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Effect of pelletizing conditions on combustion behaviour of single wood pellet

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HIGHLIGHTS

- Effect of pelletizing conditions on combustion of single wood pellet was investigated.
- Wood pellets were produced in single die pelletizer.
- Time required for single pellet combustion was affected by pelletizing conditions.
- Combustion behaviour of single die pellets was different than those from pilot scale pelletizer.

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ABSTRACT

This paper presents how pelletizing die temperature and moisture content affect combustion behaviour of single wood pellet. Pine wood particles with two different moisture contents (i.e. 1 wt.% and 12 wt.%) were pelletized in a laboratory-scale single pelletizer (single die pellets) at die temperature of 20, 100, 150 and 200 °C. The pellets were combusted in a laboratory scale furnace at 800 °C. Time required for single pellet combustion generally increased with both increase of pelletizing temperature and moisture content of biomass. In addition, combustion behaviour of single die pellets was significantly different than those produced in a pilot scale pelletizing plant (semi-industrial scale pellet). That difference was due to variation in physical properties of pellets (e.g. density, and morphology).

1. Introduction

Wood pellet industry is an important part of bioenergy industry at annual production of 14 million tons in 2010. The production capacity of pellet varies among the largest producers, North America and Scandinavia, and emerging producing countries for example Australia, South Africa and South America [1]. The wood pellet market has been growing steadily worldwide driven by industrial and residential consumers for heat and power production [2]. The performance of conversion units for heat and power production depends on the optimal design of the chemical reactors (e.g. combustors and gasifiers) [3]. Understanding fundamentals of fuel particle conversion is of great importance in the optimization of reactor performances.

Phenomena that occur during biomass pellet production are complex. Biomass particles are compacted under pressure to form densified pellet. Under mechanical pressure, biomass particles first rearrange in a pelletizing die to remove air in the gaps among particles, and then deform to remove air in intra-particle pores. At the same time, the temperature of the biomass particles increases due to the friction between biomass and the pellet die during the forced passage through press channel. Elevated temperature in wet biomass activates the natural binders in particles and makes physical bonds with neighbour particles to form a pellet. Several pelletizing conditions for biomass densification process have important roles on both process efficiency and the quality of product. For example, high pelletizing temperature and low moisture content in biomass have shown to enhance the pellet strength and density, and also reduced the pelletizing energy consumption [4].

Fig. 1 shows the schematic presentation of different factors affecting fuel conversion of pellets. We defined operational parameters as the parameters pellet producers can control directly (drying temperature etc.). Pelletizing conditions, which are the local conditions of biomass particles at the moment of pelletization and not able to be observed directly, are largely affected by these operation parameters. Chemical and physical properties of biomass

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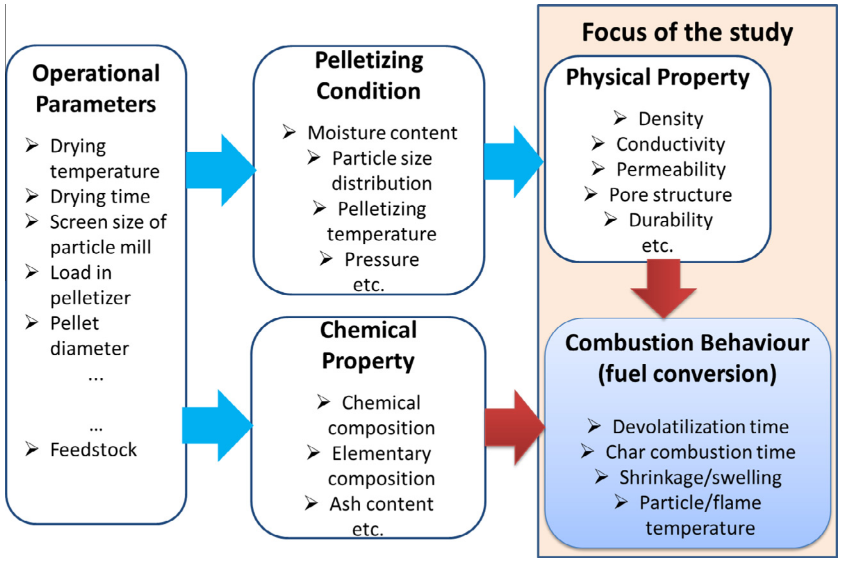

