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Research on Detection System of Intelligent Computer Optimization Algorithm for Concrete Mix Ratio Based on Big Data

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Abstract: - PLC is used to complete the control function of the concrete proportioning system. The MCGS (Configuration Software Monitor and Control System) is used to realize the real-time monitoring, data management and fault warning of the whole monitoring system. The material feed and PLC control process in the feed system are emphatically introduced. A concrete proportioning design method based on multiple parameters is proposed. The nonlinear multi-objective optimization model of concrete mix ratio was established by stepwise regression analysis and complex optimization method. The problems of narrow range of variables and single form of objective and constraint in traditional linear optimization methods are solved, which makes the selection of optimal index simpler and more flexible. Through the calculation of examples, it is clear that this method can obtain the mixture that meets the use conditions, and can greatly save the experimental work and construction cost.

Keywords: MCGS; PLC; Ingredients; Automatic Control; Nonlinear Objective Optimization; Algorithm Design.

I. INTRODUCTION

Due to China's economic development and the improvement of scientific and technological level, the demand for concrete is increasing day by day, and higher standards are put forward for the quality of concrete. Cement mixing equipment because of its good product quality, high production efficiency, environmental friendly and other advantages, has gradually developed into a new type of cement production equipment, its degree of automation is getting higher and higher [1]. Cement mixing building is a very common application of construction equipment, its control method is generally relay loop + intelligent instrument, in the actual concrete preparation, the supply of various materials and the time of each stage must rely on manual observation instruments to monitor, such a low degree of automation, poor reliability of the control system has been unable to meet the needs of construction projects.

At the earliest time, cement was manufactured by hand, by construction workers will make cement raw materials in order to weigh, and then all kinds of prepared raw materials into the blender for mixing, mixing evenly before use. Whether the raw materials required can reach the predetermined proportion depends greatly on the skill and responsibility of the measured construction workers [2]. The biggest defect of this method is low efficiency and deviation of measurement accuracy, which seriously affects the quality and cost of the house. A mixing station is a place where various raw materials are mixed in prescribed proportions [3]. Such a centralized production mode has created a premise for the automation and large-scale production of cement mixing. In the process of concrete placement, to realize the automation of concrete placement process, it is inseparable from the monitoring system of concrete mixing field. In the past, most of the cement mixing workshops were carried out by manual relays, which was not highly automated and efficient. With the progress of science and technology, through the integration of science and technology, concrete mixing device has been controllable; By controlling the mixing device, the production of concrete can be fully automatic.

Using PLC and configuration software, the whole process can be monitored in real time to achieve automatic control of concrete production. In addition, in China to high-speed railway, rail transit and other new infrastructure projects as the main content of the case, the quality and efficient performance of cement products is also increasing demand, therefore, there is an urgent need to study both accurate and efficient intelligent control of mixing equipment, in order to improve its automation [4]. After the development of relay protection, microcomputer control, programmable control and industrial PC centralized control, the production control system of mixing refinery has gradually developed into a mature fieldbus control. PLC, IPC,ET200M, field instrument, PROFIBUS and other equipment are used to form a centralized control network to meet the needs of

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multiple hybrid workshops [5]. In view of the process and requirements of a multi-machine cement mixing plant, industrial grade computers, Siemens S7-300 PLC and ET200M distributed I/O were selected to monitor the production operation of the whole mixing plant in real time in the office of the master, in which the central control room is equipped with an operation station, an engineer station and a central controller. A field network unit composed of multiple decentralized control stations is formed. With the embedded GKHNT company's industrial automatic control software WinCC6.0, CP5611 communication board and PROFIBUS communication, the real-time communication to each substation is realized [6]. Using stable and reliable PLC, MCGS configuration program, and high precision weighing instrument, a new type of automatic concrete batching control system is developed, which can make the whole process from batching, mixing to discharging to achieve automation and intelligence, and has a complete set of management capabilities such as browsing, querying, statistics and printing.

II. Intelligent system of concrete mix ratio

A. Process flow and main functional requirements

The aggregate feeding, powder storage, powder feeding, water and admixture piping, batching and discharging system, mixing and discharging system, gas path system, control system and major structural components [7]. According to the process form can be divided into single stage, double diagonal belt type and double lift three. In this case, the one-step mixing station feeds materials such as sand, stone and cement into the middle hopper on the top floor of the mixing station at one time, and then, from batching to mixing molding, it is carried out by the weight of the material itself, which is usually suitable for some large permanent mixing stations. The equipment adopts a two-stage mixing process, lifting the raw materials such as sand, stone and cement into two stages, lifting the raw materials to the middle hopper first, weighing it well, lifting the raw materials again, and then sending the raw materials to the mixing machine, which is usually used for medium and small mixing stations [8]. According to the operation concept of "one station and multiple machines", with high yield, low cost, safety and reliability as the basic requirements, a new control mode is adopted to improve the automatic regulation of the unit.

