An Intelligent Control System for Complex Grinding Processes

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Abstract — **The beneficiation process contains a number of links which are closely related to all aspects of the quality of products in a process which has a direct impact on the next one, thus influencing the product quality of all processes. Grinding operations form a critical stage in the middle position of the beneficiation process and is the most important part. Grinding operations here refers to ore processing to meet the requirements of smaller particles,- the purpose is to make all or most of the ore to reach monomer separation, and flotation to provide a stable product for the next job with strict overflow granularity. But grinding processes involve complex, large equipment, not easily manipulated, influenced by many factors, and coupled with the objective it is clear the grinding operation is difficult to achieve the desired working condition. Therefore, automation control of the grinding and classification operations become an important research topic. In this paper, the background to grinding and classification control is given first, followed by an analysis of the grinding process details to describe the basis of priorities, difficulties and complexities of control and the proposed programs to use intelligent fuzzy logic as the core technology.**

Keywords -- Grinding Process; Grinding Classification; Intelligent Control; Fuzzy Logic

I. INTRODUCTION

Target grinding process by changing the amount of water and given to the ore, so when the mill production to Taiwan to achieve optimal, and the concentration and grading overflow granularity to meet the requirements. In the grinding and classification process, to return the amount of sand ore, ore properties, the amount of discharge of the mill, classifier, return sand water, mill speed, medium filling rate, filling rate of ore, lining condition and ball mill charge ratio, etc. can affect the production and grading overflow concentration and particle size [1]. Due to the variability and randomness of the above factors increased the difficulty in controlling grinding and classification process. External conditions ore properties, mill speed, ball bearing and lining case situation, these factors can only comply with the objective facts, the automatic control system cannot be adjusted [2-3]. However, if the above-described circumstances completely ruled out to implement a control, it is obviously not feasible. Due to the nature of the ore may change at any time, any change will result in damage to the system equilibrium. It is possible to automatically analyze the nature of the ore changes, and make the appropriate adjustment is a function of the system must be controlled.

The main purpose of the grinding job is to process the ore into smaller particles, so that it is at or near the state of monomer separation, this process is to be mined ore into a final product in multiple processing of the most important steps working the stability of the process, the overflow particle size is checked so directly affect the subsequent sorting operations production targets [4]. Grinding and classification in itself is an extremely complex system, shown in Figure 1 is currently the most widely used one-piece grinding process.

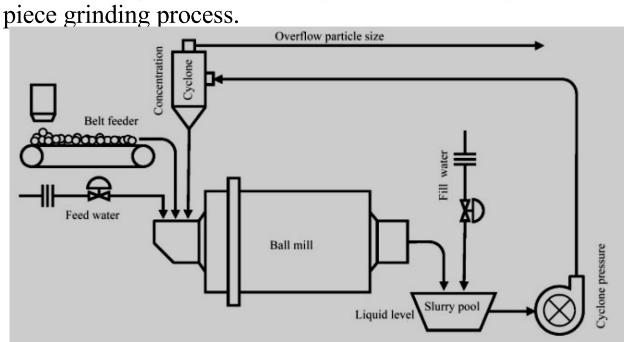

Figure 1. Grinding and classification process.

The whole process is actually the interaction and flow between the ore, water (water front, additional water) and the grinding media. Therefore, its implementation can be summarized as automatic control of ore, water and grinding media control. Throughout the grinding and classification process is a continuous, cyclical process, involving many parameters, including: the amount of ore, feed water, slurry tank liquid level, additional water, the concentration of the cyclone, swirl pump pressure, size, return the amount of sand and the like. Due to the many parameters measuring methods vary, resulting in a time measurement data with dynamic uncertainty, and also has a strong coupling between these parameters, which gave control of the grinding process has brought great difficulties. In this paper, the actual concentrator project background, discussed in detail the

DOI 10.5013/IJSSST.a.17.18.18 ISSN: 1473-804x online, 1473-8031 print

application and algorithm based on fuzzy logic in grinding intelligent control system.

