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Research on high precision equal-angle scanning method in rotary kiln temperature measurement system

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HIGHLIGHTS

- A high precision scanning method for rotary kiln temperature measurement is proposed.
- The proposed method relies on establishment of tilt scanning model.
- Height variable is introduced and viewing angle should be precisely calculated.
- The proposed method effectively improves temperature spots measurement accuracy.

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ABSTRACT

Aiming at traditional horizontal equal-angle scanning method's disadvantage of measurement error, a high precision equal-angle scanning method is proposed, the proposed method establishes a tilt scanning model by the following steps: introducing height variable, precisely calculating the viewing angle, building scanning model. The model is used to calculate scanning position on rotary kiln's surface, which helps to locate and track temperature variation. The experiment shows that the proposed method can effectively improve the precision of temperature spots' location on the rotary kiln surface.

1. Introduction

Infrared measuring temperature is an effective, fast and non-contact measurement technology, especially suitable for measuring temperature of moving objects. Infrared measuring method has many remarkable advantages such as tele-measuring, wider dynamic range and non-interference measured object. Therefore, the infrared measurement technology can be widely used in all aspects of people's lives [1]. As is known to all, rotary kiln is a key equipment in the cement production factory, and its running status directly affects production quantity, quality and energy consumption [2,3]. With the development of science and technology, infrared measuring method has played a crucial role in the temperature measurement of rotary kiln.

Infrared scanning temperature measuring system (ISTMS) can monitor the surface temperature of rotary kiln by dividing the surface into hundreds of enveloping lines, with hundreds of measurement units in each enveloping line [4], as shown in Fig. 1. Synchronous scanning technology guarantees one-to-one mapping relationship between the temperature spot and the measurement unit of rotary kiln. But the current there is an altitude difference between the rotary kilns and installation positions of ISTMS in many cement plants, which causes measurement error if the traditional equal-angle scanning method is used. This paper proposes a high precision equal-angle scanning method, which can accurately track and locate surface temperature variations in the rotary kiln, and provide guarantee for rotary kiln's safe operation.

2. Synchronous scanning technology

Fig. 2 shows a structure chart of infrared scanning system, which is the physical part of ISTMS [5]. The core structure of Fig. 2 is synchronous scanning system consisting of optical system and scanning mechanism. Moreover, the scanning system can detect rotary kiln's surface temperature according to the predetermined scanning routes and cycles under motor drive. The specific process is as follows: (1) The infrared radiation from rotary kiln's surface is reflected by reflecting mirror, then is focused on the detector by infrared lens, finally is converted to temperature

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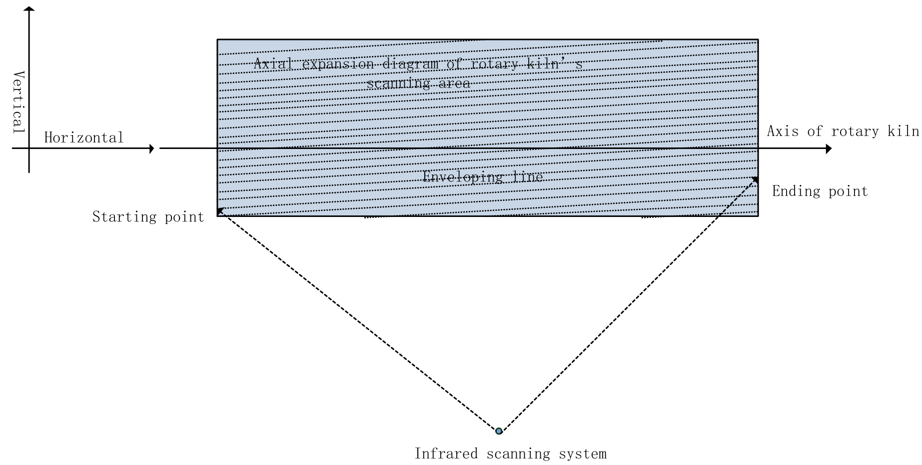

Fig. 1. Diagram of rotary kiln's temperature measurement.

