter with weighing function can be connected with up to eight 350 Q analog sensors, its maximum display graduation is 10 000 D, and its a/D conversion speed is 30 times/s. The functions of automatic peeling, automatic clearing, unit conversion, automatic tracking and dynamic detection are embedded in the system.
(2) Storage function: the storage function of the four target weight values in the excessive, normal and insufficient sorting functions: the storage function of the two preset points and the advance value.
(3) Communication interface function Panther has a RS232 serial communication interface 1:21 and parallel I/O interface, which can be used to connect serial printer or computer.
(4) PLC interface function Panther meter has Profibus-DP Field bus connected to El; Rio of Allen Bradley PLC connected to 121: Modbus Plus interface: 16 bit D/a precision analog output interface.

4.3 Batching Controller

The batching controller is the foundation and key of the system. It is directly connected with the batching actuator to realize the detection and control of the batching actuator,

such as the belt weighing, the start and stop of the conveyor, the switch of the mixer and so on. The batching controller can work independently, that is, when other structures of the system stop working, the batching controller can still independently control the batching actuator to realize the basic automatic batching function, so as to improve the reliability of the system work.

Each batching controller is connected with each other through RS.485 communication interface, and connected to industrial computer through data concentrator. A data concentrator can be connected with 32 control modules. Each control module connected to RS.485 bus can be distinguished from each other by setting different address identification by micro switch. The upper computer can access each control module individually by addressing, and detect and control its status in real time. The industrial control computer in the system mainly completes man-machine dialogue and system management functions, such as formula generation, management and download, remote control and real-time status display of batching unit, statistics of raw material consumption and finished product production, etc. The lower batching controller mainly completes the real-time control function of batching actuator, such as the real-time control of feeding speed.

Each set of batching belt weigher in the system is in the same logistics line, and there is an interlocking relationship between them. The whole batching process is programmed by PLC to realize automatic control. The communication between PLC and IPC can realize remote operation and control of IPC, and realize equipment alarm (such as belt deviation alarm). In the power control design, not only through the PLC internal software to achieve the interlocking, but also in the electrical circuit also increased the electrical signal interlocking, increased double the reliability.

The hardware structure of batching controller includes MCU, keyboard and interface, LCD and interface, analog/switch input processing circuit, analog/switch output

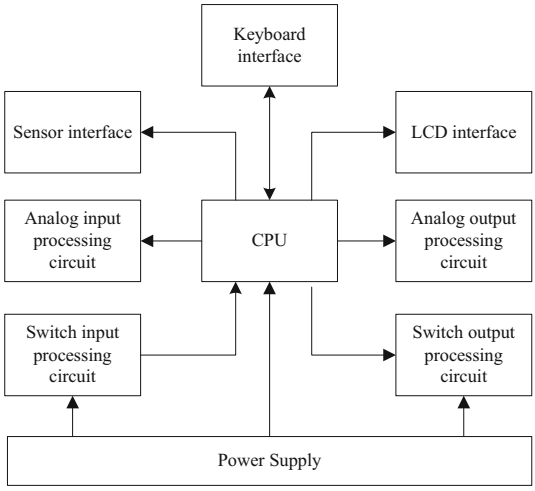

Fig. 1. Hardware structure block diagram of batching controller

processing circuit, LED status indication and interface, RS-232/rs.485 serial communication interface, etc. The hardware structure block diagram of batching controller is shown in Fig. 1.

4.4 Programming Cable

If we want to realize the effective control of the system, we need a programming cable to complete the upload and download of PLC program. The serial communication interface of the computer is different from that of the PLC. The computer generally uses USB interface, while the 57-200 series PLC uses RS485 interface. Therefore, the communication between the computer and the PLC can only be realized by converting the serial interface. Siemens programming cable can realize the conversion of serial interface, such as MPI (multiple point interface) card or PC/PPI (point to point interface) programming cable, and special usb-rs485 converter can also realize the conversion of serial interface. This paper uses the special communication cable designed by Siemens for 57-200 series PLC, namely PC/PPI programming cable.

5 System Software Design

5.1 General Procedure of System Batching

The system is divided into two parts: feeding and batching, and at the same time. Among them, the automatic feeding process can be realized only by using the proximity switch. In comparison, the batching part is slightly complicated, and its program flow is shown in Fig. 2.