In this project, two existing control systems of mixing tower are integrated, a complete fieldbus network is built, and the whole system is centrally monitored and coordinated by GKHNT automatic control software. In this way, the same order or the work in the order can be assigned to two production lines and monitored in real time on the network. The two control modes can operate simultaneously or one machine can operate independently [9]. The cement mixture uses 8 silos, 4 kinds of stone, 2 kinds of cement, admixtures, and water. A weighing instrument is installed on each funnel, which can measure the input of each material in real time, and transmit the weighing results to the industrial control computer, which is compared with the data set, and then the motor and valve are controlled by PLC. PC can realize real-time monitoring of various process parameters, such as given set value, lead amount and cumulant amount. PLC and PLC communication, real-time monitoring, data storage and other functions. PLC is a slave machine, and the program written by Windows operating system STEP7 is used to check, debug and monitor it online or offline, so that it is easier and more reliable to complete the monitoring of the field device.

B. System Structure

According to the process of "one plant and multiple machines", scattered remote control slave stations are set up on two mixing towers to connect the data of each workshop instrument and remote control device with the monitoring data. PROFIBUS is used to connect the slave station and remote equipment to the operator station, engineer station and PLC master station of the centralized control station, and connects to the manager monitor in the station through Ethernet network, and realizes various management operations [10]. The architecture enables the two production lines to network production, data sharing and scheduling during the production process. Figure 1 shows the overall architecture of the system (image cited in Quality-Driven architecture design and quality analysis method: A revolutionary initiation approach to a product line architecture).

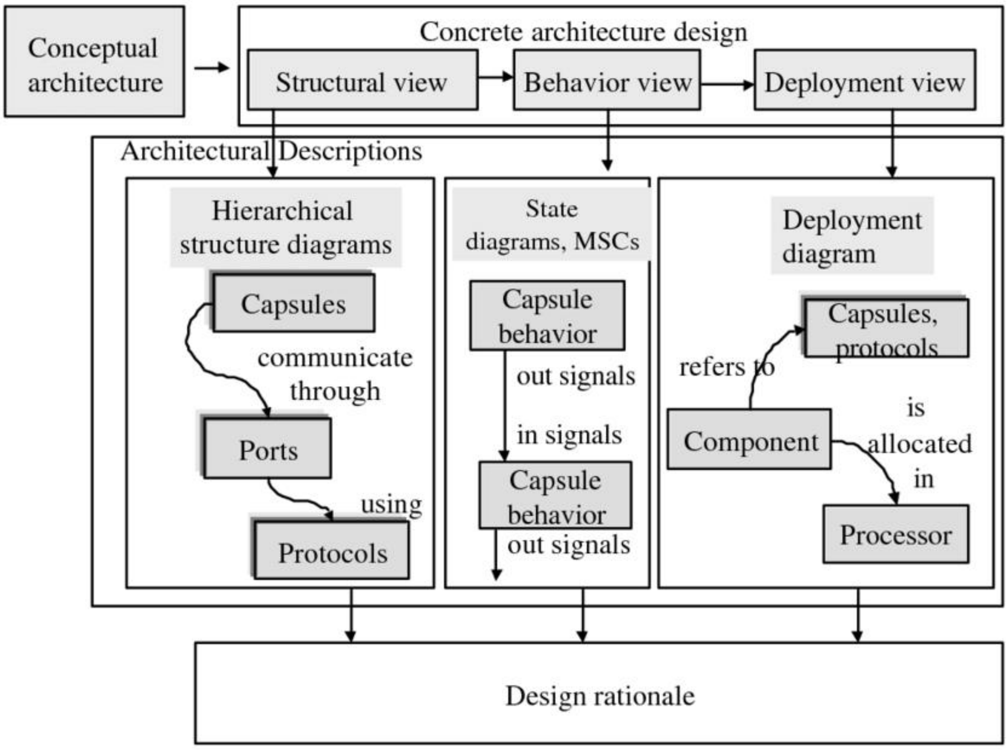

Fig.1 Overall architecture diagram of concrete intelligent proportioning system

The central control layer is centered on the host, and its function is to give the manager a good man-machine dialogue interface, so that the operator can complete the monitoring and management of the whole process correctly and timely. The central control room is equipped with operator station, engineer station and PLC master controller. Among them, the operator workstation and the engineer workstation are DPM2 secondary DP master stations respectively, and the PLC master computer is DPM1 primary primary station. The task of operator workstation is to monitor and manage the two lines in real time. The technical workstation not only has all the operation rights of the operating station, but also can set and change the system configuration and control parameters online [11]. The data exchange and monitoring between the PLC master station and the scattered PLC slave station are carried out at a certain time interval. It is divided into two subordinate control areas, which are responsible for collecting and processing the running state of the related production line, and sending the control command to each operation unit according to the operation law of the production logic to realize the related process operations. Each PLC slave station is responsible for collecting data from each sensor, controlling the remote control device, and then transmitting the data to the master computer and the host.

