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Grinding and combustion characteristics of woody biomass for co-firing with coal in pulverised coal boilers

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HIGHLIGHTS

- A vertical roller mill is suitable for woody biomass grinding.
- An interior device for vertical roller mill increases wood pellet grinding capacity.
- Wood powder can be burnt with conventional pulverised coal burner.
- Woody biomass must be burnt in lower row burners to prevent CO emissions.

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ABSTRACT

This paper presents results of grinding experiments and development of woody biomass mill for co-firing in pulverised coal fired boilers. Woody biomass co-firing with coal is already realised since it can be easily handled as a carbon–neutral fuel. Three steps have been carried out to understand the grinding and combustion characteristics of woody biomass. A suitable mill type for woody biomass grinding has been sought in laboratory-scale experiments. The selected industrial-scale mill has been modified to increase the capacity.

The objective of this experimental study is to establish and demonstrate the woody biomass firing system including mill and burner for pulverised coal fired boilers. Both, laboratory- and industrial-scale measurements, provide good understanding of woody biomass grinding and firing performance. The proper burner arrangement is found by use of Computational Fluid Dynamics (CFD) to maintain high burnout efficiency in the boiler. The study proves that the proposed mill and burner positioning is promising to utilise woody biomass with high co-firing ratio. The combination of furnace experiments and CFD modelling results in a satisfying specification of a co-firing system for woody biomass with pulverised coal in sufficient ratio whilst reducing CO_2 emissions.

1. Introduction

Coal is still an important source for power generation even though its CO_2 emission is higher than that of other fossil fuels, because coal is an abundant resource and guarantees inexpensive electricity price. Global warming and CO_2 reduction are important issues to be dealt with by the power generation sector. Woody biomass is the most abundant biomass resources in Japan, whose forest area is 68% of the total land [1]. Utilisation of woody biomass is one strategic policy for CO_2 reduction. Since a large fraction of CO_2 emissions comes from power generation, usage of woody biomass is already commenced in pulverised coal fired power boilers [2–4]. Woody biomass is solid and needs to be ground for firing in pulverised coal boiler furnace. In many cases, woody biomass is fed together with coal into the existing coal mills without any modifications. This way of utilisation can minimise the investment cost. However, the mixing rate is limited depending on the margin of mill load. Recently, some of pulverised coal fired power stations realised 100% biomass firing, which means the complete fuel switching from coal to woody biomass. Since the heating value of biomass is less than coal, more biomass must be fired in order to achieve the same power output. Hence, the grinding capacity for biomass must exceed that of coal. The present situation has been achieved by try-and-error, caused by the fact that empirical research was precedent in woody biomass grinding.

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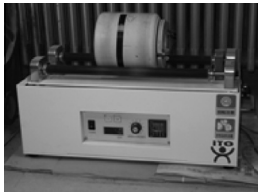
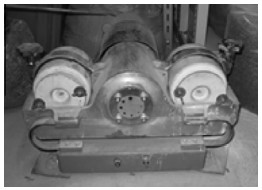
Table 1
Laboratory scale mills used for suitability evaluation of different grinding methods, specifications and experimental conditions.

Mill type	Mill size Condition-1	Grinding medium Condition-2	Specification Condition-3
Ball mill 	d = 144 mm Volume = 0.21 m^3 Grinding medium = 2000 g (Alumina ball) Specimen weight = 36.3 g Waste wood, pinus bark	Alumina: d = 20 mm Stainless steel: d = 19 mm Grinding medium = 4764 g (Stainless steel ball) Specimen weight = 36.3 g Waste wood, pinus bark, wood pellet	Rotation speed = 95 rpm (80% of critical speed) Grinding medium = 2000 g (Stainless steel ball) Specimen weight = 36.3 g Waste wood, pinus bark
Vibration mill 	d = 120 mm Volume = 0.1 m^3 Grinding medium = 1000 g (Alumina ball) Specimen weight = 18.2 g Waste wood, pinus bark	Alumina: d = 15 mm Grinding medium = 3800 g (Stainless steel ball) Specimen weight = 31.4 g Waste wood, pinus bark, wood pellet	Vibration = 1440 cpm Grinding medium = 1730 g (Alumina ball) Specimen weight = 31.4 g Waste wood, pinus bark, wood pellet
Vertical roller mill 	Table dia. = 200 mm Roller dia. = 100 mm Roller force = 640/800/960/1100/1260 N Table speed = 20/30/45/60 rpm Specimen weight = 4.5/9.1/13.5 g Waste wood	Roller pressure = 2000 N (max.) Roller force = 960 N Table speed = 45 rpm Specimen weight = 9.1 g Waste wood, pinus bark, wood pellet	Table rotation = 60 rpm (max.)