The intelligent monitoring of powder material extraction production process

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Abstract. Deep processing of rare earth powder materials is a traditional labour-intensive industry, and low production efficiency and poor production environment are prominent problems. With the development of wireless communication, low-power chips, artificial intelligence and other technologies and the reduction of its cost, it has provided favourable conditions for the traditional industry to achieve intelligent monitoring and intelligent fault detection to catch up with the current trend of intelligent industrial development. By analyzing and comparing various current intelligent algorithms, it can be applied to the powder material extraction production process, which can improve the automation degree of the extraction production process, reduce resource waste, save costs, and make the production operation more economical and effective.

1. Introduction
For mineral resources development and production enterprises, the extraction process of powder materials is still relatively low in automation, mainly relying on manual operation, off-line analysis, component detection, manual control¹, low production efficiency and high production cost, resulting in a lot of waste of resources. Today, automation, sensors and network facilities are rapidly evolving, providing more convenient conditions for data acquisition. Combined with the complex problems of complexity, uncertainty, strong coupling, large hysteresis, and difficulty in continuous measurement of extraction component content in the production process of powder material extraction process², the fault intelligent monitoring of powder material extraction production process is proposed.

In the rare earth extraction production process, the key process of extraction is the dissolution of the extractant and the extracted elements, otherwise it will cause quality accidents and waste resources. There are many factors that cause incomplete dissolution, for example, the slip of the belt and the abnormal operation of the stirring motor will cause a quality accident; When the stirring motor stops, it will affect the continuous extraction process and cause serious production accidents, affecting production. Therefore, effective fault monitoring for the production process is the guarantee of production quality and safe production.

2. Rare earth extraction production process
Rare earth elements are located in the IIIB group in the periodic table. In the same family, due to similar electronic structures and similar chemical properties, there are also commonalities between different
elements, which makes the preparation and extraction of elements difficult. In the 1970s, Xu G. X. proposed the theory of cascade extraction, which laid a theoretical foundation for the development of the rare earth industry [3]. With the development of science and technology, Professor Xu G. X., through a large number of computational reasoning, finally made a relatively large breakthrough, and obtained a series of theories more applicable to the process of rare earth extraction [4].

The extraction theory of elements is mainly based on the solubility of the same element in different solvents, the mixture is dissolved in the solvent, and the solubility of different elements in the same solvent is different. Based on this theory, the rare earth extraction production process is proposed. Figure 1 is a process flow diagram of rare earth extraction.

![Figure 1 Process flow diagram of rare earth extraction](image)

The production line of rare earth production is composed of a plurality of extraction tanks in series, and different production stages are processed in different production stages to form a rare earth cascade extraction system [5]. In the production line of rare earth extraction, the extractant and the feed liquid are fully contacted under the agitation of the mixer, so that the extracted element can be sufficiently dissolved in the extractant, and then the organic phase and the water phase which is difficult to dissolve are separated, washed and re-executed extraction. In the literature [6], the mechanical analysis of the fluid in the extraction tank is proposed. The simulation theory is used to simulate different mixing mechanical structures, which provides a reliable optimization scheme for the design of the mixing equipment.

3. Automation status of rare earth industrial production

China is a big country with abundant rare earth resources, but industrial development is still lagging behind. Combined with the characteristics of extraction theory and the low degree of automation of rare earth production equipment, according to the development degree of advanced theory, the development of production automation equipment adapted to China's development level has become an important topic.

Although China's rare earth industry is also steadily advancing, it still has a big gap with the world's advanced level. China's specific national conditions are to introduce advanced equipment from abroad to complement the shortcomings of production, but there are still some problems, for example, the cost caused of technical blockade is too high; Equipment development is not yet mature; The development of new technologies, the problem of the level of worker operation and new technology does not match.

4. Intelligent monitoring of rare earth production process

4.1. Intelligent control system for rare earth production process.

The rapid development of intelligent and technology has gradually derived artificial intelligence technology and has been promoted and applied within a certain scope. The various professional disciplines are integrated with each other, and the key technology of industrial production process—fault diagnosis has also been greatly developed. Artificial intelligence technology will be combined with various industries in various ways in the future to form interconnection and fusion.

Document [7] proposes an intelligent control unit to control the actuator. Compared with the classic PID control, the system has the advantages of smaller overshoot and faster response. Document [8] proposes an intelligent control system for rare earth extraction production process that combines industrial Ethernet and fieldbus structure, and the accuracy is greatly improved to ensure the production quality. Document [9] combines the CAN (Controller Area Network) controller LAN bus technology
with the Kingview system to achieve optimal operation and control of the production process.

4.2. Fault detection of rare earth extraction equipment.
With the continuous improvement of the level of social production, the industrialized and intelligent equipment that is compatible with it will inevitably develop synchronously, which is increasingly important for fault detection. The traditional fault detection relies on the staff to determine the alarm location, view the monitoring data, determine the fault, resolve the fault, and write the fault accident record to provide a decision basis for future fault handling. The disadvantage is that the timeliness of the on-site incident handling is insufficient. With the improvement of production level, the types of faults in the production process become more and more complicated, and the traditional fault handling methods will be gradually eliminated. Intelligent fault diagnosis algorithms have emerged.