C. System hardware design

A new automatic control method for cement mixture is proposed. With Advantech IPC as the host, the shell is an all-steel frame, with anti-impact, anti-shock, anti-electromagnetic interference functions, built-in special power supply, anti-interference performance, the use of backplane + CPU card design, with good scalability. PLC selected Siemens S7-200 series, the series of products are characterized by: a large number of instructions, fast operation, easy debugging and troubleshooting, its terminal structure is simple, strong communication ability, but also has a variety of types of expansion modules, can adapt to different customer needs [12]. The software has the characteristics of strong programmability, simple configuration and easy installation, and can easily replace simple relay protection and complex small and medium-sized automatic control systems. By using PPI communication protocol to communicate with PC, simple and efficient data transmission is realized. Weighing instrument selected Kefeng XK3201, it has the advantages of good sealing, small size, small power consumption, easy installation, easy operation and so on. The system is suitable for harsh working conditions such as high temperature, large disturbance and high frequency switching, and has strong adaptability to various working conditions. The communication between the system and the PC is based on the master-slave communication of MODBUS. The raw material is weighed in real time by the weighing sensor and transmitted to the PC, thus ensuring the accuracy and reliability of the weighing. Figure 2 shows the hardware structure of the concrete proportioning system (the picture is quoted in Buildings 2023, 13(7), 1769).

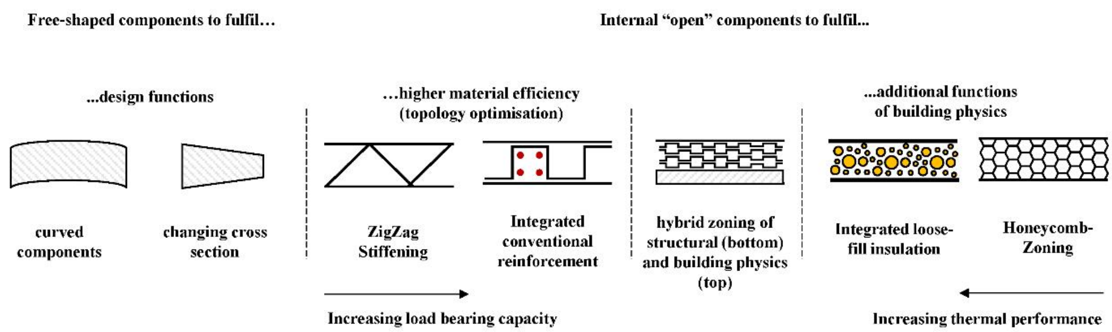

Fig.2 Hardware structure diagram of concrete proportioning system

D. System software design

1) Design of PC monitoring software

PC is responsible for communication with weighing instrument and PLC, and data exchange. You can add or change formulas at will. Since a large number of product formulas are stored in advance, the user does not have to perform any operations when selecting formulas. Categorize the various alarm types and prompt the operator to deal with them immediately through a pop-up box or warning light. The functions of data entry and query, historical data saving and query, report display and display are completed. Improve control over all stages of manufacturing by dynamically displaying the manufacturing process [13]. Manage user names, passwords, permissions and user descriptions, etc. Users must type in the correct user name and password in the login screen for remote monitoring of users and record user data to ensure their responsibility. The software flow is shown in Figure 3 (image cited in HPSA: a high-performance smart aggregate for concrete structural health monitoring based on acoustic impedance matching method).

