Fuel 188 (2017) 132–139

Contents lists available at ScienceDirect

Fuel

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

Full Length Article

Optical experimental study on the characteristics of impinging coal-water slurry flame in an opposed multi-burner gasifier

Xudong Song, Qinghua Guo *, Chonghe Hu, Yan Gong, Guangsuo Yu *

Key Laboratory of Coal Gasification and Energy Chemical Engineering of Ministry of Education, East China University of Science and Technology, Shanghai 200237, China

HIGHLIGHTS

- Optical probe based on flame emission spectroscopy is shown to be capable for the monitoring of gasifier.
- There are obvious radical emissions in the impinging area, including OH*, H*, NO*, CO_2*, Na* and K* emissions.
- The pathways of some radicals productions in gasifier have been explored.
- With the increase of O/C, more reactions occur in the upward stream and OH* can clearly reflect the changes.
- The change rules of OH* at the burner plane are similar to that of temperature and CO_2 concentration.

ARTICLE INFO

Article history:
Received 30 May 2016
Received in revised form 29 September 2016
Accepted 2 October 2016
Available online 11 October 2016

Keywords:
Impinging reaction region
OH*
Opposed multi-burner gasifier
Spectral diagnostics
Diffusion flame

ABSTRACT

Impinging flames have been used for a wide variety of industrial processes, especially for opposed entrained-flow gasification technology. The effective monitoring and controlling of flames are at the core of achieving high energy efficiency, reliable diagnosis for the gasification process and optimal gasification technology. Using an emission spectral analysis of an impinging area during coal-water slurry (CWS) gasification in a lab-scale opposed multi-burner (OMB) gasifier, the criterion for dominant reactions was identified. There were obvious radical emissions in the impinging area, including OH*, H*, NO*, CO_2^*, Na* and K* emissions. Intense black-body radiation appeared where the wavelength was longer than 400 nm. The radical emissions showed nonlinear variation with O/C, and there was a maximal value at the certain O/C, in accordance with the change of atmosphere, which could serve as a criterion for dominant reactions in gasification. The change tendency of OH* intensity on different conditions at the burner plane was similar to those of temperature and CO_2 concentration. The temperature of the burner plane was the lowest in the reaction area. The change tendency of H* was similar to that of OH*, and there was a linear correlation between OH*/H* and O/C.

1. Introduction

Entrained flow gasification is an efficient and clean technology for coal-based large-scale gas and syngas production because it has the advantages of high operating pressure and temperature, high carbon conversion, high production intensity, and near-zero emission of pollutants [1]. Since 1995, the Institute of Clean Coal Technology (ICCT) at East China University of Science and Technology (ECUST) has worked on developing opposed multi-burner (OMB) gasification technology [2]. The flow field in the OMB gasifier has already been tested and reported [3].

The effective monitoring of flames is the core of achieving high energy efficiency and optimal gasification technology. Common methodologies include the control of the feed, thermocouple temperature measurement and fuel gas analysis [4], which cannot describe the true status of the gasifier promptly and accurately. The visualization can directly collect information regarding the flame in the gasifier [5,6]. Gong et al. [7] studied the impinging flame height and pulsation frequency in an OMB gasifier using an industrial light field camera and high speed cameras combined with image processing methods.

Flame spectral diagnosis is an important method for flame visualization [8]. As is known, black-body spectrum, rotation-emission bands of high temperature gas molecules and chemiluminescence are the three phenomena that induce flames to spontaneously emit electromagnetic radiation [9]. Oh [10] suggested that the OH* and CH* distribution can reflect the different conditions of flame, since OH* and CH* can be used as an indicator of the heat release rate. Song et al. [11] analyzed the differences between normal diffusion

* Corresponding authors.
E-mail addresses: gqh@ecust.edu.cn (Q. Guo), gsyu@ecust.edu.cn (G. Yu).

http://dx.doi.org/10.1016/j.fuel.2016.10.028
0016-2361/

flame and inverse diffusion flame by measuring the OH* and CH* chemiluminescence in two dimensions. The structure of a turbulent, partially premixed flame is studied using the OH/CH planar laser induced fluorescence by Kiefer [12]. The results showed that the CH layers were closed surfaces in the entire flame, whereas the OH layers were much thicker, and the flame surface densities were determined by CH and OH.

Based on the lab-scale OMB coal-water slurry (CWS) gasifier, the change rules of radiation spectrum in flame and the relationship between macroscale variable (i.e., temperature, gas concentration, etc.) and emission have been studied. Using an emission spectral analysis of the impinging flame area, the criterion for dominant reactions was also indentified.

2. Experimental

2.1. Diagnostic system and operating conditions

The spectral diagnostics experimental platform for the lab-scale OMB CWS gasifier is shown in Fig. 1, which consisted of the following two parts: the fuel-supplying system and the monitoring system. The four burners are side-mounted oppositely with an angle of 90° in a horizontal plane. The inner diameter of the gasifier is 300 mm. The monitoring system consists of a CCD camera system (JAI BB-500CL, hereafter referred to as JAI camera), a temperature monitoring system, a gas analysis system (ThermoStar™ GSD 320 T2) and a spectroscopic diagnostic system. The details of the CCD camera system, temperature monitoring system and gas analysis system have been introduced by Gong and Fan [6,13].