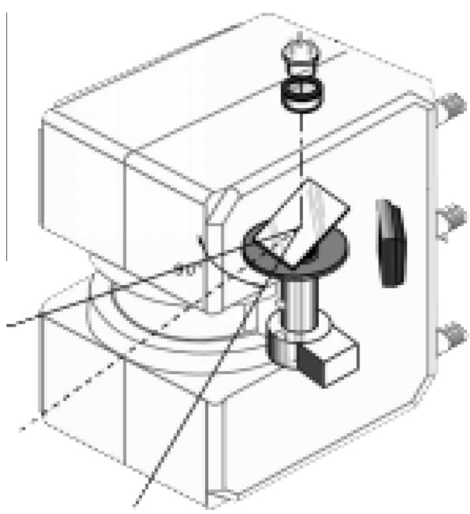

Fig. 2. Structure chart of infrared scanning system.

information by signal processor; (2) When the motor drives the reflecting mirror a cycle, an enveloping line's temperature information on rotary kiln are collected; (3) When the rotary kiln rotates a circle, a complete enveloping surface temperature information on rotary kiln are collected.

The operational principle of synchronous scanning system is that the motor driver transforms a series of pulses into the motor's angular displacements, and the motor drives reflecting mirror to scan rotary kiln's surface according to enveloping line. When the driver sends a pulse, the motor rotates to a corresponding angle, so the motor rotation rate is proportional to the pulse frequency.

3. Traditional horizontal equal-angle scanning method

As shown in Fig. 3, traditional horizontal equal-angle method is widely used in temperature measurement of rotary kiln, which can be described as below [6,7]:

The scanning system and the rotary kiln are at the same height, the angle of view β in Fig. 3 is calculated as follows:

$$\beta = \frac{180}{\pi} \cdot \arctan \frac{l}{h} \tag{1}$$

where h represents vertical distance from the scanning system to the rotary kiln, l represents horizontal distance from the vertical line endpoint o to the kiln head.

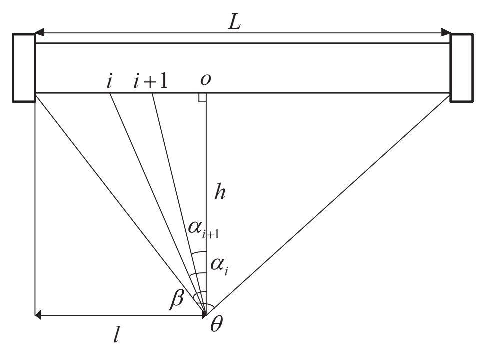

Fig. 3. Traditional horizontal equal-angle scanning method diagram.

Each rotation cycle of the scanning system send out M scanning points, so the field angle between two adjacent scanning points is $\frac{360}{M}$. The scanning points corresponding to the length of rotary kiln are calculated as follows:

$$N \approx \frac{M\theta}{360} \tag{2}$$

where θ represents the scanning angle of infrared scanning system, N represents the scanning points corresponding to the length of rotary kiln. If the distance between two adjacent scanning points is x_i, then L' is calculated as follows:

$$L' = \sum_{i=0}^{i \leqslant N} x_i \tag{3}$$

where L' represents the kiln's length calculated by the horizontal algorithm, the R is calculated as follows:

$$R = \frac{Nl}{L'} \approx \frac{M\theta l}{2\pi L'} \tag{4}$$

where R represents the scanning points corresponding to the length of l. Then we assume that a_i represents the angle between the point o and the scanning point i, and a_{i+1} represents the angle between the point o and the scanning point $i + 1$.

If $0 \leqslant i < R$, a_i, a_{i+1}, x_i can be calculated as follows:

$$a_i = \beta - \frac{360i}{M} \tag{5}$$

$$a_{i+1} = \beta - \frac{360(i+1)}{M} \tag{6}$$