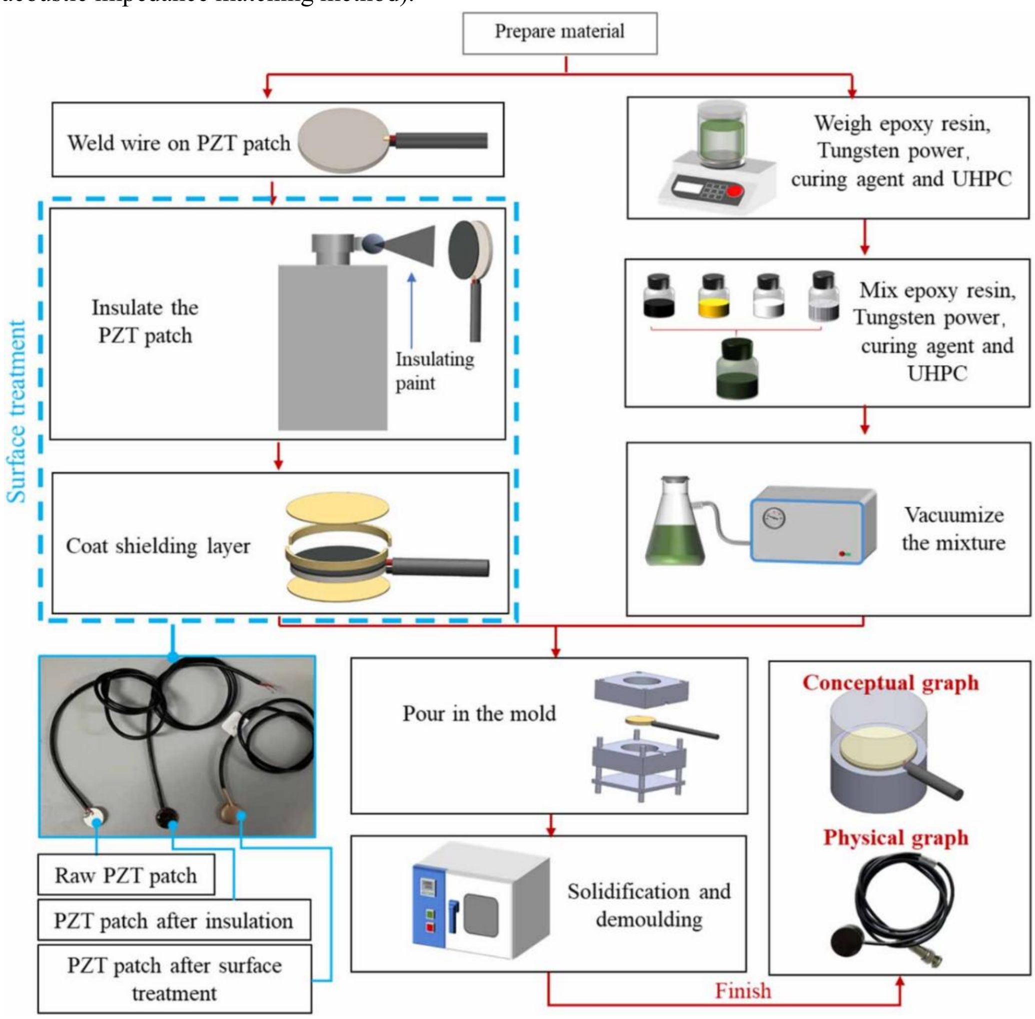

Fig.3 Flow of concrete intelligent proportioning system

2) Implementation of communication function

In the weighing process, the weighing device is collected by the controller and transmitted to the PLC slave station to realize the control of the start and stop of the relevant sensor; The remote device is connected to the programmable controller slave via decentralized input and output terminals. According to the above instructions, the lower PLC realizes the control of various devices of the mixing station and sends real-time data to the upper machine[14]. The system can be composed of multiple PCS, and it can be controlled and managed according to the working mode of Client/Server. PC is a server, which mainly completes the data transmission of multiple PCS and the communication with the lower PLC; PC is a client, it usually does not communicate with the PLC, but through the access to the server to achieve the acquisition of data and save in the server database. In this scheme, the actual control of the whole system is realized by the technician workstation or the administrator workstation. For example, the setting of ingredients parameters, the setting of work orders, startup, shutdown, etc.; And some PCS can only carry out information query, report printing, real-time monitoring and other functions, can not directly participate in the production. Table 1 shows the composition of the data.

Table 1. PPI communication protocol data composition format

SD	First symbol
LE	Data length
LEr	
SD	First symbol
DA	Destination address
SA	Source address
FC	Function code
DSAP	Destination service access point
SSAP	Source service access point
DU	Data unit
FCS	Check code
ED	terminator

The data length here is from DA to DU. The starting symbol is 68 H; The read and write function code is 6 CH,7 CH, and the termination code is 16 H. The communication between the computer and the electronic scale uses MODBUS communication, and the working mode is RTU,8 bytes. The specific composition is shown in Table 2.

Table 2. MODBUS communication protocol

byte number	1	2	3	4	5	6	7	8
significance	Device address	Function code	Register address		Data area		CRC check	

E. Animation Configuration

In order to understand the actual production status of the mixing plant system in real time, the system makes full use of the animation configuration function of MCGS, and makes the operator accurately grasp the working status of the actual site by synchronizing the animation between the upper computer and the actual production process [15]. Using the existing elements in MCGS library, the main structure of ZS60 mixing plant is simulated through a variety of combinations, and the corresponding variables are defined for the elements in the real-time database and connected with the DI signal of the lower machine, so that the animation is synchronized with the actual production, and the monitoring function of the upper computer is also realized. The picture after configuration is shown in Figure 4 (the picture is quoted in Mathematics 2023, 11(6), 1499).