With the development of interdisciplinary research, different types of fault monitoring research have been applied to different industries. One case is to establish different simulation models through data fusion, verify the error between the simulation data and the monitoring data, process the data, and determine the fault category; In another case, the fault data is acquired by the monitoring system, the data error is calculated, the fault type is determined, and the self-correction is achieved by the iterative model. The key point of the first case is whether the construction of the simulation model is reliable and the calculation process is relatively simple; The second case retains all the data, and the calculation amount is relatively large and relatively complicated. In general, the first case will be considered first\textsuperscript{[10]}. 

4.3. Intelligent monitoring fault detection method.
With the advent of the era of big data, in the field of fault monitoring, there are mainly expert systems (ES), artificial neural networks (ANN), cluster analysis (CA), Bayesian networks (BN), Petri nets (PN), rough Set (RST), numerical analysis, information fusion and other methods\textsuperscript{[10]}. Figure 3 fault detection method.

![Fault detection method](image)

**Figure 2. Fault detection method**

4.3.1. Expert system. Expert systems are widely used in the field of artificial intelligence. Through computer technology, using the relevant knowledge theory of interdisciplinary subjects, combined with the knowledge and knowledge of experts and technicians in relevant fields to form a fault diagnosis system. Figure 3 is a schematic diagram of the expert system:

![Expert system](image)

**Figure 3. Expert system**

This system is highly targeted and greatly improves the ability, efficiency and accuracy of problem solving.
4.3.2. Artificial neural network. Artificial neural network is an intelligent technology that is inspired by the mode of human brain information transmission and combines with the complexity of modern production process.

\[ H_i = f_1(\omega_i x^p + b_i) \]  \hspace{1cm} (1)
\[ Z = f_2(\omega_2 x^p + b_2) \]  \hspace{1cm} (2)

The above formula is a backpropagation function. The training data passes from the input information through the hidden layer \( H_1 \) to the output layer \( Z \). The random gradient descent method is used to adjust the parameters \( W, b \) to minimize the global error, and the diagnostic knowledge is acquired through the training process to form a diagnostic model.

4.3.3. Petri net. Petri nets are mainly for discrete systems, describing the logical relationship of data activities or production activities based on the data generated by discrete systems. The general relationship is as follows:

\[ N = (P, T, F) \]  \hspace{1cm} (3)

Where \( P \) represents the set of libraries, \( T \) represents the set of transitions, and \( F \) represents the set of flow relationships. The Petri net is mainly used to simulate the dynamic changes of the system and can intuitively reflect the dynamic characteristics of the system. However, there are too many nodes to describe the time.

4.3.4. Bayesian network. Bayesian network is a model based on Bayesian theory. It has a great advantage in dealing with uncertain information. The key point is the determination of prior probability.

\[ P \mid B_i | A = \frac{P \mid B_i \mid P \mid A \mid B_i}{\sum_{j=1}^{n} P \mid B_j \mid P \mid A \mid B_j} \]  \hspace{1cm} (4)

The posterior probability \( P \mid B_i | A \) is calculated by the prior probability \( P \mid B_i \), the uncertainty problem is determined, and the Bayesian diagnosis model is constructed.

4.3.5. Fuzzy set theory. Fuzzy set is a model based on fuzzy set theory. A series of problems are given fuzzy control, and the control results are given. The fault tolerance performance is better.

\[ A = \{ (x, \mu_A(x)) | x \in X \} \]  \hspace{1cm} (5)

Where \( \mu_A(x) \) is the membership of element \( x \) belonging to fuzzy set \( A \). The fuzzy set is described by the membership function. Each set of faults is set up, the set is operated, and the membership is found to be the largest, as a demarcation point, to determine the fault range. However, when the amount of data is small, it may affect the accuracy of the judgment; if the accuracy is to be satisfied, it will inevitably increase the amount of calculation.

4.3.6. Rough set theory. Rough set theory is a data processing model based on probability theory and rough set theory. Membership function:

\[ u_r(a, X) = \frac{\text{card}(\{a\} \cap X)}{\text{card}(\{a\})} \]  \hspace{1cm} (6)

Where \( R \) is the equivalence cluster on domain \( U \). Such a method does not require any a priori data, and fully processes and classifies the data set. This theoretical feature is that it can effectively inaccurate and incomplete data without any additional information and a priori knowledge. Analyze and process, and find that there is an implicit relationship between the data, revealing its underlying laws.
5. Summary
In the era of big data, a large number of various types of fault information appear, and through the processing of data, a more complete information system is obtained, and data loss is reduced. Through the comparison of various detection methods, each has its own advantages and disadvantages, through the mutual integration of various methods, to achieve complementary advantages, combined with the actual production conditions, through simulation, to obtain a more accurate powder deep processing production line Fault detection method.

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