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Research article

Co-firing of pulverized coal with Pinion Pine/Juniper wood in raw, torrefied and pyrolyzed forms

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A B S T R A C T

A program was funded by the U.S. Forest Service to perform pilot-scale co-firing studies at the University of Utah in a 1.5 MW pulverized-coal test facility, to examine the emissions, deposition behavior and ash characteristics, when co-firing pulverized coal with wood culled from pinion–juniper (P–J) forests in Utah.
The woody material was evaluated in each of three forms: 1) raw, untreated material; 2) torrefied material, and 3) biochar from the pyrolysis of the P–J material. The different types of the thermally processed P–J material were produced by Amaron Energy in a 1/2 t per day prototype pyrolysis facility prior to the testing at the University of Utah.
Results of the pilot-scale co-firing trials indicated essentially no major differences in gaseous emissions or unburned carbon in flyash or baghouse ash when co-firing pulverized coal with any of the 3 biomass fuels for the conditions investigated. In addition, no significant deposition problems would be anticipated using 5–10% biomass on a thermal input basis. Operation with 10% or greater percentage of raw or torrefied wood resulted in feeding problems at this scale; however, the bio-char could be fed with no problems for levels as high as 20% (the highest percentage tested).

1. Introduction

1.1. Identification of a biomass resource

The U.S. Forest Service hires contractors each year to clear vast quantities of pinion pine and juniper (P–J) as part of their mandated woodland management program to break up fuel loads, and to control and maintain habitats and watersheds [1]. Much of this material is chained, chipped and left on site. The Institute for Clean and Secure Energy at the University of Utah teamed with agronomists from Utah State University, a local company Amaron Energy, and representatives from the U.S. Forest Service and the Bureau of Land Management, to identify potential uses for this woody biomass waste. One approach considered is use of the P–J material as a co-firing fuel in coal-fired power plants.

One significant drawback of the use of woody biomass as a co-firing fuel is the low energy density of the wood relative to coal, which makes collection and shipping of the fuel less viable, particularly if the collection radius is greater than 34 km [2]. The use of a distributed system of pyrolysis or torrefaction units would allow for densification of the biomass prior to shipping. Amaron Energy has developed a field-deployable unit capable of operating in either a pyrolysis or torrefaction mode for processing a wide variety of biomass materials, and this technology was used to prepare the co-fired biomass fuels for this study.

1.2. Use of biomass as a co-firing fuel

Biomass co-firing has not been widely adopted, due to a number of potential operational concerns. A detailed review [3] of biomass co-firing summarizes some of these issues as follows:

- fuel availability;
- price (primarily due to availability and location relative to the use point);
- deposition and high-temperature corrosion, particularly due to the presence of elevated potassium and chlorine levels relative to coal;
- flame stand-off distance, which affects flame stability and NOx, and
- pulverizer/feeding considerations.

While there have been many studies to identify the impact of co-firing raw wood and torrefied wood with coal [4–6], along with considerable operational experience [7–9], there did not appear to be much data in the literature providing a comparison of the co-firing of raw,

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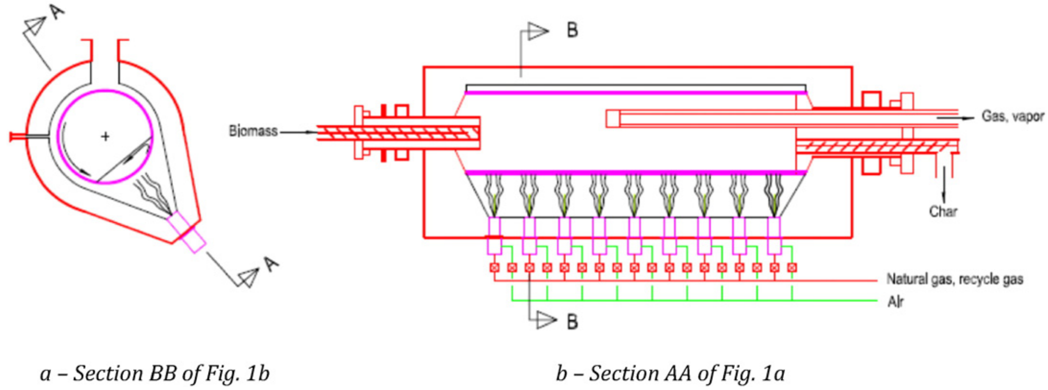

Fig. 1. Amaron Energy indirectly-fired rotary-kiln pyrolysis process for the production of biochar and torrefied wood [10–11].

partially pyrolyzed (torrefied) and fully pyrolyzed (biochar) wood in a coal-fired system. We thus undertook a pilot-scale study to assess the performance of these 3 different forms of P–J wood, with respect to the operational issues identified above.

