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Research on position calibration method in infrared scanning temperature measurement system of rotary kiln

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HIGHLIGHTS

- A precise position calibration method for rotary kiln locating is proposed.
- The proposed method introduces feature points to make a position correction.
- The best result is obtained, when four feature temperature points was introduced.
- The proposed method effectively improves the location measurement accuracy.

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ABSTRACT

Aiming at the large error in the equal-interval locating method, a precise position calibration method is proposed. The proposed method improves the location measurement accuracy by introducing some feature temperature points to divide the rotary kiln into several segments, then the equal-interval locating method was applied to each segment, ultimately, a position calibration data more closing to the actual situation was got. The feature temperature points can be selected from the temperature points of kiln tyres or the highest temperature point and so on. Taking the practical application into consideration, the best result is obtained, when four feature temperature points was introduced to divide the rotary kiln into five segments. The experiment result shows that compared with the equal-interval method, the accuracy of the proposed method has raised about 5.6 times when four feature temperature points is used.

1. Introduction

Rotary kiln is the key equipment in the material burning process of cement production, whose performance directly affects the cement production and the main technical economic indicator [1–3]. Rotary kiln lining is constructed of firebreak brick, which may be seriously worn out or even fall off because of the temperature factor, chemical attack and mechanical wear, etc. Once the local firebreak brick falls off, it will pose a serious threat to the production and security [4,5]. The thickness of the rotary kiln lining can be detected through monitoring the surface temperature of the rotary kiln shell [6]. When somewhere on the rotary kiln appears abnormal high temperature, there may exist a hidden danger of “the red kiln” accident [7–9]. Therefore, it is necessary to accurately locate the fault position of rotary kiln, such as “the red kiln”, to find out the fault position in time and to take remedial measures. The infrared scanning temperature measuring system of rotary kiln adopts equal-angle scanning mode, whose scanning angles between adjacent scanning points are equal. But the existing equal-interval locating method assumes that the distance between the adjacent scanning points is equal [10], while the distance between adjacent scanning points is not equal, so there is a large location error in equal-interval locating method, which could not meet the demand to achieve accurate position calibration. This paper proposes the precise position calibration method, which can improve the accuracy by introducing some feature temperature points to make a position correction on the equal-interval locating method. The test proves that precise position calibration method can control the positioning error in a smaller range, and it can meet the requirements of engineering applications.

2. Equal-angle scanning method of rotary kiln

2.1. Working principle of scanner

The infrared scanning temperature measurement system of rotary kiln is made up of infrared temperature measurement

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scanner and temperature analysis software which is installed on computer [11]. The infrared scanner is consisting of infrared probe, motor and processor. The infrared scanner scans the whole surface of the rotary kiln through the rotation of infrared probe and rotary kiln. The infrared probe driven by motor scans the rotary kiln in horizontal direction and the rotary kiln rotates in vertical direction, as shown in Fig. 1, therefore the scanner can detect the whole surface temperature data of rotary kiln. The infrared scanner collects the temperature data and sends it to the temperature analysis software to display whole temperature distribution of rotary kiln [12,13].

2.2. The equal-interval locating method

The point i and the point $i+1$ represent two adjacent scanning points, as shown in Fig. 2, the distance between the two adjacent scanning points is Δd; the length of rotary kiln is L; the total scanning point number is N.

The principle of the equal-interval locating method is that it assumes that the distance between each two adjacent scanning points is equal [14]. Δd can be expressed as follow:

$$\Delta d = L/N \tag{1}$$

The position of scanning point i (the length from i to the head of rotary kiln) can be expressed as follow:

$$L_i = \sum_{n=0}^{i} \Delta d = \Delta d \times i = \frac{i \times L}{N} \tag{2}$$

3. The precise position calibration method

Rotary kiln has four tyres and the temperatures at the position of the tyres are very low, so the position of tyres is easy to distinguish. The precise position calibration method introduces some temperature point of tyres to make a correction on equal-interval method, and then get position data that are more close to the actual situation.

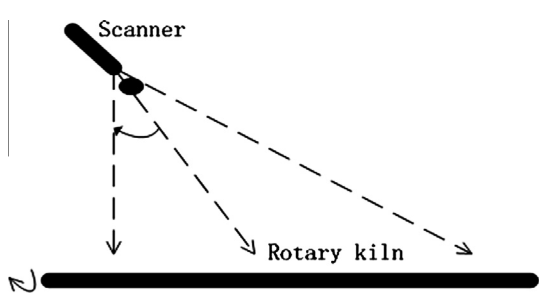

Fig. 1. Equal-angle scanning diagram.

