Research on the Temperature Control System of 6KA Neodymium Oxide Electrolysis Furnace with BAS_PID Algorithm

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Abstract: In order to solve the obvious temperature fluctuations in the cell during the neodymium oxide electrolysis process, the traditional PID control algorithm has a large lag, the timeliness of the multi-variable electrolysis temperature control system is poor, and the manual parameter adjustment is difficult, the beetle PID automatic temperature control system is proposed. Through the control of the key variable cathode current density, speed up the system to adjust the output speed; use the orthogonal temperature measurement method to replace the traditional single point temperature measurement, and use the domain temperature to represent the point temperature to solve the problem of large temperature measurement errors. This algorithm model is based on MATLAB2017 platform for modeling simulation and experimental research. Compared with traditional PID, this method has better adaptive ability and robust performance. The maximum deviation between the actual electrolysis temperature and the set target temperature is 45°C, and the overshoot is 3.3 %, to meet the process index requirements in the actual production process, and provide a reference case for the improvement of neodymium oxide electrolysis process.

1. Introduction

In the process of neodymium oxide electrolysis, the control of electrolysis temperature is a crucial link in the process of rare earth electrolysis. Due to the backward smelting and processing equipment of some enterprises, the acquisition and control of electrolysis temperature still rely on visual observation and manual adjustment, which makes it difficult to achieve effective Temperature control [1-2]. In the process of continuous large-scale production of rare earth enterprises, due to design reasons such as heat preservation and heat dissipation, as well as the feeding operation of the furnace, the electrolytic cell will bring significant temperature fluctuations to the electrolysis process. How to maintain the temperature in the cell at the process temperature has always been an industry research [3-4].

This paper selects the 6KA electrolytic cell in the No. 3 workshop of a rare earth enterprise in Hezhou, Guangxi as the object of physical research, constructs the long beetle PID control algorithm. The long beetle beard algorithm's rapid optimization ability to optimize the PID parameter setting can adapt to the nonlinearity of the electrolytic cell. The method of time-varying control object and orthogonal temperature measurement at the same time, through the method of orthogonal experiment...
for systematic temperature measurement, overcomes the problem that the traditional electrolytic cell temperature measurement is not objective.

2. Model establishment of the temperature control system for neodymium oxide electrolysis

2.1. BAS_PID temperature control model of neodymium oxide

As shown in Figure 1, the neodymium oxide beetle PID control model is based on the beetle algorithm combined with the PID algorithm to adjust the proportion, integral, and differential coefficients in real time. The PID of the beetle beetle is modeled and converted through the matlab2017 platform. ST language is deployed in Siemens 1200PLC. The system mainly includes temperature acquisition module, cathode current density output, and BAS_PID controller to form a closed-loop control unit to perform real-time and effective temperature control on the neodymium oxide electrolyzer.

2.2. Design of electrolyzer temperature model

Figure 2 is a schematic diagram of the structure of a 6KA neodymium oxide electrolytic cell. The temperature of the traditional electrolytic cell is obtained by thermocouple contact temperature measurement. The measured temperature can only reflect a little temperature and cannot objectively express the temperature of the electrolytic cell. The author designed it in combination with orthogonal experiments. Ring temperature measurement program. Because the orthogonal experiment has the advantages of no less control experiment and even data distribution, the orthogonal method is applied to the temperature measurement program. The main temperature measurement area of this program is in the main electrolysis area, that is, the middle temperature area of the cathode and anode plates. The specific temperature measurement point layout plan is shown in Figure 3 and Table 1.
3. BAS-PID controller

3.1 BAS algorithm principle
In 2017, Beetle Antennae Search (BAS) algorithm was proposed as a new type of intelligent bionic algorithm [5]. Its biggest feature is that when the mathematical model and gradient of the function are not clear, the calculation of the algorithm is significantly reduced by establishing a mathematical model for the single beetle. The bionic principle [6]: The head of the long cow has two long tentacles. The location of the food is not known, and it only depends on the strength of the tentacles to receive the food smell. The intensity of the smell received by the right antennae of the beetle is greater than that of the left, then the beetle will fly to the right in the next step, otherwise it will fly to the left [7]. The odor can be abstracted as a specific function. The purpose of the long-horned beetle search is to
find the point of the global maximum odor. According to this method, the long-horned beetle can find food quickly and efficiently.