2. Experimental systems

2.1. Pyrolysis process

Traditional methods of fast pyrolysis for biomass (such as fluidized bed pyrolysis) can be complex and expensive. Amaron Energy has developed a patented precision-controlled indirectly fired rotary-kiln process that can achieve typical fast pyrolysis oil yields [10–11]. The process is simple and inexpensive and can operate in either a pyrolysis or a torrefaction mode. A basic schematic of the process is shown in Fig. 1.

Biomass feedstock is auger-fed into the main reaction zone, which consists of a rotating cylinder (typically stainless steel) that is indirectly heated by a series of computer-controlled burners. The array of burners allows for precise control of the temperature along the length of the reaction zone. Pyrolysis vapors are extracted though a movable vapor probe, and the location of this probe dictates gas-phase vapor residence time inside the reactor chamber. Solid char or torrefied product is removed by an auger at the end of the kiln into a char cooler/collection system, and the pyrolysis vapors pass into a multi-stage condensation setup for oil collection. Non-condensable vapors are filtered and recycled to the burners to provide heat for the pyrolysis reactions.

Amaron Energy has several years experience operating a prototype unit at 450 dry kg per day (0.5 dry ton per day or tpd) on a variety of biomass fuels. The prototype unit was built into a 6.1-m (20-ft) shipping container mounted to a trailer, so that it could be deployed remotely for use in densification of biomass materials prior to shipping. Four remote field demonstrations for the production of bio-oil and bio-char were successfully completed with the prototype unit during 2013 and early 2014. Scale-up of the prototype to 18,000 kg/day (20 tpd) commercial demonstration mobile pyrolysis unit was completed in the Summer of 2014, and the commercial unit was installed in a 13.7-m (45-ft) shipping container mounted on a semi-truck trailer. Four field demonstrations of the 18,000 kg/day (20 tpd) unit were held in the Fall of 2014 and Summer of 2015 in locations in Nevada, Washington and Utah.

2.2. Pilot-scale pulverized-coal test facility

The University of Utah pilot-scale combustion test furnace, referred to as the "L1500", is a nominal 1.5 MW pilot-scale furnace designed to simulate commercial combustion conditions. A major objective of this combustion facility is to study pollutant formation and control, carbon utilization, fuel blending and co-firing, and ash management in a system which operates under combustion conditions similar to commercial boilers. The L1500 pilot-scale furnace has the following characteristics:

- Simulates the range of time/temperature histories that are found in commercial utility boiler units.

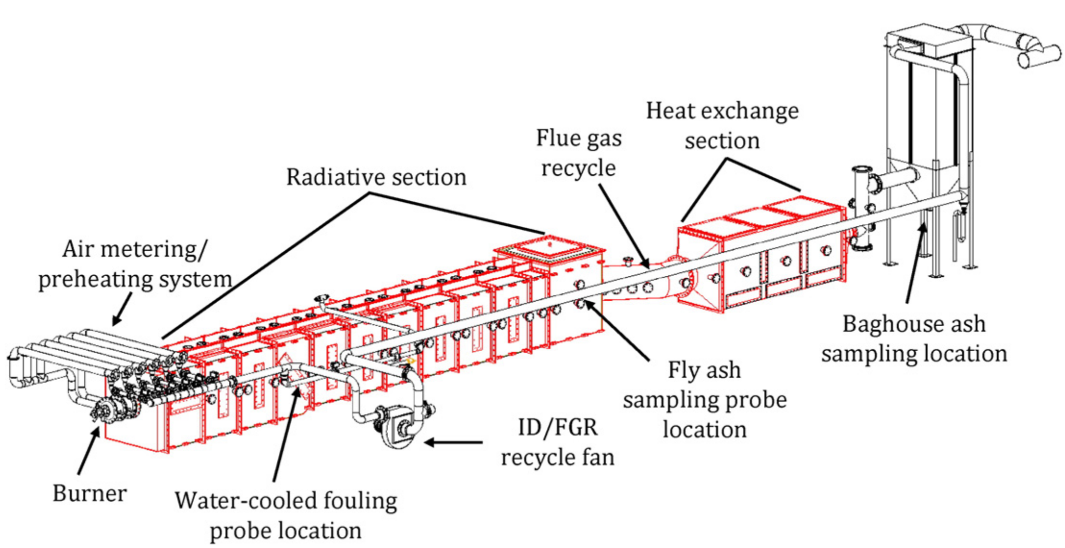

Fig. 2. Schematic of the 1.5 MW multi-fuel combustion test furnace (L1500) at the University of Utah.