II. CONTROL OF GRINDING AND CLASSIFICATION

Grinding jobs are in the process of crushing the most important aspect of it is the crushing process continues, ore grade during the last pre-processing, classification in fact, in each of the ore with the ingredients separated from the current classification method magnetic separation, flotation and the like. The project grinding method using a ball mill, flotation and grading methods. Grinding operations associated with the great job grading, grading the quality of work indicators, it depends largely on the quality of ore grinding operations [5-6]. Grinding operations to comply with the required fineness grading operations, all the ore has a grinding fineness economy, • the fineness should be strictly controlled, appropriate grinding is often the key to effective implementation of dressing, grinding will be inadequate so that products are too thick, the degree of dissociation is not sufficient for economic separation, mineral recovery and enrichment rate is not higher than the mill is wasted valuable energy and mineral ground to a particle size less than the most effective method to sort out the required such cases are not allowed. In addition to size, the grinding operation but also to meet the required concentration of grading operations. Appropriate concentration range of various grading operations has its requirements, too low will not work, especially in the flotation operation, ore flotation tank to a stable concentration has an important influence on the flotation and concentrate grade.

Grinding and classification is a complex process, changes in the nature and quantity of ore and all kinds of external disturbances caused by the difficulty of grinding and classification operations, there may be some problems milling grade units in operation, as in the hour of interference in efficiency low state interference in the process of ups and downs of the job is large, ball mill bloating or empty, it is running rough or graded sand return excess and even a vicious circle. How to make grinding and classification operations to maintain stable operation under disturbance conditions, the production process is an urgent need to solve the problem. Since the grinding and classification random interference factors, long process, big lag, the need to control multiple parameters and associated large. If only a single control of each sub-process can be formed several independent closed-loop system, only to achieve a stable level, the unit cannot fully utilize the efficiency of the whole process must be integrated control [7-8]. Comprehensive analysis of the grinding process, the project team made grinding and classification system overall structure shown in Figure 2..

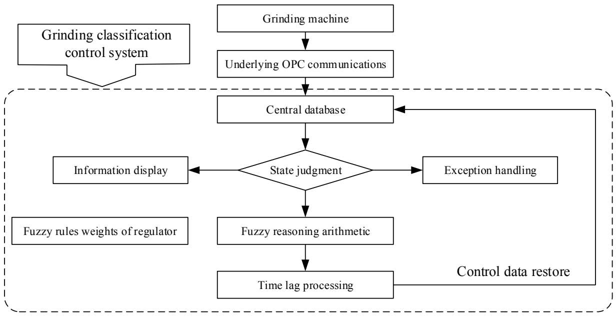

Figure 2. Grinding and Classification System control.

Due to the nature of ore into the mill and change in particle size, water pressure fluctuations and other factors have caused the production process grinding and classification recurrent or even a significant disturbance, it is difficult to detect and overcome these disturbances under the conditions of manual operation, timely adjustment of operating conditions. Automatic grinding mill control system is likely to cause overload or under load, chestnut pool installed mine spill, the pump surge, resulting in grinding and classification process of production instability, not only affects the output of the mill and reach the size classification overflow process requirements, but also directly affect the stability of the subsequent sorting process, affecting the yield and quality of the final product. Concentrator grinding process for the key features of automatic control of grinding mill is at medium filling rate meet the technical requirements of the premise, to control the amount of ore to the mill, the mill the ore loading is always at the right within range, to prevent mill overload or under load, to ensure grinding size and export capacity allows subsequent sorting process conditions appropriate increase capacity of the mill. Ore concentration mill fitted within the control within a range of process requirements. Spring period of pool pump outlet concentration is controlled within the range of process requirements.

III. RELATED INTELLIGENT CONTROL TECHNOLOGY

While industrial production technology continues to progress, control theory also continues to develop, especially in the upgrading of the computer, is to promote the control technology continue to move forward. Control Theory discipline has 70 years of development history, in which the current phase is the intelligent control theory advanced stage following the classical control theory and a third after the main stages of modern control theory, but also the development of automatic control. The creation and development of intelligent control theory is artificial intelligence, knowledge engineering, pattern recognition, cybernetics, systems theory, information theory, bionics, a variety of cutting-edge height neurophysiology, evolutionary computation and computer science disciplines, advanced technology and scientific methods synthesis and integration, is an emerging interdisciplinary edge [9-11].