In this process, the upper computer first transmits the relevant parameters to the field control system, so that the PLC can quickly calculate the required closing advance and closing weight. In the batching process, the batching weighing control system continuously transmits the weighing data to the PLC; when the real-time weight value is far from the rated weight value, the PLC opens two feeding doors at the same time to improve the batching speed; in order to reduce the impact caused by the falling of raw materials on the scale bucket, once the real-time weight value is equal to the fast casting weight value, the PLC closes one of the feeding doors to improve the batching accuracy; when the real-time weight value is far from the rated weight value, the PLC opens two feeding doors to improve the batching speed When the weight value is equal to the closing weight value, PLC will close the remaining feeding door and delay for a period of time, so that all the remaining materials in the air fall into the weighing bucket. The program of batching control algorithm updates the relevant parameters after a single batching. The stop condition of unloading process is that the real-time weight value read by PLC is the expected residual weight value W, but the weighing system fault will make the unloading process unable to stop, so the timer control program is specially added, that is, once the set unloading time is exceeded, the control system will force to stop the unloading process.

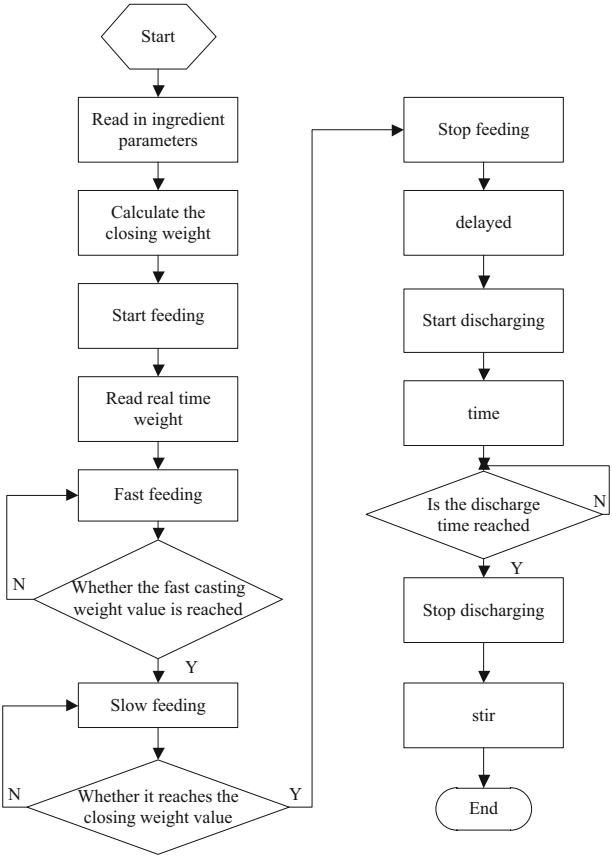

Fig. 2. Workflow of bearing alloy intelligent batching system

5.2 Algorithm Program of Electrical Control for Batching

Fuzzy control is a kind of computer control which takes human control experience as knowledge model and is realized by computer. Its basic idea is to summarize the control strategy of human experts for a specific controlled object or process into a series of control rules expressed in the form of "if (condition) then (action)", and obtain the control action set through fuzzy reasoning, which acts on the controlled object or process [7]. Therefore, fuzzy control is suitable for the control of complex systems without mathematical model or difficult to establish mathematical model. The control action set is a group of conditional sentences, and the state condition and control action are a group of quantified fuzzy language sets. Therefore, what fuzzy control should do is: first, summarize human control ideas, that is, the knowledge of experts or the experience of operators into fuzzy control rules, and then turn these control rules into algorithms that can be executed by computers, and then control the controlled object [8].

The fuzzy control system usually consists of five parts: fuzzy controller, I/O interface, actuator, controlled object and measuring device.

(1) Fuzzy controller is the core of fuzzy control system. It is a language type "fuzzy controller" based on fuzzy control knowledge representation and rule reasoning. The fuzzy controller stores the fuzzy control algorithm derived from rules, which is generally implemented by computer program or hardware [9].
(2) The D/A fuzzy controller takes the difference between the given value and the feedback value of the controlled quantity as the input, which is synthesized by the fuzzy control algorithm to obtain the corresponding control quantity. Because the control quantity is digital quantity and the actuator accepts analog quantity, D/A conversion is needed between fuzzy controller and actuator. Sometimes a level conversion circuit is needed after D/A conversion.
(3) The actuator includes AC/DC motor, stepping motor, hydraulic motor, pneumatic control valve, etc.
(4) The controlled object can be a kind of equipment or device and its group. They work under certain constraints to achieve people's goals. These controlled objects can be deterministic or fuzzy, univariate or multivariable, with or without delay, or linear or nonlinear, steady or time-varying, as well as strong coupling and interference.
(5) Sensor is a kind of device that converts various non electric quantities of the controlled object, such as flow, temperature, pressure, speed and concentration, into electrical signals [10]. When selecting sensors, we should pay attention to the accuracy of sensors.
(6) The A/D sensor converts the information of the controlled quantity into an electrical signal, which is then fed back to the computer.

According to the above analysis, the fuzzy control model of the weighing batching process can be established, as shown in Fig. 3.