The coal content of CWS is 61%. The proximate and ultimate analyses of the coal in CWS are shown in Table 1. The specific operation conditions for CWS are shown in Table 2. CWS and oxygen were all fed under room temperature. The values in Table 2 were chosen based on scaling factors and stoichiometric ratio (O/C). The flow rate of CWS is about 10 kg/h for each burner, which guarantees that the oxygen velocity is approximately 120 m/s when O/C = 1.0 (typical gasification condition).

Along the side of the gasifier, there are many sampling ports where the spectral, temperature and gas concentration data were collected (see Fig. 1). Here, *L* is the vertical distance between the sampling port and the burner plane.

2.2. Spectroscopic diagnostic system

The Ocean Optics spectrometer used in the spectroscopic diagnostic system combines four HR2000+ devices and each has a specific optical bench as shown in Table 3. The core diameter of the fiber-optics probe is 600 µm, and the field of view (FOV) is about 25°. The probe and the gasifier center is approximately 150 mm, as shown in Fig. 2. The detection area of the impinging

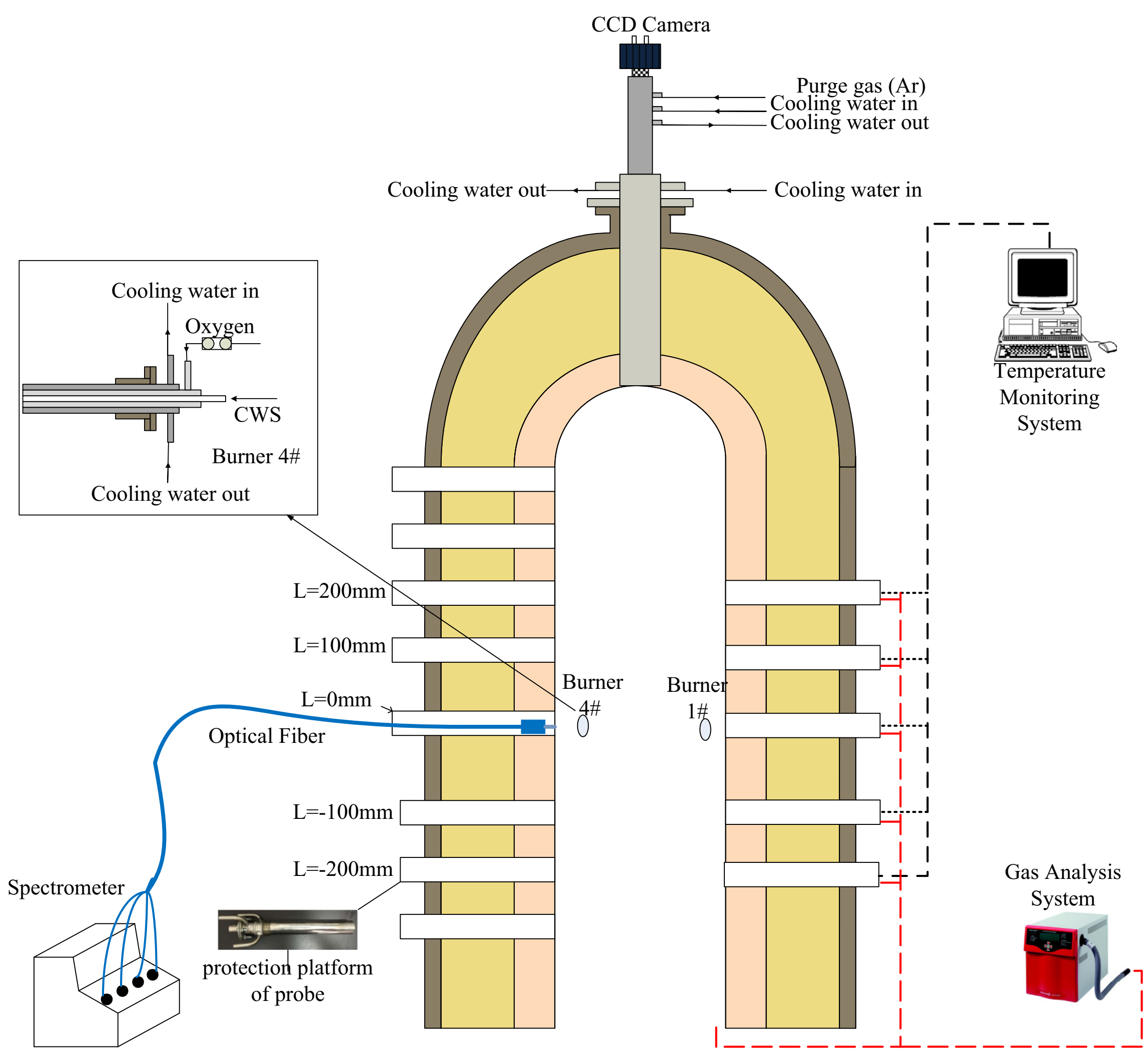

Fig. 1. The schematic diagram of the experimental setup.