1) Fuzzy control. Traditional control strategies are usually needed to develop a mathematical model of the

DOI 10.5013/IJSSST.a.17.18.18

ISSN: 1473-804x online, 1473-8031 print

object to be controlled, but with the increasing complexity of the controlled object, especially the non-linear system, you want to establish a precise mathematical model has become a very difficult task. Work in practice, it was noted that the operator can by virtue of their wealth of experience good control of this complex system. In the concentrator, for example, the operator can by hearing, seeing, touching hands and manual sampling to determine the working status of the mill, and then adjust the corresponding parameters of the system based on the experience of working in a stable state. This suggests that the human brain has the good judgment and the ability to blur the process, if you can mimic the human brain way of thinking the controller design can be achieved on the control of complex systems, which give rise to a fuzzy control.

2) Neural Network. Neural networks have decades of history, the main idea is to mimic biological systems work of neurons, with parallel processing, pattern recognition, adaptive, memory and other features. Neural network control neural network theory is introduced to control which areas, from the operating mechanism of the human brain to simulate a simple structure, so that it can learn and adapt to the complex and uncertain system. Neural network control using parallel and distributed information processing, has strong robustness and fault tolerance, the current application in the field of control has been involved in various aspects, including nonlinear system control, optimization, and control system is the system fault diagnosis and fault tolerant control. With the further development of neural network theory and the theory itself and related technology, applications of neural network control will be more broad.

3) Genetic Algorithm. The genetic algorithm is based on the global principle of natural selection and genetics of adaptive probabilistic search optimization method, it is the theoretical basis of Darwinian evolution, by using a computer simulation of biological evolution mechanism is proposed for solving complex optimization problems common framework . Genetic algorithm does not depend on the specific problem areas, global convergence J risk and parallelism, wide applicability and requires less priori knowledge.

IV. FUZZY CONTROL MODEL AND IDENTIFICATION PROCESS

Industrial automation, process automation proceeds slowly, owing to the continuous process, the case of more advanced forms of exercise forms, inhomogeneous internal effect, superposition, more intense interaction and coupling, at the same time, due to the large production of large random disturbances , complex process mechanism, etc., resulting in process control mathematical model is difficult to complete the online application to obtain. Therefore, in order to be able to effectively control complex production process, we must continue to learn and master the process mechanism, combined with experience constitute the original artificial intelligence expert systems, and by generating or learning system, against the actual production process continuously changing, improve and expand, thereby build up experience-based expert system. Production or use of learning system to determine the process deal with the problem, and the original knowledge feedback correction, which is intelligent fuzzy control.

Fuzzy control is an analog fuzzy reasoning function of the human brain has, fuzzy math, simulate human thinking. The transformation of control strategies people use natural language to fuzzy control rules, as the input and output fuzzy sets, fuzzy inference method for processing according to the process of determining the amount of the fuzzy control. Fuzzy model is a rule-based fuzzy inference system is based on fuzzy set theory, fuzzy rules and fuzzy inference computing model is a description of the fuzzy logic propositions. This article is a study of this type of problem learning system, collectively referred to as fuzzy model. one. The basic structure of fuzzy model fuzzy model shown in Figure 3. Model realized from the clear input to clear output nonlinear mapping, the mapping is complete a set of fuzzy rules, each rule describes a local mapping behavior.

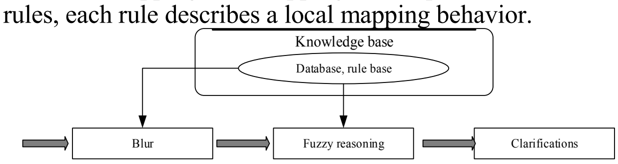

Figure 3. The basic structure of fuzzy model.