Fig. 1. Schematic presentation of different factors affecting fuel conversion of wood pellet.

pellet are affected both by these factors (see Fig. 1). Chemical properties (e.g. organic and inorganic composition) are determined mainly by the choice of feedstock, but they might change during and after pelletization process as well [5,6]. On the other hand, physical properties (density, thermal conductivity, permeability) are affected by pelletizing conditions. For instance, pelletizing conditions (i.e. pressure, temperature and moisture) significantly affect pellet density and thermal conductivity due to compression of vacuole in wood particles as well as improved solid–solid contacts.

Combustion behaviour of pellets is significantly affected both by chemical and physical properties (Fig. 1). Chemical and physical properties of the fuel determine heat and mass transfer rate, reaction path and kinetics [7]. Effect of chemical property (i.e. raw material composition) and particle size distribution of biomass sample on single fuel pellet combustion was investigated by Erlich et al., Bergström et al. and Rhén et al. [8–10] although the results have not been validated with full scale pellets. Combustion time of single pellet was significantly affected by biomass composition while the role of particle size distribution in pellets was insignificant. No study was found on the effect of pelletizing temperature and biomass moisture content on single pellet combustion.

Modeling of detailed reactor scale combustion is computationally expensive process due to presence of multiple particles. Simplification of particle conversion model is often practiced to overcome problem associated to the time of computation. Study of single particle combustion can provide information to modelers to choose most important phenomena to take into consideration and to discard least important one while modeling combustion process. The aim of this study is to investigate the effect of pelletizing conditions (i.e. pelletizing die temperature and moisture content) on fuel conversion behaviour of single wood pellet combustion. The focus was especially onto identify which physical/chemical parameters play significant roles on fuel conversion. Pine wood particles were pelletized in a laboratory-scale single die pelletizer under controlled conditions. The same material was also pelletized in a semi-industrial pelletizer. Fuel conversion time was examined by using a laboratory-scale combustion furnace. Morphology of pellet and char was examined by a scanning electron microscope (SEM).

2. Experimental

2.1. Sample preparation

Pine sample was ground for pellet production. The particle size distribution of the ground sample from sieve analyses is presented in Table 1. A cylindrical die with diameter of 8 mm was used to produce pellet in a piston press at the die temperatures of 20, 100, 150 and 200 °C. Moisture contents of raw biomass were 12 wt.% and 1 wt.%.

A cylindrical die was heated to desired temperature. When the temperature of the die reached target temperature, around 600 mg of biomass was placed in the die and compressed at 0.5 mm/s to 398 MPa with a computer controlled hydraulic press. When pressure reached 398 MPa, the sample was held for 10 s and then released. Later on, pellet was pressed out of the die. To compare single die pellets with pellet from semi-industrial scale plants, the same raw biomass was used to produce pellets in a semi-industrial roll die type pelletizer. The detailed descriptions of the pelletizing processes can be found elsewhere [11,12].

2.2. Experimental procedure

A laboratory scale furnace was used to determine the combustion characteristics of single pellet. Similar equipment has been used for previously published single pellet combustion studies [8–10], but this furnace was also equipped with an analytical balance enabling using it as a macro-TGA. Fig. 2 presents schematic diagram of the furnace. The furnace was heated by PID controlled electrical wall heaters to reaction temperature prior to the experiments. Pre-heated air was continuously supplied to the furnace from the bottom through a distribution plate. The sample was hung in a Pt-basket connected to an analytical balance (±1 mg) with a steel wire, and kept in a cooling chamber with nitrogen flow before the and after the experiment. The cooling chamber was isolated from the radiation of the furnace by a slide hatch. Experiments started when the sample was inserted into the furnace from the cooling chamber using a pneumatic elevator device. The furnace had an observation window in front to record the