During the establishment of the configuration screen, a display bar was added to the right of the storage funnel to facilitate observation of the amount of material in the bin and prevent excessive aggregate from leaking out of the storage hopper, and a weighing screen was also added to monitor the actual weight of the material. During the operation of the device, the sand and stone stored outdoors are fed into the corresponding storage bin through a threaded feeder [16]. When the weighing is complete, the gate at the bottom of the storage bin is opened, it is unloaded, and the material is transported through the lower part of the storage hopper to the sand mixer. At the same time as the powder is weighed, the powder is fed from the steel warehouse through a screw conveyor into a temporary weighing silo, and it is measured. When the measurement is over, the device sends out a feedback signal, which is processed by the CPU and sends out a starting air valve, and the powder in the storage funnel goes into the blender. The water extracted from the pool by the pump is measured by the flow meter and then passed through the pipe into the agitator. If the sensor measures a predetermined value, it stops and automatically closes to prevent the backflow of the measured water, which adversely affects the collapse rate of the concrete. After the mixer is stirred for a certain time, the material can be stirred [17]. At this time, a control signal is issued by the system to lower the agitator, and when it is lowered to the lowest point, it hits the limit switch below. The feedback signal is transmitted to the CPU, and the CPU sends a control signal to control the stirring lift motor. At this point, the mixer is released, and then, at the end of the discharge, the system sends a feedback, causing the mixer to rise, stopping when it reaches the upper limit, ready for the next stage of production.

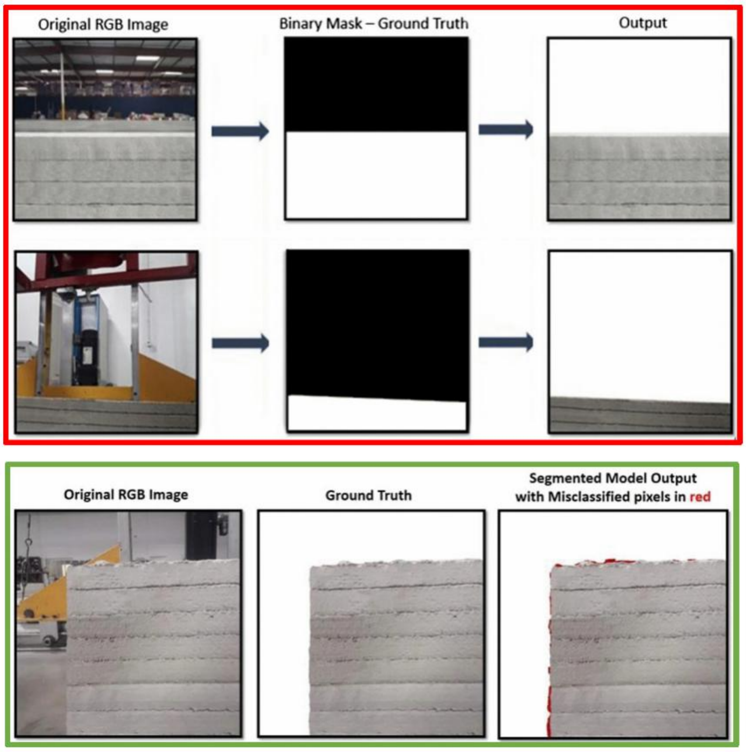

Fig.4 Control window of automatic concrete proportioning system

The alarm screen will have the exact time of the alarm and the corresponding parameters, so that the operator can have a real-time understanding of the operating status of the system, if there is a variable of the operating parameters and the preset value is very different, more than the predetermined value, then the alarm will be issued, so that the operator can quickly find the problem. And can quickly find out the cause of the failure, so as to facilitate maintenance.

Among them, the graph drawing methods are: dynamic graph and historical graph. Real-time measurement data chart, in an intuitive way to directly reflect the dynamic changes of various raw materials; Historical measurement data chart, used to reflect the quality changes of each raw material of cement products [18]. The different colors to distinguish it from other curves for easy identification. After establishing the configuration interface, the animation interface of each function is set up, and the command language is programmed to complete the operation of the screen. Using the workflow oriented design idea, it can generate the human-machine interaction interface that meets the actual production needs and has good visual effect, and realize the intuitive and intuitive reflection of the field equipment. Through the software keys of the upper computer, the valve, water pump, mixer and other equipment can be controlled.

