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Study of briquetted biomass co-firing mode in power plants

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HIGHLIGHTS

- The biomass co-firing mode is suitable for biomass dispersedly distributed areas.
- High economy and efficiency of biomass pretreatment can be realized.
- The biomass can be used through existing equipments efficiently and cleanly.
- Economic analysis shows that this mode is of good economic sustainability.

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ABSTRACT

A briquetted biomass co-firing mode that is feasible in China and other areas with dispersedly distributed biomass resources was proposed, and the details and characteristics of this mode are discussed. Raw biomass from sources such as corn stalks, twigs, and straws was crushed in farmlands and then transported to briquetting stations. The crushed biomass was dried and compressed into briquettes until the moisture content was less than 25%. Finally, the biomass briquettes was stored and delivered to plants like coals for combustion. One of the six layers of the pulverizing system in a 300 MW power plant could be used, and 100% biomass briquettes could be ground by an existing MPS medium speed pulverizer. The biomass briquettes could then be delivered directly into the furnace by primary air. No additional equipment investments were needed for the plant because almost all equipments were already available. Advantages such as cost-effective on biomass collection and transportation, high efficiency and low cost on biomass preprocessing, biomass briquette economic grinding and feeding, and efficient and clean combustion could be realized by this method. The economic sustainability of this mode was also analyzed.

1. Introduction

Coal-fired power plants account for more than 70% of the total power generation capacity in China. This large-scale coal consumption results in severe CO_2 emissions. China has been ranked No. 1 in CO_2 emissions since 2009. Thus, plans have been made to reduce CO_2 emission by 55%–60% by 2020 under different macro-control measures of the state. Renewable energy is important to achieve energy savings and reduce CO_2 emissions.

Biomass is considered a CO_2-neutral fuel because biomass consumes the same amount of CO_2 from the atmosphere during growth and combustion. It yield in China is approximately 1.17 billion tce/a, 48% of which can be used for power generation [1,2], compared with the total potential bio-energy in the whole world (i.e.,3.42 tce/a to4.95 tce/a (2050)) [3].

Biomass power generation will reach 13,000 MW by 2015 with an estimated electricity price of 0.122 USD/kWh, which is higher than the electricity from a coal-fired power plant (0.054 RMB/kWh) [4], according to the documents released by the National Energy Administration of China. However, subsidy is only provided for dedicated biomass firing power plants and does not cover coal/biomass co-firing plants, which have unmanageable co-firing ratios and quantities.

Dedicated biomass firing plants have rapidly developed in recent years under the support of government policy. Over 100 dedicated biomass firing plants are distributed in China [5]. However, in biomass direct-firing power generation, the alkali metal and particularly high content of potassium and chlorine in biomass lead to severe slagging and corrosion [6–11]. The thickness of the slagging on superheaters can reach 900 mm after operating for only a month in some boilers [6,7]. Nevertheless, biomass co-firing in large-scale thermal power plants can significantly ease slagging

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and corrosion problems [12–16]. The thermal parameter of dedicated biomass firing power plants is lower than the thermal parameter of large-scale pulverized coal (PC) boilers. The combustion and overall power generation efficiencies are lower than 85% and 25% for dedicated biomass firing boilers, respectively. For large-scale co-firing PC boilers, the power generation efficiency can be higher than 40% [17,18]. Furthermore, the sensitivity of co-firing plants to biomass supply price is lower than the sensitivity of biomass direct-firing plants. Co-firing plants can adjust their co-firing ratios according to the price and supply of biomass. Previous studies have shown that biomass co-firing can reduce CO_2/SO_2/NO_x emissions without affecting the operation of the units if the biomass co-fired quantity is controlled at a reasonable level [12–15,19]. Most coal power plants in England are subject to the requirement of at least 5 cal% co-firing capability. However, such biomass co-firing power plants are few in China.

The first demonstrated PC/straw co-firing power plant in China began operations in Shandong Province in 2005 [20]. The technology from Burmeister&Wain Energy A/S, Denmark, is introduced in this paper. A new set of straw transport and mill equipment are installed, and two straw burners with 30 MW input ability are equipped in the middle of the original two-layer PC burners. Air supply systems and associated control systems are also improved. However, the adaptability of the straw pretreatment equipment is weak, and only wheat straw can be processed. The excessive dependence on a single type of biomass has led to the sharp increase of biomass price from 30 USD/t to nearly 80 USD/t. Nevertheless, the plant can obtain small profits by obtaining a subsidy of 0.0127 USD/kWh from the local government. The family pattern agricultural production structure in China differs from ranches in Western countries. Such a small scale farming structure scatters straw resources and increases the difficulty of straw collection and transportation. The biomass used in plants is simply packed with low bulk density. This biomass co-firing mode has not been extended to other parts of China because of these afore mentioned reasons.