Fuzzy modeling is in the process of the given object input and output data expected behavior under the premise of the fuzzy inference system configured to obtain object. Fuzzy modeling is often seen as gray box modeling, fuzzy gray box modeling mainly reflected in: First, the rules of natural language structure and fuzzy reasoning model is particularly suitable for the employer, it is easy to be experts in relevant fields About knowledge used directly in the modeling process; additional models can be extracted and interpreted by the model shown objects of knowledge. Gray box is the point of difference with other models fuzzy modeling established when there is an object-oriented complex input / output relationships, fuzzy model parameter identification requires a lot of expertise in the field at the same time for the system is also difficult to meet the requirements at this time We need analysis to identify historical sample data obtained fuzzy model object, shown in Figure 4 which identification process.

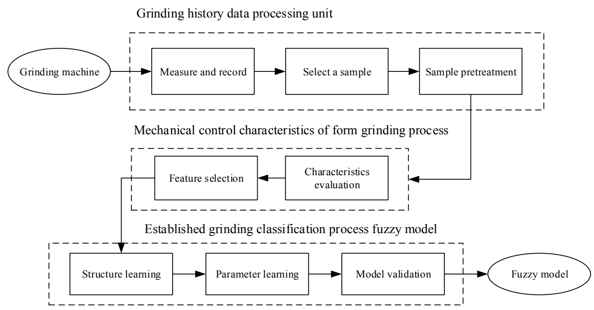

Figure 4. The process of fuzzy model identification.

The so-called structure identification is through large amounts of data analysis and processing, the system determines the best representatives of input and output variables; and parameter identification is passed to the data processing system to determine the parameters with each unit expression. In practice, in order to obtain the fuzzy model to meet the requirements of each step in the figure can be classified using a variety of clustering algorithms and neural network approach; between steps can also be integrated into a complete learning algorithm under. To create an object model of the most important preparation is to obtain historical data typical sample, these data objects need to fully reflect the operating mechanism in various states. After obtaining the data, to carry out the corresponding pre-processing to ensure the integrity, fault-tolerance data, were in favor of feature extraction. Fuzzy Control feature extraction in the modeling process is the key. Usually by cluster analysis to obtain the input and output of the corresponding feature, this method can be combined with expert knowledge to guide. You can use data mining techniques to obtain input and output implied logic, extract a new control features. Structure and parameter learning model is a broad concept, different objects and application objects, may take different forms and different model of learning. Models of different application purpose of their verification in different ways, such as for approximation and prediction models to verify the validity of the model is to verify the accuracy of the test samples for classification and decision-making model for the correctness of the test sample.

V. GRINDING CLASSIFICATION MODEL BUILDING

The objective of this section is to derive a stationary state of the abrasive particles linear model. Suppose particles dispersed valuable material worthless material. Mill production of valuable materials reduce the size of the particles and the liberation of worthless material at break. Development model shows the change in the size of the solid particles into the mill equipment, and the liberation of valuable material encapsulated in the particle due to the intimidation. Careful composition and size, and a parameter used to quantify the level of intimidation group particles. The model must be simple it can be included in the synthesis problem. Particle grinding equipment may enter in the composition and size of the class described can represent these classes set K = {K / K} class composition and J = {J / K size class} sets may consider mixing, particle composition, particle-based chemical heterogeneity, set the size in the range of J class material flow (J = approximately) from a maximum particle size (J = 1) minimum sizes. For simplicity, here belong to k particle composition and size class j abbreviation (k, j) particle class. Demographic balance exercise machine and grinding K and J can be represented by Figure 1, the green and yellow colors represent different materials, for example, green may represent a valuable component, and the yellow represents the gangue. In Figure 5, non-liberated particles class mark (k, j) are receiving the same type of material composition, while the material (k, j) can give other materials of different size classes and class composition. Set K and J as a discrete set after milling to allow the maximum size of the material remains.

