Science of the Total Environment 599–600 (2017) 926–933

Contents lists available at ScienceDirect

Science of the Total Environment

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

Experimental studies on combustion of composite biomass pellets in fluidized bed

Feihong Guo *, Zhaoping Zhong *

Key Laboratory of Energy Thermal Conversion and Control of the Ministry of Education, School of Energy and Environment, Southeast University, Nanjing 210096, Jiangsu, China

HIGHLIGHTS

- Explore the use of catkins as an additive to the CBPs fuel and assess its utilization.
- Combustion of CBPs is a first-order reaction, and it is divided into three stages.
- Combustion of CBPs is mainly focused on the stage of volatile-release.

GRAPHICAL ABSTRACT

This work presents studies on the combustion of Composite Biomass Pellets in fluidized bed. The use of catkins as an additive to the CBPs fuel is first time and proved well.

Note: the photo (fluidized bed) was taken by author in southeast university.

ARTICLE INFO

Article history:
Received 19 November 2016
Received in revised form 1 May 2017
Accepted 3 May 2017
Available online xxxx

Editor: D. Barcelo

Keywords:
Fluidized bed
Composite biomass pellets
Characteristics
Combustion

ABSTRACT

This work presents studies on the combustion of Composite Biomass Pellets (CBP_S) in fluidized bed using bauxite particles as the bed material. Prior to the combustion experiment, cold-flow characterization and thermogravimetric analysis are performed to investigate the effect of air velocity and combustion mechanism of CBP_S. The cold-state test shows that CBPs and bauxite particles fluidize well in the fluidized bed. However, because of the presence of large CBPs, optimization of the fluidization velocity is rather challenging. CBPs can gather at the bottom of the fluidized bed at lower gas velocities. On the contrary, when the velocity is too high, they accumulate in the upper section of the fluidized bed. The suitable fluidization velocity for the system in this study was found to be between 1.5–2.0 m/s. At the same time, it is found that the critical fluidization velocity and the pressure fluctuation of the two-component system increase with the increase of CBPs mass concentration. The thermogravimetric experiment verifies that the combustion of CBPs is a first-order reaction, and it is divided into three stages: (i) dehydration, (ii) release and combustion of the volatile and (iii) the coke combustion. The combustion of CBPs is mainly based on the stage of volatile combustion, and its activation energy is greater than that of char combustion. During the combustion test, CBP_S are burned at a 10 kg/h feed rate, while the excess air is varied from 25% to 100%. Temperatures of the bed and flue gas concentrations (O_2, CO, SO_2 and NO) are recorded. CBPs can be burnt stably, and the temperature of dense phase is maintained at 765–780 °C. With the increase of the air velocity, the main combustion region has a tendency to move up. While the combustion is stable, O_2 and CO_2 concentrations are maintained at about 7%, and 12%, respectively. The concentration of SO_2 in the flue gas after the initial stage of combustion is nearly zero. Furthermore, NO concentration is found to be closely related

* Corresponding authors.
E-mail addresses: kerry151@126.com (F. Guo), zzhong@seu.edu.cn (Z. Zhong).

http://dx.doi.org/10.1016/j.scitotenv.2017.05.026
0048-9697/© 2017 Elsevier B.V. All rights reserved.

to O_2: the NO reaches its peak value after initial stage and later decreases with the continued depletion of O_2. Towards the end of combustion, NO increases with the increase of O_2.

© 2017 Elsevier B.V. All rights reserved.

Edited by: D. Barcelo

1. Introduction

Because of the energy shortage and environmental problems, many researchers are investigating alternative to fossil fuels, where in particular biomass combustion has becomes more attractive (Panoutsou et al., 2009; Zeng et al., 2016). Fluidized-bed combustion technology has been proven as one of the most effective technologies for energy conversion of different kinds of biomass (Kaynak et al., 2005; Chyang et al., 2008; Youssef et al., 2009). Biomass pellets type fuel has high burning efficiency, environmentally friendly, with convenient storage and transportation, and can be used in the field of heating, power generation and so on (Fournel et al., 2015; Nunes et al., 2014; Forbes et al., 2014; Saidur et al., 2011). In this study we focus on China's particle fuel, with a variety of raw materials and relatively wide range of physical and chemical characterizations (Tian, 2006). The Composite Biomass Pellets (CBPs) used in this experiment is mainly composed of wood chips, rice straw and Chinese parasol catkins, produced in Nanjing with different supply seasons. There are numerous Chinese parasol trees planted in Nanjing, where every March, under the high temperature and wind condition, flying catkins seriously affects the lives of the residents (Fig. 1). In this study, we are exploring the use of catkins as an additive to the CBPs fuel and assess its utilization.

CBPs are relatively large and can affect the mixing and flow characteristics when blended with the bed materials during fluidization. The flow characteristics of biomass particles have been studied by a number of researchers (Abdullah et al., 2003; Clarke et al., 2005; Cui and Grace, 2007; Rao and Reddy, 2010; Si and Guo, 2008; Shao et al., 2013), however these studies are often based on relatively smaller biomass particles with regular shape, such as sawdust, rice husk and straw etc. Furthermore, their physical properties and geometric dimensions are very different from that of CBPs and the conclusions are not suitable for the CBPs in this study, hence the fluidization characteristics of CBPs need to be studied.

The combustion mechanism of biomass pellets has been studied by numerous researchers. Li et al. (2012) investigated the reaction mechanism of four typical types of Chinese biomass by TG-DTG and the results showed the combustion of biomass could be divided into three phases: (i) water evaporation process, (ii) volatile component combustion process, and (iii) the fixed carbon combustion process. According to the combustion characteristics of biomass, Demirbas (2004) found that the burning rate of the biomass was much higher than that of coal. Qian et al. (2011) conducted experiments on the NO emission of biomass. It was noted that NO emission decreased with the excess air, and increased with the bed temperature. Compared with char-N, volatile-N is the more dominant reactant source for NO emission. Ninduangdee and Kuprianov (2014) determined the best combustion and emission performance of the conical fluidized-bed combustor was achievable when burning palm kernel shell with a mean particle size of about 5 mm at an excess air of 40–50%. Khan et al. (2009) pointed out that the high percentages of alkali (potassium) and chlorine, together with high ash content, were the major sources of agglomeration problems. According the study of Duan et al. (2013) CO emission increased with the in-bed stoichiometric oxygen ratio, but decreased with excess oxygen ratio.

Despite numerous research devoted to the biomass study, the mechanisms and kinetics of the reactions involved in the combustion of the type of CBPs proposed in this study is not understood as it has not yet been fully investigated.

2. PROPERTIES OF CBPs

CBPs are made from wood, rice straw and catkins, with real density of about 1100 kg/m^3. High density CBPs are easy to store and can be easily mixed with the bed materials. As compared with rice husk and straw, the shape of CBPs is cylindrical and the particle size is larger (5–7 mm) as shown in Fig. 2. Calorific value of CBPs is 17–19 MJ/kg, less than 24.3 MJ/kg of the coal, but more than 13–15 MJ/kg of the straw. However, the biomass may contain alkaline that could be a cause of bed

Fig. 1. Chinese parasol trees in Nanjing.

Fig. 2. Photograph of CBPs and three raw materials.

Download English Version:

https://daneshyari.com/en/article/5750557

Download Persian Version:

https://daneshyari.com/article/5750557

Daneshyari.com