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Experimental investigation on the fixed bed of a small size biomass boiler

Gianluca Caposciutti[a]*, Federica Barontini[b], Marco Francesconi[a], Marco Antonelli[a]

[a] *Department of Energy, Systems, Territory and Constructions Engineering, University of Pisa, Italy*
[b] *Department of Civil and Industrial Engineering, University of Pisa, Italy*

Abstract

During the last decades, the increase of the world energy consumption promoted the renewable resource development and use. Together with wind, solar and hydro energy, biomasses play a key role in the reduction of the industrial environmental impact; moreover, the biomass combustion systems are very attractive for micro-generation purpose. In this paper, experimental tests on a 140kW small size fixed bed biomass boiler were carried out. The main goal was to study the thermal behavior and some chemical products, such as CO, CO_2, Methane and Ethylene, from the combusting fixed bed of the system. In fact, despite the wide amount of literature for the laboratory scale systems, the commercial scale boilers have been seldom studied by the experimental point of view. The data were obtained by varying the operational parameters of the boiler, that are the air excess and the secondary to primary air feeding ratio. Furthermore, the collected data were analyzed and the relationship between the thermal-chemical data and the control variables was discussed.

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Keywords: Biomass combustion; Small Scale Biomass Boiler; Experimental Data; Fixed Bed System

1. Introduction

The increase in the energy consumption and the purpose of reducing the pollutant emissions, lead to improve the use of renewable energies. The biomass appears to be suitable for this purpose because it can be employed as an integrative foreseeable source between solar, wind and hydro energy. The use of biofuels in combustion facilities is

* Corresponding author.
E-mail address: gianluca.caposciutti@ing.unipi.it

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the most common way to produce heat and power; furthermore, the small-scale systems are very interesting for micro-generation purpose [1]. From the literature, the semi industrial scale systems (such as >100kWth) were seldom studied with respect to the laboratory scale or domestic systems. For instance, similar boilers were recently studied by [2,3], however, the thermal power involved was always below 100 kW thermal input. Other studies, such as [4,5], involved systems with 300 kW and more as thermal input, using moving grate feeding mechanism. Between these power levels (particularly between 100 kW and 200 kW) the combustion system presents intermediate characteristics. Firstly, these are characterized by high heating rate, and the chemical kinetics behavior is close to the higher scale systems [6,7]. For instance, [8,9,10] studied the reaction parameters both in laboratory scale and real scale burners, highlighting the many differences found. The other important issue is the modeling of the fixed bed, which is composed by discrete elements of biofuel. For instance, [11,12] use a Discrete Element Model (i.e. DEM) to calculate the biomass behavior inside fluidized bed. However, the use of DEM in fixed bed boilers requires thermal data for validation purpose. Considering the chemical emission modelling, the lumped parameter models are attractive for their simplicity and good accuracy [13], and many authors evaluated the combustion products through these models [14,15]; however, the comparison with experimental data has a key role for validation and tuning purpose, especially in these seldom studied systems. In this paper, the authors present the experimental results carried out on the fixed bed of a 140 kW thermal power biomass boiler. The main goal was to provide chemical as well as thermal data of the exhaust gases and the fixed bed. Particularly, the chemical data were collected both from the boiler outlet and from the biomass surface, in which the devolatilization products are predominant. Moreover, the relationship between the operative parameters, that are the air excess and the ratio between the primary and secondary air feeding flow, and the measures involved was studied. Finally, the results were both analyzed and discussed in the further sections.

2. Methodology

The experimental equipment is a 140kWth modified Standard Kessel Italiana S.r.l. fixed bed biomass boiler installed at the "Biomass to Energy Research Center" (CRIBE) facility in Pisa. The boiler is composed by a fixed bed combustion system and by a secondary air diffuser (Fig. 1). The big post-combustion volume ensures the ash deposit and the complete volatiles combustion. The air is totally provided by means of a primary blower of 0.75kW power.

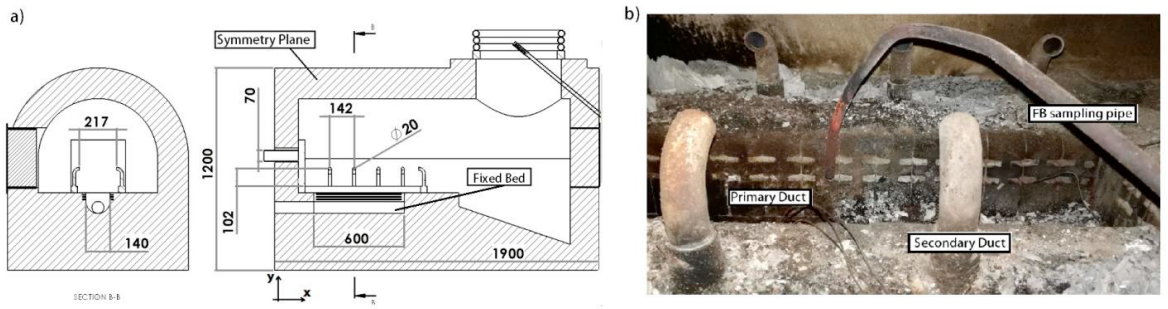

Fig. 1. (a) boiler general scheme with size in millimeters, (b) fixed bed overview

The exhaust gases pass through an oil to gas heat exchanger, in order to heat up a Seriola 1510 diathermic oil, that ensures a constant thermal load to the system; further details about the facility can be found in [16]. A secondary blower extracts the flue gases by keeping the in-chamber pressure of 20 below the atmospheric. The biomass is introduced from the bottom of the fixed bed by means of a screw conveyor, whose rotating speed was set at 2 rpm for all the test. This value was a compromise found by previous tests, that ensured both stable measuring conditions and the required thermal power. The feeding air can be divided into a primary flow, placed by the side of the fixed bed, and a secondary flow, that was inserted above and parallel to the fixed bed surface, by means of two hand actuated sphere valves. In Fig. 2 the whole system scheme is presented.