The purpose of this section is not classified by linear models and hydropower cyclone, obtained using a model mill grinding circuit. Model requires grinding circuit is included in the flotation circuit synthesis problems, they can be deduced define each semester according to the circuit, and the residence time using an expression for each class mill (k, j). In this part of the first phase of the deduced model mill, then grinding-classification circuits. There are a variety of configurations, grinding and classification circuit shown in Figure 6. Figure 6 illustrates the mill not classified, and Figure 6 b and c show the use of hydropower classification cyclone direct circuit (Figure 6 b) and the inverse circuit (Figure 6 c). D represents a combination of the first two circuits of Figure 6. These circuits are used for grinding mineral processing plants before the solid phase solid phase separation, including separation of the flotation plant to improve the metallurgical properties.

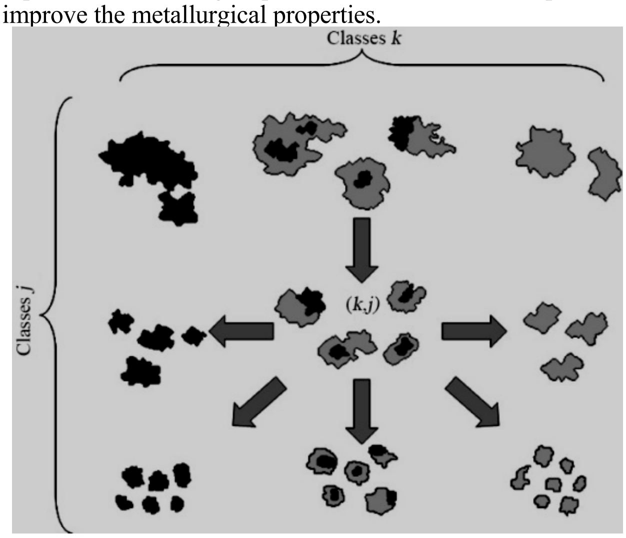

Figure 5. Scheme of grinding effect on both size and composition distribution.

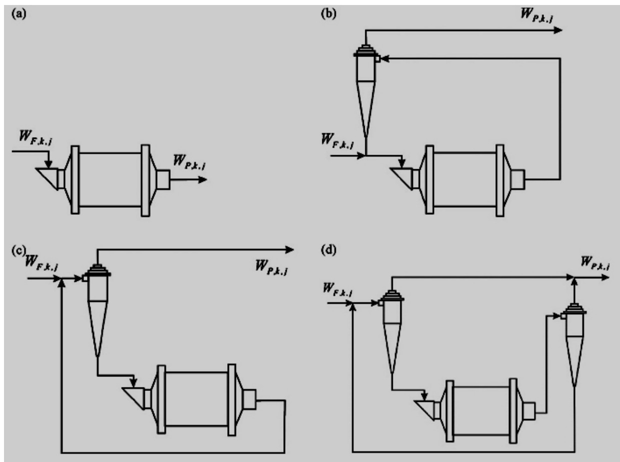

Figure 6. Grinding-classification circuits studied.

VI. SIMULATION OF GRINDING AND CLASSIFICATION PROCESS

Previous work, we use the ideas of fuzzy control for grinding process control. First, the entire grinding and classification process to be divided, for the number of working units obtained according to the process target, independent closed-loop control. Traditional closed-loop is divided into: work unit to process ore, pulp and pulp processing work unit classification process unit of work. Essentially, fuzzy control system is a rules-based system. Anthropomorphic method is a summary of these fuzzy rules from experts or working experience of the operator were out, so compared to the traditional two-valued logic, fuzzy control system makes these human experience are fully utilized, and close to human thinking and natural language more easy to be generally accepted and understood. On the other hand, the expertise is not the system, we must consider whether these expertise includes all situations. In addition, these experiences, there are some subjective factors, it simply depends on human perception and experience often lead to some serious problems.

According to the external characteristics of a typical ball mill, grinding and classification process to consider the following:

$$\begin{cases} x_1(k+1) = -0.3x_2(k) \\ x_2(k+1) = 0.2x_1^2(k) + 0.7x_2(k) + u(k) \\ y(k) = x_1(k) \end{cases} \quad (1)$$

Where, y (k) as the controlled parameters, that characterize the sound of the grinding mill filling rate, u (k) for the control parameters, namely the grinding amount. x (k) is the state variable, its initial state is 1x(0)=0，2x(0)=0.

