Infrared Physics & Technology 88 (2018) 128–132

Contents lists available at ScienceDirect

Infrared Physics & Technology

journal homepage: www.elsevier.com/locate/infrared

Regular article

Research on surface temperature compensation of rotary kiln based on inverse exponential model

Shaosheng Dai, Liangbing Yu *, Xiaoxiao Zhang, Yajun Cheng, Yamei Chen

Chongqing Key Laboratory of Signal and Information Processing, Chongqing University of Posts and Telecommunications, No. 2 ChongwenRoad, Nan'an District, Chongqing 400065, China

ARTICLE INFO

Article history:
Received 7 November 2017
Accepted 14 November 2017
Available online 21 November 2017

Keywords:
IST
Rotary kiln surface
Temperature compensation
Nonlinear model

ABSTRACT

Aiming at large measurement error of the kiln head in the process of measuring the temperature of the rotary kiln surface, this paper presents a high-precision temperature compensation algorithm for rotary kiln surface based on the inverse exponential model. The algorithm is implemented as follows: First of all, this paper chooses a series of points on the surface of the rotary kiln as monitoring points and calculates the difference between the actual temperature of the monitoring points and the temperature measured by infrared scanning thermometer (IST); Then a relation curve is plotted between the temperature differences and measuring distances; Finally the nonlinear model of inverse exponential function is established according to the curve trend. The experimental results show that the algorithm can obviously reduce the error of temperature measurement, and compared to the traditional method, the proposed method reduces the error of temperature measurement from 1.26% to 0.14%.

1. Introduction

Rotary kiln is the core equipment for clinker calcination. It is widely used in cement, chemical industry, metallurgy and building materials industry. Its operation directly affects quality of the product and energy consumption. If the temperature inside the kiln is too high, the refractory brick will be damaged and even the red kiln accident will be occurred, which will cause great economic losses. Therefore the surface temperature must be monitored during the production process of rotary kiln [1]. The conventional temperature monitoring method is difficult to apply because of the constant rotation of the rotary kiln, but infrared scanning thermometer is widely used to measure the temperature of rotary kiln surface due to the capability of non-contact scanning [2]. However, the distance between the IST and the rotary kiln will seriously affect the measurement accuracy of the surface temperature of the rotary kiln. Therefore, it is of far-reaching significance to research the effect of the distance on temperature measurement.

So far, many experts and scholars have done much research on the effect of scanning distance on the temperature measurement of rotary kiln surface. Zi Feng studied the influence of object-system distance on accuracy of temperature measurement with IR system [3]. Chrzanowski proposed a theory that the differences between the true scanning distance and correction distance will cause large error of temperature measurement [4]. Y Li deduced a general computing formula for the measurement of surface temperature with an infrared thermal imager according to the principles of thermal radiation [5]. Guo introduced an error compensation method according to the influence of measuring distance and field angle [6]. Sun proposed a data fitting method to reduce error of temperature measurement [7]. In the above methods, linear compensation methods are proposed for the influence of distance, but there is still a large error in the temperature measurement. Therefore a high-precision temperature compensation algorithm is proposed based on inverse exponential model in this paper, and the experimental results show that the method can significantly reduce the error of temperature measurement.

2. The principle of infrared scanning thermometer (IST) to measure the temperature on surface of rotary kiln

IST is the electronic, communication, mechanical and optical integrated equipment, and combines the temperature measurement technology based on infrared radiation with the mechanical rotation technology [8]. As shown in Fig. 1, IST is made up of five parts: infrared detector, motor drive module, optical system, signal processor and transmission module, PC display module. The principle of the IST is as follows: firstly, infrared reflector in optical system is driven by motor to rotate along the axis of rotary kiln and

* Corresponding author.
E-mail address: yuliangbing1991@163.com (L. Yu).