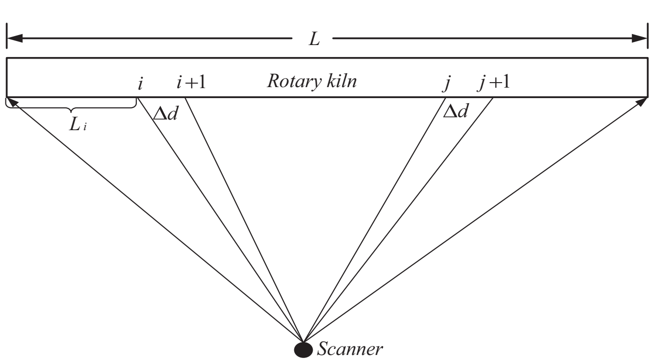

Fig. 2. Diagram of equal-interval positing method.

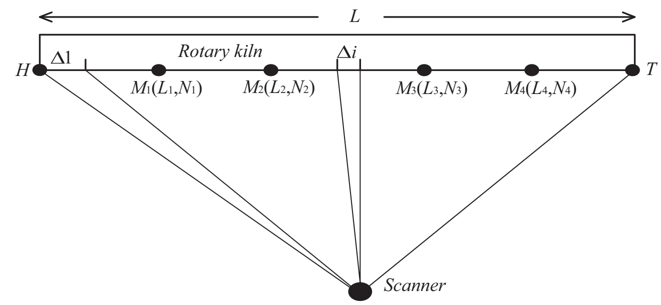

Fig. 3. Diagram of precise position calibration.

In this paper, we take four feature temperature points precise position calibration method for example, as shown in Fig. 3, M_1, M_2, M_3 and M_4 represent the four feature temperature points; L_1, L_2, L_3 and L_4 are their real position. The position of the four feature points in equal-interval locating method are L_{11}, L_{12}, L_{13}, L_{14} ; the scanning point number of feature points are N_1, N_2, N_3, N_4; the length of rotary kiln is L; the total scanning point number is N, as shown in Fig. 2, Δd in equal-interval locating method can be calculated as below:

$$\Delta d = L/N$$

The scanning point number of each feature temperature point can be express as follows:

$$\begin{cases} N_1 = L_{11}/\Delta d = \frac{L_{11} \times N}{L} \\ N_2 = L_{12}/\Delta d = \frac{L_{12} \times N}{L} \\ N_3 = L_{13}/\Delta d = \frac{L_{13} \times N}{L} \\ N_4 = L_{14}/\Delta d = \frac{L_{14} \times N}{L} \end{cases} \tag{3}$$

Then the position correction is made to improve the positioning accuracy, whose specific process is as follow.

Assuming the scanning interval Δi between each two feature temperature points is equal, Δi in precise calibration method can be expressed as follows:

$$\Delta i = \begin{cases} L_1/N_1 = \frac{L_1 \times L}{L_{11} \times N} & (0 \Leftarrow i < N_1) \\ \frac{L_2 - L_1}{N_2 - N_1} = \frac{(L_2 - L_1) \times L}{(L_{12} - L_{11}) \times N} & (N_1 \Leftarrow i < N_2) \\ \frac{L_3 - L_2}{N_3 - N_2} = \frac{(L_3 - L_2) \times L}{(L_{13} - L_{12}) \times N} & (N_2 \Leftarrow i < N_3) \\ \frac{L_4 - L_3}{N_4 - N_3} = \frac{(L_4 - L_3) \times L}{(L_{14} - L_{13}) \times N} & (N_3 \Leftarrow i < N_4) \\ \frac{L - L_4}{N - N_4} = \frac{(L - L_4) \times L}{(L - L_{14}) \times N} & (N_4 \Leftarrow i < N) \end{cases} \tag{4}$$

The position of scanning point m, which can be expressed as l_m, are calculated as follow:

$$l_m = \sum_{i=0}^{m} \Delta i \quad (0 < m < N) \tag{5}$$

Through Eqs. (4) and (5) the position of each scanning point in precise calibration method can be calculated as follows:

$$l_m = \sum_{i=0}^{m} \Delta i = \begin{cases} \frac{L_1 \times L}{L_{11} \times N} \times m & (0 \Leftarrow i < N_1, 0 < m < N_1) \\ L_1 + \frac{(L_2 - L_1) \times L}{(L_{12} - L_{11}) \times N} \times (m - N_1) & (N_1 \Leftarrow i < N_2, N_1 < m < N_2) \\ L_2 + \frac{(L_3 - L_2) \times L}{(L_{13} - L_{12}) \times N} \times (m - N_2) & (N_2 \Leftarrow i < N_3, N_2 < m < N_3) \\ L_3 + \frac{(L_4 - L_3) \times L}{(L_{14} - L_{13}) \times N} \times (m - N_3) & (N_3 \Leftarrow i < N_4, N_3 < m < N_4) \\ L_4 + \frac{(L - L_4) \times L}{(L - L_{14}) \times N} \times (m - N_4) & (N_4 \Leftarrow i < N, N_4 < m < N) \end{cases} \tag{6}$$