Available online at www.sciencedirect.com
ScienceDirect
Fuel 86 (2007) 867–876
FUEL
www.fuelfirst.com

Influence of the amount of bed material on the distribution of biomass inorganic elements in a bubbling fluidised bed combustion pilot plant

M.J. Fernández Llorente *, R. Escalada Cuadrado

Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), CEDER, Ctra. N-111, km 206, 42290 Lubia, Soria, Spain

Received 23 September 2005; received in revised form 20 March 2006; accepted 10 August 2006
Available online 20 September 2006

Abstract

The purpose of this work is to study how the amount of silica bed material affects the distribution of the inorganic elements in a bubbling fluidised bed (BFB) combustion pilot plant (1 MW th). Combustion tests with poplar biomass at similar fluidisation velocities and other operational conditions were assayed.

The degree of interaction between the sand bed material and the biomass ash is a very important factor in the distribution of the inorganic elements in a BFB combustor. The higher the amount of silica bed material, the greater the retention of elements in the bed material. Bed accumulation can be very significant and can even retain more than 40% for major elements in poplar ash, such as calcium and potassium, as well as for trace elements such as barium, manganese, nickel, strontium and vanadium. The bed accumulation of an element depends specifically on the volatility of each element.

Keywords: Biomass; Combustion; Inorganic elements

1. Introduction

Combustion of biomass to generate heat and electricity should increase in coming years as many countries attempt to reduce greenhouse emissions. In contrast to fossil fuels, biomass fuels have a CO_2-neutral conversion and are renewable. However, the problems of slagging, fouling and corrosion associated with the mineral matter of biomass are well known [1–5]. This is especially true with biomasses with a high-content in alkaline compounds. Potassium compounds are abundant in lignocellulosic biomass. Moreover, agglomeration of the bed material in bubbling fluidised bed combustor occurs during the combustion of biomass, leading to the rapid shutdown of the BFB combustion thermal plant [6,7]. Fluidised bed combustion is a highly suitable combustion technology for a wide variety of fuels. The main feature of fluidised bed combustion is high-heat transport due to intense agitation of the bed material, reducing the combustion temperature and, consequently, the emission of toxic gases.

Emission of toxic trace elements in the flue gases is another important problem that could be influenced by the bed material due to the interaction between fuel ash particles and the bed material [8]. In general, the trace element content in biomass is low, although on occasion it can reach high-values in biomass from land contaminated by anthropogenic processes associated with fossil energy use, e.g., cadmium emitted by coal combustion [9]. The development of combustion technologies and processes with a high-potential for trace elements retention implies concentrating trace elements in a small ash fraction and recycling most of the ash (usable ash) by returning it to the soil [9,10].

* Corresponding author. Tel.: +34 975 281013; fax: +34 975 281051.
E-mail address: miguel.fernandez@ciemat.es (M.J. Fernández Llorente).

0016-2361/$ - see front matter
doi:10.1016/j.fuel.2006.08.023

The main objective of this paper is to determine the distribution of the inorganic elements of the lignocellulosic biomass in a BFB combustion pilot plant as a function of the amount of bed material. The amount of bed material could create important differences in the distribution of the elements at various locations in the thermal plant. The distribution of the fuels' inorganic elements in the power plants is an important factor to be considered when developing new combustors, planning strategic changes in the combustion processes and improving the design of the thermal combustion plants. This paper focuses on the major inorganic elements contained in ligno-cellulosic biomass ash (Ca, K, etc.), as well as on some trace elements such as Cu, Mn, Pb, Ni, V and Zn.

2. Materials and methods

2.1. Biomass tested

Only one poplar biomass was studied. Poplar was cultivated and collected to investigate its production in short rotation coppice crops [11] as well as to carry out the combustion tests in the BFB combustion pilot plant.

2.2. BFB combustion pilot plant and initial combustion conditions

A schematic diagram of the BFB combustion pilot plant, where the biomass combustion tests were done, is shown in Fig. 1. The furnace was cylindrical in shape, with an inner diameter of 1.1 m and a height of 4 m. The primary air (60% of the total air) was distributed through multiple nozzles mounted on a plate. The biomass supply system basically consisted of a conical bin and a variable speed screw conveyor. The poplar discharge, around 200 kg/h, was 30 cm above the distributor.

The bed material utilised was silica. To study the influence of the amount of bed material on the distribution of elements in the pilot plant, three combustion tests were carried out with three different amounts of silica bed material (150 kg, 175 kg and 200 kg). The total duration of each combustion test was around 10 h, with approximately eight hours of steady-state conditions.

Horizontal heat exchangers were placed in the freeboard. An economiser was installed after the combustor. The ash cleaning system was a multicyclone (Fig. 1). The gas and residual particles flow was forced towards the stack by a fan installed after the multicyclone. The pilot plant was equipped with instrumentation to measure temperatures, pressures and flows. A continuous gas analyser was utilised for determining the levels of CO, CO_2, NO, NO_x and SO_2. A continuous zirconium oxide cell meter was used to measure O_2.

2.3. Samplings

In order to obtain data to carry out mass balances on the inorganic elements with relevance for the distribution of the elements, the following materials were sampled in the atmospheric BFB combustion pilot plant:

- Biomass (BIO). At least seven gross samples were collected in each one of the combustion tests. Moisture content was carried out in each biomass sample. After this process, all biomass samples were mixed, generating the laboratory sample.
- Initial bed material (IB) and final bed material (FB). The sampling of the bed material was carried out before and after each combustion test.
- Ash from the economiser bin (EC) and the multicyclone bin (MC). One ash sample was taken after each combustion test.

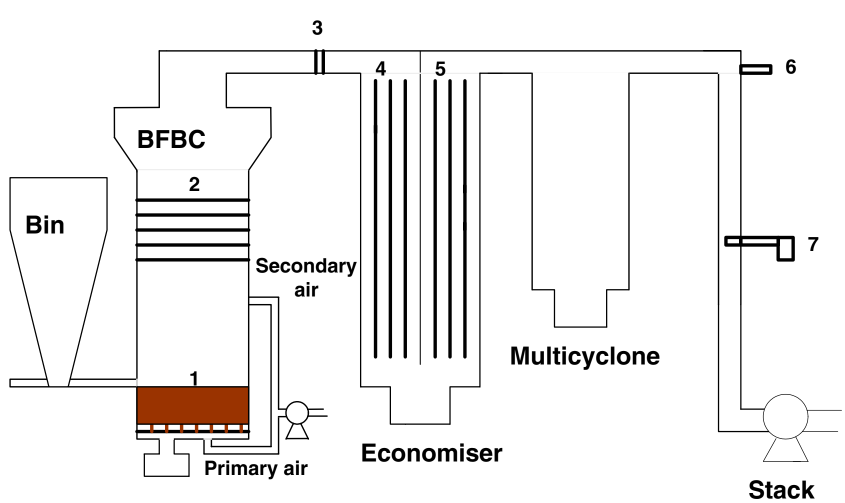

Fig. 1. Scheme of the atmospheric bubbling fluidised bed combustion pilot plant. 1: bed material, 2: main heat exchanger, 3: water cooled tubes placed in fouling area, 4: first heat exchanger of economiser, 5: second heat exchanger of economiser, 6: outlets for continuous analysers of gases, 7: stack sampling system.