In the space of possible output systems, select 4: 12y=0,y=1,， 34y=2,y=3, respectively, to characterize four types of ore (hard grind, grind harder, general grind ability total 4 balance point. Balance around these four points to give four linear model:

$$\begin{cases} x_1(k+1) = -0.3x_2(k) \\ x_2(k+1) = 0.7x_2(k) + u(k) \\ y(k) = x_1(k) \end{cases} \quad (2)$$

$$\begin{cases} x_1(k+1) = -0.3x_2(k) \\ x_2(k+1) = 0.4x_1(k) + 0.7x_2(k) + u(k) - 0.2 \\ y(k) = x_1(k) \end{cases} \quad (3)$$

$$\begin{cases} x_1(k+1) = -0.3x_2(k) \\ x_2(k+1) = 0.8x_1(k) + 0.7x_2(k) + u(k) - 0.8 \\ y(k) = x_1(k) \end{cases} \quad (4)$$

$$\begin{cases} x_1(k+1) = -0.3x_2(k) \\ x_2(k+1) = 1.2x_1(k) + 0.7x_2(k) + u(k) - 1.8 \\ y(k) = x_1(k) \end{cases} \quad (5)$$

Take reference input

$$y_r = \begin{cases} \sin(t), & 0 \le t < 100 \\ 2\sin(t), & 100 \le t < 200 \\ 3\sin(t), & 200 \le t < 300 \\ \sin(t), & 300 \le t \le 400 \end{cases} \quad (6)$$

At t = 100 when the reference input becomes twice the original; when t = 200 when the reference input becomes three times the original; when t = 300 when the reference input back to the original reference input. In this paper, using the control input and output of the algorithm shown in Figure 7.

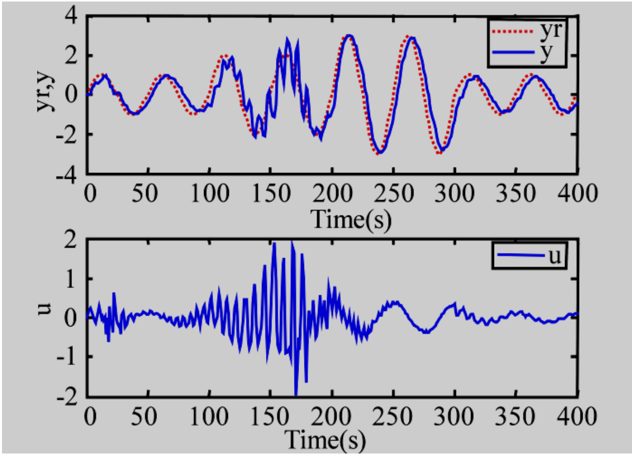

Figure 7. Input and output system.

VII. CONCLUSION

Grinding classification process is a typical complex system, grinding and classification system, effective control has been automated concentrator a hot and difficult. Grinding classification process is an important mineral processing industry, production processes, product size control its effects directly affect quality and efficiency of the flotation concentrate product recovery operations. Therefore, the use of advanced intelligent control technology to ensure its product size qualified premise of improving grinding and classification of production efficiency, reduce production costs for enterprises to improve beneficiation economic efficiency and enhance market competitiveness in the process of grinding and classification has important practical significance. This paper combines Concentrator grinding operations intelligent control system development projects to expand research. By principle and grinding and classification system operating characteristics analysis of grinding and classification system, according to the process of grinding and classification process characteristics, combined with on-site grinding and classification equipment actual situation to determine the grinding and classification process intelligence control system design, has a strong practical value.

ACKNOWLEDGEMENTS

Hebei province department of project,Item number: 15211607.

Langfang city technology bureau project ,Item number: 2014011032.

Langfang normal university project ,Item number: LSLQ201412.

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