Fuel Processing Technology 156 (2017) 1–8

Contents lists available at ScienceDirect

Fuel Processing Technology

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

Research article

Morphology of woody biomass combustion ash and enrichment of potassium components by particle size classification

Norio Maeda [a,b], Takaaki Katakura [b], Tomonori Fukasawa [b], An-Ni Huang [b], Takashi Kawano [c], Kunihiro Fukui [b,*]

[a] Environmental Engineering Department, TAKUMA Co., Ltd., 2-2-33 Kinrakuji-cho, Amagasaki, Hyogo 660-0806, Japan
[b] Department of Chemical Engineering, Graduate School of Engineering, Hiroshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8527, Japan
[c] Energy Engineering Department 1, TAKUMA Co., Ltd., 2-2-33 Kinrakuji-cho, Amagasaki, Hyogo 660-0806, Japan

ARTICLE INFO

Article history:
Received 20 August 2016
Received in revised form 20 September 2016
Accepted 22 September 2016
Available online 1 October 2016

Keywords:
Combustion ash
Particle size
Size classification
Potassium
Woody biomass boiler
Enrichment
Japanese cedar
Oregon pine

ABSTRACT

The mass balance of the ashes and their potassium component was investigated when different biomass fuels were incinerated using a fluidized bed furnace and stoker furnace, respectively. The properties of the ashes were analyzed, and the dependence of the potassium content in the ash upon its particle size was also examined. Very little K is exhausted in the flue gas, and nearly all is included in the ashes. The stoker furnace is thought to be more appropriate than the fluidized bed furnace to obtain bag filter ash, which has the highest potassium concentration. Moreover, the potassium content in the ash decreased with an increase in its mass median diameter. To enrich the potassium concentration in the ash, a method was proposed for collecting the finer ash selectively using a particle-size classification technique. Using it, ash having >35% of K concentration could be successfully obtained at factory scale. It was also confirmed that the enriched potassium bag filter ash, and the chemical fertilizer manufactured from it, completely satisfy the official specifications fixed by the Fertilizers Regulation Act in Japan.

1. Introduction

The promotion of energy conservation and the introduction of renewable energy have become of considerable importance as the issue of global warming has increased in severity [1,2]. It is essential to reduce atmospheric levels of greenhouse gases such as carbon dioxide for the reduction of global climate change. Specifically, after the Great East Japan Earthquake in 2011, the government of Japan began to consolidate the utilization of renewable energy for electric power generation. It also established the Feed-in Tariff Scheme for Renewable Energy in 2012 [3,4]. This scheme promotes power generation using woody biomass, and the power generation capacity of woody biomass power plants in Japan rose to 2.5 million kW in 2014 [5]. This path was selected because carbon dioxide emitted from the combustion of biomass is considered to be carbon neutral [6]. The government of Japan aims to increase its renewable power generation capacity to 3.8 million kW using 6 million m^3 of biomass fuel [7]. In order to achieve this target, the cost of power generation must be reduced greatly.

The inorganic components in the biomass are left behind after combustion of biomass in the form of several types of ashes (e.g., cyclone ash, bag-filter ash). In Japan, all types of ashes from the combustion of biomass must be transferred to a final disposal site as industrial waste [8]. The cost of conveyance and land filling is about 20,000 JPY/t, which appears sufficient to inhibit the spread of the use of woody biomass power plants.

It has been reported that the combustion ash produced by the combustion of biomass could be effectively utilized as an adsorbent material [9], soil improving agent [10], alkali source [11], and others [12,13]. However, these have not been realized at an industrial scale. On the other hand, the ash produced by burning plants during agricultural processes has traditionally been used as fertilizer because it contains a high concentration of potassium components. Because the combustion ash of woody construction waste material includes high concentrations of harmful heavy-metal components such as Pb, Cd, Cr, Cu, and Fe [14,15], it is difficult to utilize it. However, the combustion ash obtained from the combustion of wood from forest thinning, unutilized wood, and virgin woody biomass could be used as the raw material for making fertilizer because it contains very low concentrations of heavy metals [16,17]. Specifically, chemical fertilizer manufacturing companies could pay for combustion ash with a potassium content of 25% or more as a valuable raw material. This scheme not only could reduce the cost of power generation but would also contribute to the recycling of an essential resource (potassium).

Furthermore, studies have been done of the chemical compositions and physical properties of combustion ashes obtained from burning

* Corresponding author at: Department of Chemical Engineering, Graduate School of Engineering, Hiroshima University, 1-4-1 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8527, Japan.
E-mail address: kfukui@hiroshima-u.ac.jp (K. Fukui).

http://dx.doi.org/10.1016/j.fuproc.2016.09.026
0378-3820/

various biomass fuels at a number of different furnaces in Europe [18, 19]. The dependence of the chemical composition in the combustion ash on its particle size has been also studied, which reveals that the volatile component is concentrated in ash having a relatively smaller particle size [16,20,21]. However, these important findings concerning biomass as a resource have been little reported in Japan [22].

Accordingly, in this study, with respect to two types of furnaces and biomass fuels, the mass flow of the ashes and the material balance of the potassium component between the biomass fuel and the ashes produced were investigated. Based on the effect of the particle size of the ash on its potassium concentration, a method to separate the ash-fraction having the most condensed potassium using the particle-size classification technique was proposed. Moreover, this proposal was substantiated by factory-scale experiments using an actual biomass-fueled boiler plant.