3.2 BAS—PID algorithm
Among them \((K_p, K_i, K_d)\) direct parameters determine the control performance of the PID algorithm [8], but the tuning of parameters is a process that relies on strong experience [9]. In this paper, BAS algorithm optimizes and adjusts the parameters of PID algorithm to form BAS_PID algorithm. The steps of the algorithm are as follows.

(1): Randomly establish the direction vector of BAS and normalize it, as shown in formula 3.

\[
dir = \frac{\text{rands}(d,1)}{||\text{rands}(d,1)||}
\]

Where \(\text{rands}()\)—— random function;

\(D\)——spatial dimension.

(2): Create the spatial coordinates of the left and right whiskers of longhorn beetle, as shown in formula 4.

\[
\begin{align*}
x_{r1} &= x_i + d_0 \frac{dir}{2} \\
x_{l1} &= x_i - d_0 \frac{dir}{2}
\end{align*}
\]

Where \(x_{r1}\)——the position coordinates of the right mustard of longhorn beetle in the i-th iteration;

\(x_{l1}\)——the position coordinates of the left mustard of longhorn beetle in the i-th iteration;

\(x_i\)——the centroid coordinates of longhorn beetle at the i-th iteration;

\(d_0\)——The distance between two whiskers.

(3): According to the fitness function of the system, as shown in formula 5, calculate the fitness values of the left and right whiskers, and compare the sizes.

\[
\begin{align*}
ex_{r1} &= x_i + d_0 \frac{\text{dir}}{2} \\
ex_{l1} &= x_i - d_0 \frac{\text{dir}}{2}
\end{align*}
\]

Where \(e(i)\)——the control error of the i-th iteration;

\(u(i)\)——the controller output of the i-th iteration;

\(b_1, b_2\)——weight coefficient.

(4): Update the position of the longhorn.

\[
x_{i+1} = x_i - \sigma_i \times \text{dir} \times \text{sign}[F_{\text{PID}}(x_{r1}) - F_{\text{PID}}(x_{l1})]
\]

(5): Meet the maximum iteration value \(T\), and output the optimal control curve; otherwise, continue to iterate to meet the iteration number \(T^{[10]}\).

4. System modeling and analysis

4.1 Model building
Based on MATLAB2017b platform, the conventional PID control and BAS_PID algorithm were simulated and compared. The mathematical model of the rare earth electrolytic cell is \(G(s) = \frac{ke^{-\tau s}}{Ts+1}\), where \(d=1.60, \tau=50, T=3000\), and the expected value of the electrolytic cell temperature is set to 1050°C. Set the parameters of the traditional PID algorithm as \(K_p=20.31, K_i=0.05, K_d=21.8\). The parameter settings in the BAS_PID algorithm are: \(b_1=1.2, b_2=0.02, k=3, K_p \in [0,50], K_i \in [0,5], K_d \in [0,30]\). The simulation models of PID and BAS_PID are shown in Figure 4 and Figure 5 respectively.
4.2 Simulation and analysis
Take the unit step signal as input, run the simulation program, and get the comparison of the simulation results of the above algorithms.

Sample the temperature of a furnace product on the beetle neodymium oxide temperature-controlled electrolytic cell, the total time is 30min, the sampling frequency is 0.17HZ, each temperature measurement time is about 1min, the test temperature is shown in Table 2.

It is found from Fig. 6 that the conventional PID control has obvious temperature fluctuations, and the system temperature adjustment is unstable. The time for the algorithm to stabilize is about 900s.

By comparison, it is found that the overshoot is 7.9%, and the BAS_PID adjustment time is 500s. The
amount is 3.3%. Through comparison, it is found that the control system of BAS_PID algorithm is stable, has a small overshoot, and has better robust performance.

5. Conclusion
Electrolysis temperature plays a key role in the smelting process of neodymium oxide. When traditional algorithms cannot meet the temperature control of neodymium oxide electrolysis, a stable electrolysis temperature control system is essential. In response to this problem, the BAS_PID tank temperature control system is designed. After simulation verification, the test results show that the BAS_PID temperature control system has short adjustment time and small system fluctuations, which provides a new technical solution for designing a stable neodymium oxide electrolysis temperature system.

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