F. Implementation of functions

Among them, the feeding process is the most critical step, mainly through the PC and PLC to achieve. The system adopts two stages of initial fast feeding and late slow feeding to reduce the falling error caused by large impact. After parking, due to the characteristics of the material itself and the speed of the valve and motor, the final measurement results will be affected [19]. By analyzing and processing the errors in the past, forecasting the errors in the future, and compensating in advance, the amplitude of the real weight is very small on and below the given value, and with the multiple times of weighing, the real value is also closer and closer to the set value. The specific feed control algorithm is shown in Figure 5 (image cited From waste to food: Optimising the breakdown of oil palm waste to provide substrate for insects farmed as animal feed).

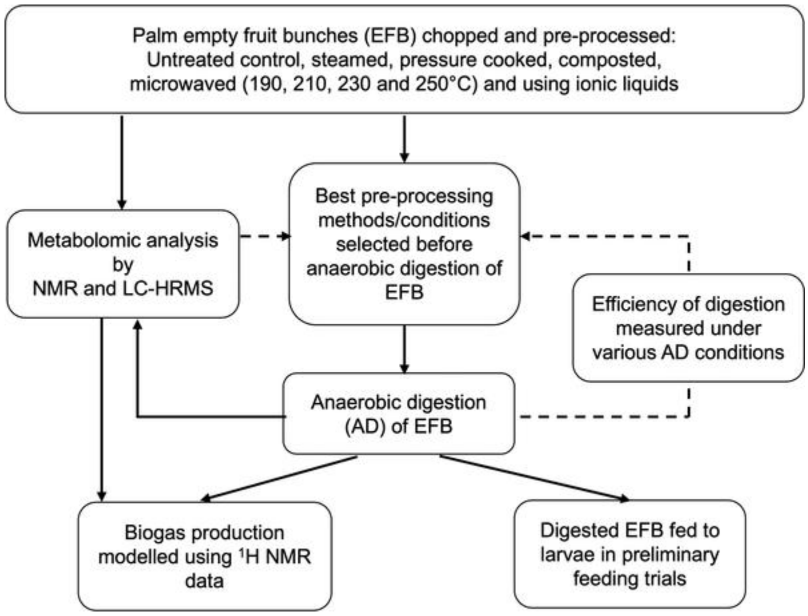

Fig.5 Feed control flow chart

Among them, the main work includes some main modules, such as: the main program OB1,FB1,FB2 and so on. The main process determines the work at various time points from start to end, and its function is to control each motor and valve [20]. When there is an anomaly, the system will cut off the coal blending process in time, and alarm. The outputs the instructions to various actuators, such as solenoid valves, motors, etc. Its Control flow chart is shown in Figure 6 (image referenced from Automated Control of Plasma Ion-Assisted Electron Beam-Deposited TiO2 Optical Thin Films).

