Experimental Thermal and Fluid Science 35 (2011) 416–421

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

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

Estimation of radiative properties and temperature distributions in coal-fired boiler furnaces by a portable image processing system

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ARTICLE INFO

Article history:
Received 13 March 2010
Received in revised form 10 October 2010
Accepted 13 October 2010

Keywords:
Combustion measurement
Coal-fired boiler furnaces
Temperature
Radiative properties
Image processing

ABSTRACT

This paper presented an experimental investigation on the estimation of radiative properties and temperature distributions in a 670 t/h coal-fired boiler furnace by a portable imaging processing system. The portable system has been calibrated by a blackbody furnace. Flame temperatures and emissivities were measured by the portable system and equivalent blackbody temperatures were deduced. Comparing the equivalent blackbody temperatures measured by the portable system and the infrared pyrometer, the relative difference is less than 4%. The reconstructed pseudo-instantaneous 2-D temperature distributions in two cross-sections can disclose the combustion status inside the furnace. The measured radiative properties of particles in the furnace proved there is significant scattering in coal-fired boiler furnaces and it can provide useful information for the calculation of radiative heat transfer and numerical simulation of combustion in coal-fired boiler furnaces. The preliminary experimental results show this technology will be helpful for the combustion diagnosis in coal-fired boiler furnaces.

1. Introduction

Thermal radiation is the predominant mode of heat transfer in coal-fired boiler furnaces. Both temperature distributions and radiative properties of the particulate medium play key roles in combustion. The temperature distributions in coal-fired boiler furnaces are closely related to pollutant emissions, e.g., NOx, and combustion efficiency [1]. Various laser diagnostic measurement techniques are applied in combustion system [2]. However, impressive large dimensions of coal-fired furnaces cause significant attenuation for any laser. Besides that, there are many physical constraints such as noise, vibrations, and limited optical access in industrial-scale furnaces. Laser diagnostic techniques are seldom used in experimental investigations in coal-fired furnaces. Radiative properties of particles, such as emissivity, absorption and scattering coefficients, are important parameters in the numerical simulation of combustion and calculation of radiative heat transfer in coal-fired furnaces [3]. Generally, radiative properties of particles in coal-fired furnaces are approximately estimated by Mie theory [4]. However, as of today the knowledge about the chemical composition of these particles, their shapes and size distributions, and their optical properties is limited. Furthermore, the radiative properties of these particles vary as their temperature, sizes and shapes change as they travel through the furnace. Therefore, any prediction of radiative properties from Mie theory carries a good amount of uncertainty and the results may only be regarded as fairly crude approximations. The accurate predictions would have to depend on in situ measurements for the flame.

In recent years, flame image processing techniques have been used in combustion diagnosis [5–8], as well as in temperature measurement in coal-fired furnaces [9–13]. However, the flame images obtained from these systems are limited to two dimensions only, and the third dimension, line-of-sight direction, has not been taken into account. The temperature distributions measured in [9,10] are the cumulative result of the three-dimensional (3-D) distribution of flame radiation, just like pyrometers. These systems cannot acquire information on temperature along the direction of a visible ray. Therefore, a reconstruction technique is needed to calculate local values of temperature inside furnaces from captured flame images. Zhou and Lou et al. [11–13] performed simulation and experimental investigations on visualization of the two-dimensional (2-D) and 3-D temperature distributions inside large-scale coal-fired boiler furnaces. In this paper, experimental investigations on the estimation of radiative properties (emissivity, absorption and scattering coefficients) and temperature distributions in large-scale coal-fired boiler furnaces by a portable imaging processing system are presented. The experimental system will be described briefly and measurement results will be analyzed.

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doi:10.1016/j.expthermflusci.2010.10.005