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Effect of co-combustion of chicken litter and coal on emissions in a laboratory-scale fluidized bed combustor

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ABSTRACT

Co-combustion of chicken litter (CL) with coal was performed in a laboratory-scale fluidized bed combustor to investigate the effect of CL combustion on pollutant emissions. The emissions of major gaseous pollutants including CO, SO_2, H_2S and NO and temperature distribution along the combustor were measured during the tests. Effects of CL fraction and secondary air on combustion characteristics were studied. The experimental results show that CL introduction increases CO emissions and reduces the levels of SO_2. The ratio of H_2S/SO_2 increases with increasing fraction of CL. NO emissions either increase or decrease depending on the percentage of CL in the mixed fuels. The temperature in the freeboard region increases with increasing the fraction of CL while the reverse is true for the bed temperature.

1. Introduction

Litter from poultry farms is traditionally used in land applications as a fertilizer because it is rich in nutrients. But over-application of this material could lead to an overabundance of water nutrients resulting in eutrophication of water bodies, the spread of pathogens, the production of phytotoxic substances, air pollution and emission of greenhouse gases [1–3]. One of the alternative disposal methods is direct combustion with the potential to provide a cost-effective, environmentally benign disposal route for the litter while providing for both space heating of poultry houses and large-scale schemes involved power generation or combined heat and power. However, the high moisture and ash contents as well as low heating value of the poultry litter could arouse problems on maintaining steady and complete combustion of poultry litter alone, as indicated in the literatures [1,4]. Therefore, co-firing poultry litter with coal is considered as a feasible means.

Several investigations on this aspect have been reported [4–6]. These research efforts have shown that co-combustion could address the energy supply issues and aid in the solution of air pollution control problems.

Compared with the conventional combustion technology, the fluidized bed combustion is considered as an optimal technology to dispose the animal waste with energy recovery due to its ability to accept fuels with a relatively high ash and moisture content, the low cost associated with fuel preparation, operational flexibility with regard to ash collection and easy control for pollutant emissions [7]. However, the use of poultry litter as a secondary fuel in a fluidized bed combustor has not been yet investigated extensively.

The purpose of this paper is to present the results obtained from an experimental study on co-combustion of chicken litter (CL) and coal in an atmospheric bubbling fluidized bed combustor with respect to the emissions characteristics of

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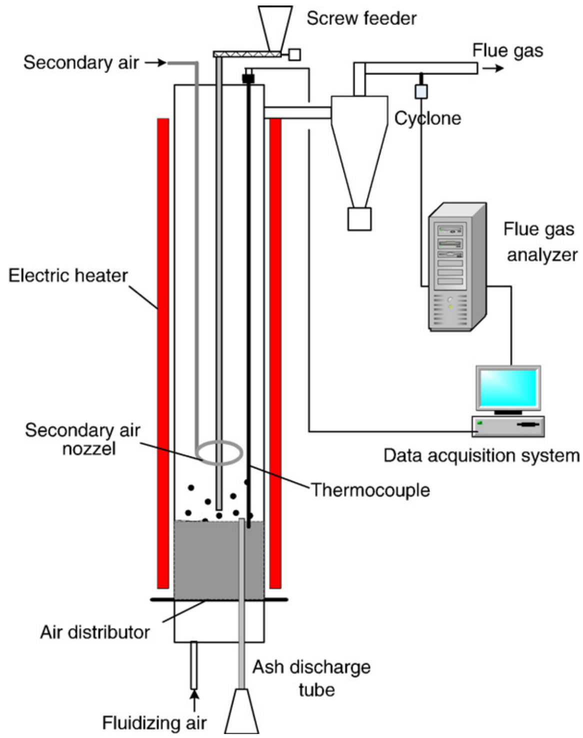

Fig. 1 – Schematic diagram of the laboratory-scale fluidized-bed combustor.

gaseous pollutants including CO, SO_2, H_2S and NO_x. Specially, the influence of CL mass fraction in the mixture and secondary air is described.

2. Experimental

2.1. Experimental set-up

All the experiments were carried out in an atmospheric bubbling fluidized bed combustor, as illustrated in Fig. 1. The combustor is a stainless steel pipe of 76 mm I.D. and 1.2 m in height, placed in an electrically heated oven consisting of total four silica carbon rods that preheat and make up for the heat loss from the bed. Fluidization air is introduced into the bed through a distributor, which is 10 mm thick stainless steel perforated plate with openings of 1 mm. A secondary air nozzle, which is a series of small holes arranged on a ring of 1/4 inch stainless steel tube, is located above the bed surface in order to promote the mixing of air with fuel. The fuel mixture is fed into the bed through a screw feeder. A minor compressed air is introduced into the fuel silo in order to avoid the flue gas back flow. The bed height can be controlled by adjusting the inserted height of the discharge tube from the bottom. Bed materials including the fuel ash and inertial sand come out of the combustor through the discharge tube once the bed height exceeds the height of the discharge tube inside the combustor. The pressure right before the air distributor is measured with a pressure transducer to monitor the quality of fluidization. The air is regulated by mass flow controllers based on the thermal mass flow sensing technique. The analysis of the flue gas is carried out on the gas stream exiting from the cyclone. Concentrations of SO_2, CO and H_2S are measured with on-line infrared gas analyzers. NO_x concentration is measured with an on-line chemiluminescence detector. O_2 concentration is monitored using a paramagnetic sensor. All data is displayed and logged on a PC via data acquisition unit. A K-type thermocouple is employed to measure the temperature within the combustor.

2.2. Experimental procedure

To attain the steady-state combustion and stable bubbling mode, it is essential to heat up the inert bed material above the ignition temperature of the fuel. After the required temperature was reached, the fuel was slowly fed into the bed. The duration of the test run was about 4 h, out of which 1–1.5 h period was used to reach the steady state condition. The steady state condition criteria were to have steady bed temperature and steady pressure drop. After steady state was reached, flue gas composition was measured. The cyclone were emptied and cleaned after each test, and fly ash samples were collected.

2.3. Characteristics of fuels

The ultimate and proximate analysis of both CL and coal are presented in Table 1. CL includes sawdust, wood chip and fecal matter. As a fuel, it has lower heating value equivalent to low rank coal (on the order of 5000 BTU/lb) due to high moisture, oxygen and ash content. High level of volatile matter and very little of fixed carbon imply that most of combustion for the litter takes place in the gas phase. The coal used in this experiment is a bituminous coal with relatively higher sulfur and lower chlorine. Table 2 shows the ash composition of both fuels. Compared with the coal ash, the ash of CL contains relatively high Ca, K and Na and low Si. This probably indicates that chicken litter ash has relatively lower fusion temperature and higher sulfur-retention ability.

3. Results and discussion

The experimental conditions of the co-combustion tests are shown in Table 3. In this experiment, baseline data was first

Table 1 – Characteristics of the fuels used

Parameter	Coal	CL
Proximate analysis (%)		
Moisture	2.6	11.3
Ash	9.4	24.8
Volatile matter	31.6	57.8
Fixed carbon	56.4	6.1
Ultimate analysis (%,dry)		
Carbon	71.3	28.2
Hydrogen	5.3	5.0
Oxygen	8.8	35.0
Nitrogen	1.4	3.4
Sulfur	3.5	0.9
Ash	9.7	27.5
Miscellaneous analysis		
Chloride(ppm)	1537	11639
Btu(1b)	12948	5074