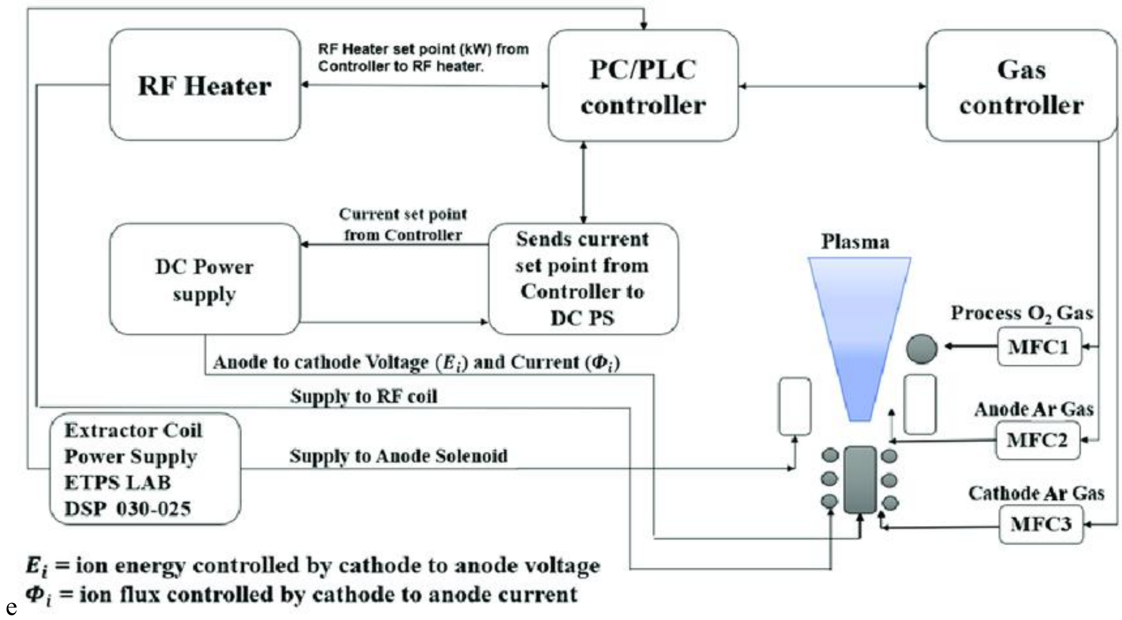

Fig.6 Control flow of programmable controller

III. The prediction equation of concrete performance is established by multivariate nonlinear regression method

A nonlinear model based on multiple variables is proposed on the premise that the types and quality characteristics of raw materials do not change [21]. Using the Taylor series of computing methods, the paper uses polynomials to approximate any nonlinear equation with multiple differentials in the range of its independent variables:

$$f = g(0) + g(0)\cdot t + \frac{g^{n}(0)}{2!}\cdot t^{2} + \cdots + \frac{g^{n}(0)}{n!}\cdot t^{n} + \cdots$$

Now let f and $t_1,\cdots,t_t$ be the amount of various raw materials:

$$R(f\mid t_1,t_2,\cdots,t_t)=\lambda_0+\lambda_1\cdot g_1(t_1,\cdots,t_t)+\lambda_2\cdot g_2(t_1,\cdots,t_t)+\cdots+\lambda_n\cdot g_n(t_1,\cdots,t_t) \tag{1}$$

Where all $g_i(t_1,\cdots,t_t)$ are determined nonlinear functions of the independent variable $t_j(j=1,\cdots,t)$, in order to simplify the calculation, take C as a quadratic polynomial, then equation (1) can be rewritten as

$$R(f\mid t_1,t_2,\cdots,t_t)=\lambda_0+\lambda_1 t_1+\cdots+\lambda_t t_t+\lambda_{t+1}t_1^2+\lambda_{t+2}t_1t_2+\cdots+\lambda_t+\eta_t^2-1t_{t-1}t_t+\lambda_t+\eta_t^2 t_t^2 \tag{2}$$

Considering that not all functions g_i of the independent variable in equation (1) have a significant effect on the dependent variable f, the effect of some of these components is insignificant. If the above factors are included in the regression model, it will not only increase the calculation amount, but also increase the error, reduce the accuracy of the prediction, and have an adverse impact on the stability of the model. Therefore, g_i can be screened by stepwise regression method to form the optimal regression equation.

IV. CONCRETE MULTI-OBJECTIVE OPTIMIZATION MODEL AND ITS SOLUTION

For different types of concrete, its performance design requirements are different, and the selection of restraint system should also have elastic changes. For some specific problems may be goals, but may be limitations, it is better to be able to choose each other. The multi-objective optimization process is shown in Figure 7 (the picture is quoted in Journal of Cleaner Production, 2021, 39:129665.). The project plans to use the multi-objective flexible modeling method, through the selection and synthesis of multiple targets, and take them as targets or constraints to select and combine [22]. The multi-objective optimization problem is studied by using hierarchical sequence method, evaluation function method and target point method. Here the paper chooses a method to evaluate the function, which is called "ideal point method".