2. Materials and methods

2.1. Performance of biomass furnace and ash sampling

The mass flow and the material balance between the biomass fuel and produced ashes were examined when the biomass fuels were combusted in two types of furnace. Fig. 1 demonstrates the schematic diagram of biomass fuel boiler plants equipped with different combustion technologies. A fluidized bed combustion furnace and a stoker furnace are installed in Plant A and Plant B, respectively. As listed in Table 1, the fluidized bed combustion furnace had a combustion chamber volume of 280 m^3. The gas temperature at the exhaust port of this furnace was maintained at 790 °C. During the time that the boiler generated 39 t/h of high-temperature steam (3.14 MPa, 305 °C), the gas temperature decreased to 330 °C. In contrast, the stoker furnace had a combustion chamber volume of 110 m^3, and the gas temperature at its exhaust port was kept at 890 °C (considerably higher than that of the fluidized bed furnace). During the time that the boiler of the Stoker furnace generated 20 t/h of high-temperature steam (1.86 MPa, 310 °C), the gas temperature decreased to 350 °C. The stoker furnace in Plant B gives a larger temperature difference between the exhaust port of the furnace and the outlet of the boiler than does the fluidized bed furnace. This means that the gas from the stoker furnace, which includes various volatile components, is cooled more rapidly than that from the fluidized bed furnace.

The properties of the biomass fuel incinerated by each furnace are listed in Table 2. Raw sawdust and bark of Oregon pine was the biomass fuel fed into the fluidized bed combustion furnace (at 15,800 kg/h) in

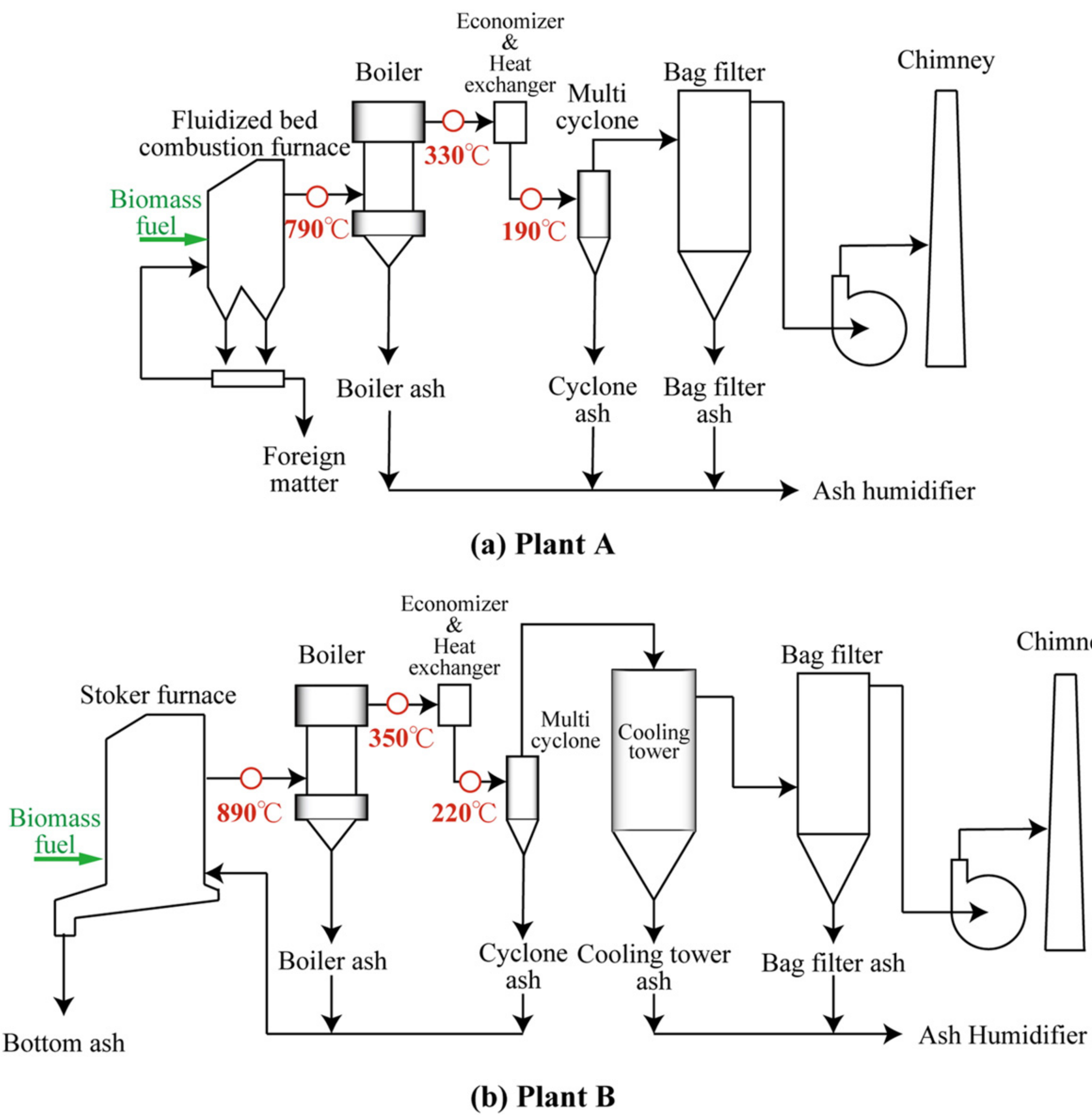

Fig. 1. Schematic diagram of biomass fuel boiler plants equipped with different combustion technologies.