A new biomass co-firing mode, which has been applied in a 300 MW unit in Baoji, Shaanxi Province, is proposed in this study to explore a suitable biomass co-firing mode for China or other areas with distributed biomass resources. This mode has been implemented for two years. The details and characteristics of this mode are discussed in this paper.

2. Mold biomass co-firing mode

2.1. Background of the mode

This biomass co-firing mode has been applied in a coal-fired power plant in Baoji, where is the major-grain producing area in Shaanxi Province and is also one of the major wheat and cotton-producing areas in China. Crop straw output in Baoji is approximately 2.7779 million t in 2008, accounting for 12.17% of the total output in Shaanxi Province, among which 49.2% of the total straw is used for daily cooking or warming [21]. Furthermore, about 24 million t of straw are discarded or burnt in fields, causing energy waste and serious atmospheric pollution [21]. To make full use of this straw resource, USD 5.55 million has been invested by the Shaanxi government and China Guodian Group to promote mold biomass co-firing in large-scale coal-fired power plants.

2.2. Details of the co-firing mode

A mold biomass co-firing mode in 2 × 300 MW PC power plant is proposed. This co-firing mode would be described detailedly in three major areas: fuel characteristics, biomass pretreatment, feed system and combustion organization.

2.2.1. Fuel characteristics

The plant in this case commonly uses Huating bituminous coals, and the co-fired biomass briquettes are made from straws, corn stovers, tobacco poles, branches, and other agriculture wastes. The proximate and elemental analyses of the bituminous coal and co-fired biomass are listed in Table 1. Biomass briquettes are highly volatile and contain lower carbon, sulfur, and calorific values than Huating coal. The density of biomass briquettes is 780 kg/m^3 to 1180 kg/m^3, which is significantly higher than that of raw biomass (50 kg/m^3 to 120 kg/m^3 for wheat straw and other soft straws; 200 kg/m^3 to 350 kg/m^3 for corn stalks and other hard straws; 125 kg/m^3 for rice husk). The briquettes have cylindrical shapes, 34 mm diameters, less than 65 mm lengths.

2.2.2. Supply, pretreatment, and storage of biomass fuel

The supply chain of biomass is designed in accordance with the family patterns of farming in China as follows: farmers → straw brokers (briquetting station) → power plant. The power plant contacts and develops a group of straw brokers and assists them in establishing biomass briquetting stations. The straw brokers then purchase raw biomass from dispersed farmers within about 50 km around the briquetting station. Raw biomass is crushed once collected in fields to reduce its volume. Then the crushed biomass is dried in air until the moisture content is less than 25% and then compressed into briquettes at the briquetting station. The process capacity of each set of briquetting equipment is 0.8–1.0 t/h. Then the processed briquettes are sent to the power plant for co-combustion with coal. The local government donates one set of briquetting equipment to biomass brokers per equipment purchased to encourage biomass brokers to establish straw briquetting stations. A total of 19 straw briquetting stations currently exist within 100 km around the plant and are equipped with 50 sets of briquetting equipment. The number of briquetting stations is still increasing.

2.2.3. Feed system and combustion organization

The boiler used in the presented case (DG1025/18.3) is designed and manufactured by Dongfang Boiler Work (China), with a capacity of 300 MW and an evaporation time of 1025 t/h, which is equipped with a four-corner fired combustion system. The layout of combustors is shown in Fig. 1. Six layers (A–F from bottom to top) of combustors comprise the combustion system, and each layer is equipped with an individual mill system and primary air injectors. The five layers (A–E) are used to maintain maximum continuous rating operating conditions. A group of MPS medium speed pulverizer and direct-blowing pulverizing system exists in each layer. The remaining layer (F) is used to grind and burn biomass briquettes.

The design of a biomass feeding system is one of the key issues [13] in biomass co-firing power generation. Two major types of biomass feeding systems exist for a biomass co-firing plant: (1) biomass feeding system that mixes biomass directly with coal at

Table 1
Proximate and ultimate analyses of tested fuels.

Fuel	$Q_{net,ar}$/MJ kg^{-1}	Proximate analysis			Ultimate analysis				
		M_{ar}	V_{daf}	A_{ar}	C_{ar}	H_{ar}	O_{ar}	N_{ar}	S_{ar}
Coal	18.7	18.5	35.5	17.6	52.5	3.03	9.96	0.51	0.64
Biomass briquette	12.2	10.1	79.3	6.5	44.7	3.43	44.2	0.81	0.30