$$y(H(t))=\left[\sum_{i=1}^{t}(f_i(t)-f_t^*)^p\right]^{\frac{1}{p}} \tag{3}$$

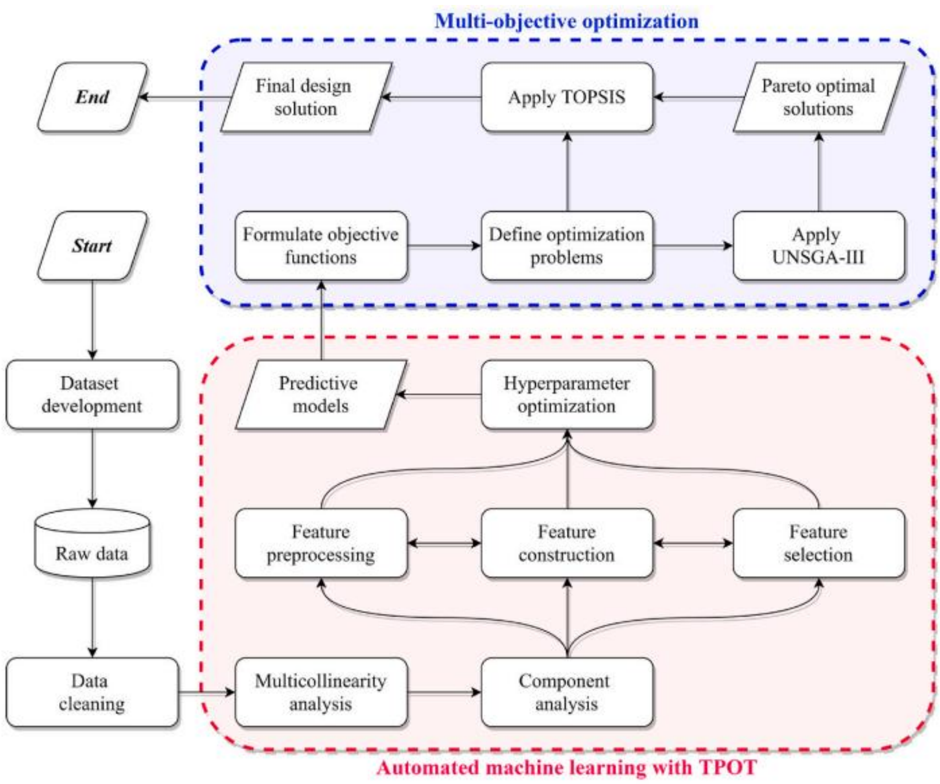

Fig.7 Multi-objective optimization process of concrete

f_t^* is the ideal value of each sub-objective function, which can be the minimum value obtained in the single objective optimization, or can be given according to specific requirements. p is an integer greater than 1, and when $p=2$, the right end of equation (3) is the Euclidean distance. The vector $[f_1^*, f_2^*, \cdots, f_t^*]^T$, the "ideal point" of the image set, is generally not in the reachable domain, but only as close as possible. In this project, an optimization design method based on mechanical parameters of concrete is proposed and applied to practical engineering. In this way, the searching distance is shortened and the optimization is accelerated. The different restrictions and their standard formats are listed below:

1) Concrete performance requirements in addition to optimization objectives

$$f_i(t) \le f_i^*; i = t+1, t+2, \cdots, m \tag{4}$$

2) Water binder ratio

$t_\varphi, t_c, t_\upsilon$ is the amount of water, cement and admixture in concrete per unit volume, then the water-binder ratio constraint can be expressed as

$$t_1 \le t_\varphi /(t_c + t_\upsilon) \le t_e \tag{5}$$

Where: t_1, t_e is the lower and upper limit of the water-binder ratio respectively.

3) Concrete bulk weight

Set the lower and upper limits as D_1, D_e respectively, and record the amount of various raw materials as t_i, then

$$D_1 \le \sum_i t_i \le D_e \tag{6}$$

4) Sand rate

The amount of sand and stone is represented by t_s, t_g respectively, and the upper limit is set as Q_1, Q_e:

$$Q_1 \le t_s /(t_s - t_g) \le Q_e \tag{7}$$

5) Raw material consumption

If the amount of raw material is denoted as t_i, then $t_{i,1} \le t_i \le t_{i,e}$. Complex method can be used to solve the ideal point method of multi-objective optimization. The coordinates of the first vertex in the initial complex are given first, and all the constraints are satisfied. Then, by moving, deforming, rolling and shrinking the complex, the minimal point of the function is approached step by step. When the difference between the current and the last calculation results reaches the given accuracy requirement, or the number of iterations reaches the predetermined maximum number, the end operation outputs the optimization results.

V. System operation and debugging

RS232 serial port is used to communicate with PLC, and ladder diagram software is imported into PLC, and then the main screen of "Monitoring System of concrete mixing station" is opened. When the mixing station is made of cement according to the pre-set formula, water, cement and additives are transported to the mixer, the mixer is stirred, and the raw materials used to make cement are fully stirred. At the other end of the mixer, sand and stones are transported to the corresponding funnel through the conveying device, and the quality of the measured substance is monitored through the weighing sensor at the bottom of the funnel. When the weight of sand and stone is weighed, the control system separates the two conveying mechanisms, and controls the rate of conveying material through frequency conversion speed regulation, which can shorten the measurement time and increase the precision of weighing. When its quality reaches a certain degree, the corresponding funnel opens the corresponding valve, pours the sand and sand together on the belt, and then the raw materials are sent into the blender by the belt, and the blender always maintains a good working condition. After the mixing is completed, the mixed cement is unloaded to the pre-prepared conveying device, and during this period the discharged cement is uniformly discharged, and after the unloading is completed, the operation of the next cycle is carried out.

VI. Conclusion

This kind of cement mixture control system will PLC high reliability, perfect function, product standardization, simple and direct program characteristics play incisively and vividly, it can be a good solution to the lack of reliability of relays and microcontrollers, combined with industrial computers, easy to operate and manage. The system has the characteristics of uniform batching, smooth operation and easy operation. The use of frequency conversion feeding method and high-precision electronic scale can make high-precision automatic batching and fully automated control, so that the work efficiency has been greatly improved, but also to reduce the labor intensity of workers, thus saving labor costs, produced a good economic benefits.

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