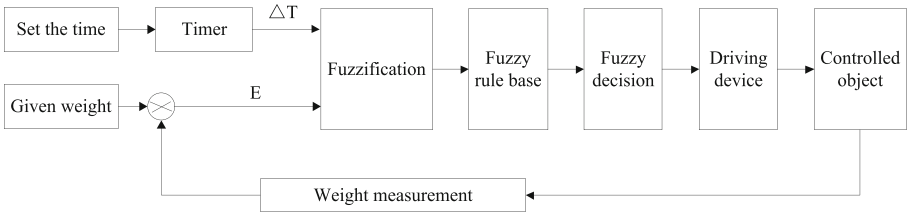

Fig. 3. Electrical paste control principle of bearing alloy intelligent batching

Two inputs of the fuzzy control system are weight deviation E and time deviation ΔR, and one output is control voltage U. The principle of the fuzzy control system is: the system compares the actual weight of the material with the set value to produce the weight deviation E, at the same time, the timer compares with the set time to produce the time deviation at, and sends these two variables into the fuzzy controller. According to the value of the weight deviation E and the time deviation ΔT, the fuzzy controller conducts fuzzy reasoning according to the fuzzy rule base of the system to produce a fuzzy control system a control output voltage U controls the feeding speed of the electromagnetic vibration feeder, so as to realize the control of the controlled system. In this system, when the deviation e is large, the constant speed feeding of PID control is

adopted to ensure the weighing time; when the deviation is small to a certain value, the fuzzy control is adopted to make the control quantity U decrease with the decrease of weight deviation E and time deviation Δt until the weighing is completed to ensure the weighing accuracy.

6 System Test Experiment

Using MATLAB software and its fuzzy logic toolbox, the design and performance test of bearing alloy intelligent batching system based on electrical control can be realized conveniently and quickly.

6.1 Proportioning Scheme of Bearing Alloy

Cast a batch of copper base bearings for pumps (zcupb2sn5, Brinell hardness no less than 560 HBW, tensile strength no less than 150 MPa), prepare 500 kg furnace charge, require Pb no less than 20%, Sn no more than 6% (mass fraction), raw materials are Cu-CATH-1 (Cu no less than 99.99%), sn99.95 and pb99, corresponding burning loss mass fraction are 1%, 1%, 1.4% respectively.

6.2 Experimental Platform

In order to study the control effect of batching control algorithm, this paper designs and builds a batching weighing experimental platform to simulate the fine blanking process, as shown in Fig. 4.

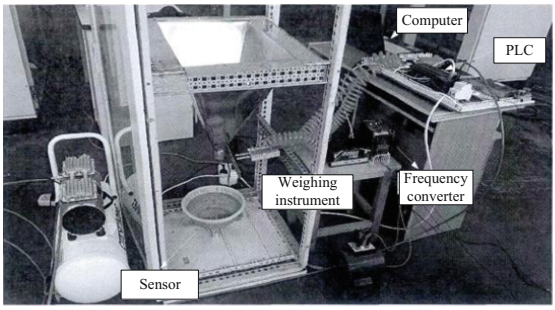

Fig. 4. Diagram of batching and weighing experimental platform

6.3 System Test Index

The batching error is calculated by formula (1): the batching error is calculated by formula (2).

$$Z = X - Y \tag{1}$$

In formula (1), Z is the error value of batching, X is the instrument display value, and Y is the formula setting value.

$$P = \left| \frac{Z}{Y} \right| \times 100\% \tag{2}$$

In formula (2), P is the batching error.

6.4 System Operation

The batching system has been in good condition since it was put into operation in June, and there is no major batching error accident. It shows the advantages of friendly interface, stable operation, high control precision and strong function. Some production commissioning records are shown in Table 1.

Table 1. Production record of copper base bearing for pump

Time	Recipe set point (Kg)	Instrument display value (Kg)	Batching error (Kg)	Batching error (%)
9:55	500	510.0	10.0	2.02
10:00	500	507.2	7.2	1.44
10:02	500	503.6	3.6	0.72
10:05	500	500.4	0.4	0.08
10:10	500	501.3	1.3	0.26
10:15	500	498.8	−1.2	0.24
10:20	500	499.5	−0.5	0.2

From the analysis of the results shown in Table 1, it can be seen that the bearing batching error was relatively large at the beginning of the debugging. After constant modification of the system in this paper, the batching error is gradually reduced and basically controlled within ±1%, which proves that the system in this paper has a high batching accuracy.

7 Conclusion

In this paper, an intelligent batching system based on electrical control process is designed and developed independently. The system is suitable for the proportion optimization of bearing alloy and intelligent feeding control, and has the advantages of low efficiency, convenient application and easy control of alloy cost. In the process of operation of the system, the minimum error is taken as the control index, and the batching control is completed based on the fuzzy control algorithm, which meets the requirements of bearing technology for batching accuracy, and proves that the system in this paper has a good application prospect.

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