https://doi.org/10.1016/j.infrared.2017.11.014
1350-4495/

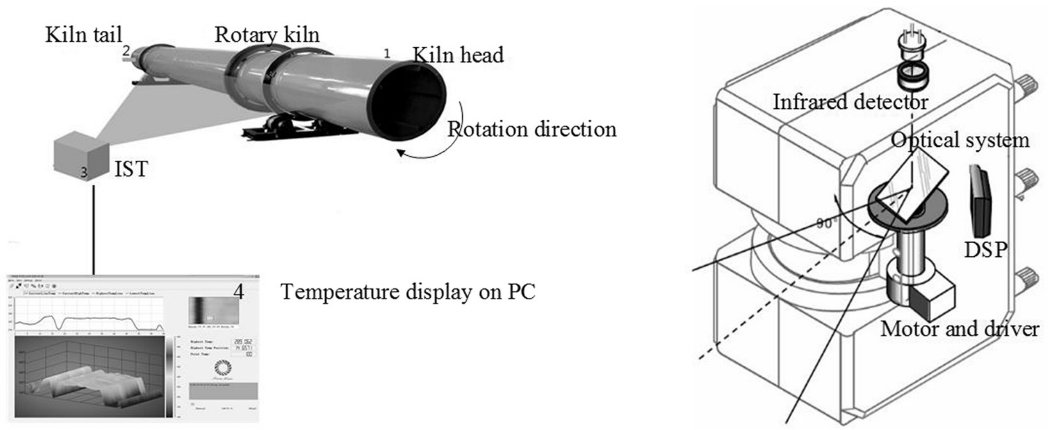

Fig. 1. The principle of temperature measurement and the structure of IST.

reflect the infrared radiation to focused lens, and the surface scanning is realized by self-rotation of rotary kiln. Then the infrared energy of each measuring point is transformed to electrical signal by infrared detector. Then the electrical signal is transformed to temperature value by signal processor. Finally, the collected temperature value is transferred to the PC via the network port for display [9].

3. Traditional temperature compensation algorithm for surface of rotary kiln

The traditional compensation algorithm [10,11] has been used in surface temperature measurement of rotary kiln. The specific realization principle is described as follow. As shown in Fig. 2(a), this paper mainly calculates the compensation temperature of the O point to the kiln head, and the IST is placed at the same level as the axis of the rotary kiln. The point P is the IST installation location, and the line PO is perpendicular to the rotary kiln and intersects O point. The h is the distance from IST to the rotary kiln. The l is the distance from O point to kiln head. The s is the distance between measuring point and O point, The α is the angle between measuring point and O point.In order to calculate the coefficients of the traditional temperature compensation algorithm, air humidity and the emissivity of rotary kiln surface are set to guarantee that the temperature measured by the IST is consistent with the actual temperature at O point. And then the maximum temperature difference is calculated as follows:

$$\Delta T_{\max} = T_{rt} - T_{mt} \tag{1}$$

where the T_{rt} is actual temperature on kiln head, the T_{mt} is temperature measured by IST without any temperature compensation methods on kiln head.

As shown in Fig. 2(b), according to the principle of infrared radiation that infrared radiation in the direction of the vertical rotary kiln is the strongest, therefore, the temperature compensation value is expressed as follows:

$$\Delta T = A.\sin\alpha.\Delta T_{\max} \tag{2}$$

When $\alpha = \alpha_{\max}$, the corresponding $\Delta T = \Delta T_{\max}$. A is calculated as follows:

$$A = 1/sin\alpha_{max} \tag{3}$$

The temperature of the measuring points on the surface of rotary kiln are calculated as follows:

$$T = T_m + \Delta T \tag{4}$$

where the T_m is temperature measured by IST without any temperature compensation methods, the T is temperature calculated by IST with traditional temperature compensation.

4. Principle of temperature compensation algorithm based on inverse exponential model

Although the traditional algorithm is widely used, there is still a large measurement error. Actually, there is a inverse exponential connection between the measuring distance and compensation temperature, so this paper studies the temperature compensation algorithm based on inverse exponential model which is more consistent with the infrared attenuation characteristics, as distance between measuring points and IST increases, infrared radiation decays more and more, but when the range is exceeded, infrared radiation decays will tend to be steady.Based on the above law, the following experiments are carried out: blackbody are used in standard infrared radiation sources, whose emissivity is 0.98. In

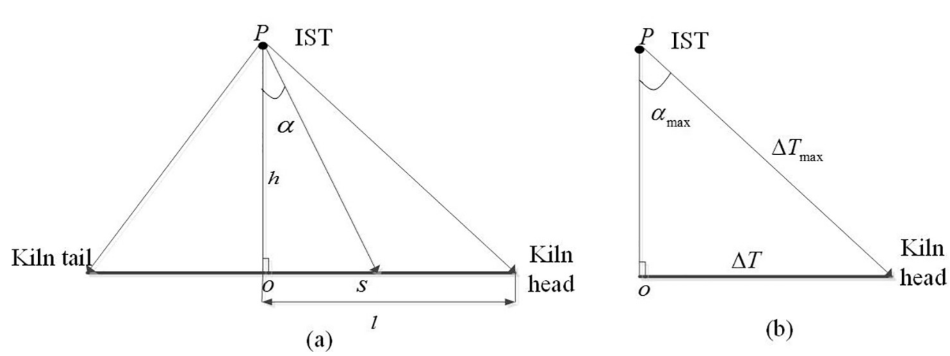

Fig. 2. Simplified diagram of the traditional compensation method.