Coal and Acai Seed Cofiring into Bubbling Fluidized Bed Boiler

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Abstract

In line with the Greenhouse Gas Protocol (scopes 1 and 2 emissions), Hydro aims to reduce its CO_2 emissions by 30 % in 2030. Alunorte, Hydro's alumina refinery in Para, Brazil, will make a significant contribution to this goal, reducing its direct and indirect CO_2 emissions by 70 %. Alunorte burns approximately 720 kt/year of mineral coal in three fluidized bed boilers to produce high-pressure steam for energy generation and subsequent use in its thermal processes. The objective of this work was to show a way of decarbonization by replacing coal with local biomass, acai seed (Euterpe oleracea). Acai seed is a locally abundant agroforestry residue, with an availability of 1.4 Mtpy. Using such residue as boiler fuel fits the circular economy concept and will benefit the local community in the environmental, economic, and social spheres. The methodology consisted of acai seed energy characterization in the laboratory, computer simulation of the combustion, and industrial test execution with biomass and coal cofiring, in which the biomass contributed up to 20 % of the boilers' overall energy input. The results contain boiler operational parameters, ash properties, and atmospheric emissions. Besides the avoided emission of 52 000 t CO_2 up to this phase of tests, this work shows the feasibility of using acai seed as fuel regularly and safely for bubbling fluidized bed boiler operation. These activities are part of the ongoing development stage to gather technical knowledge to support the conversion studies of the coal-fired boilers for exclusively biomass feeding and prepare the supply chain for this new raw material with the future quantity and quality needed for 2030.

Keywords: Biomass, Circular economy, Combustion, Decarbonization, Sustainability.

1. Introduction

Hydro aims to reduce its direct and indirect greenhouse gas emissions by 10 % in 2025, 30 % by 2030, and become carbon neutral by 2050 or earlier. Alunorte, Hydro's alumina refinery in Brazil, with a nominal capacity of 6.3 Mtpy, will significantly contribute to the company's global target by improving its energy and steam matrix. By 2025, Alunorte will have switched the fuel oil used in six boilers and seven calciners to natural gas, a fuel typically used in the global energy transition. Furthermore, three new electric boilers with immersed electrode technology will start operating and will be powered by renewable solar and wind energy. Both initiatives will reduce 1,4 Mtpy CO_2 emissions, representing a more than 30 % drop in refinery emissions compared to the 2017 baseline and reaching 0.45 t CO_2/t alumina.

For 2030, Alunorte's CO_2 reduction ambition is even more robust, foreseeing decarbonizing 70 % of scopes 1 and 2 emissions from 2017. In addition to the extension of the electrification plan for part of its matrix, Alunorte is also studying biomass as a potential alternative to replace bituminous mineral coal, whose annual consumption was 720 000 t in 2017. This fossil fuel currently feeds three high-pressure boilers (8.79 MPa and 485 °C) to generate energy and steam for the Bayer process, two of which are Bubbling Fluidized Bed (BFB) with a nameplate of 240 t/h each, and the other a Circulating Fluidized Bed (CFB) with a steam production capacity of 340 t/h.

Acai residue (seed) was the first biomass chosen to begin the studies due to the presence of the fruit in great abundance and the growing industry in Para, where the refinery is located, whose annual production is around 1 400 000 t/year [1]. CO_2 emissions from biomass combustion are considered neutral due to the recapture of this gas through photosynthesis during fruit planting, configuring a short carbon cycle. Among the biomasses from agroforestry residues available in the region, acai seed proved to be a good option also due to its shape (spheric) and thermochemical properties. In addition to decarbonizing the refinery and slowing down the effects of global warming, transforming the acai seed into energy will generate income and environmental benefits for the community (circular economy) by developing and strengthening this still-incipient type of business in the region. The accumulation of acai residue represents an environmental impact once it is often disposed of in open space, producing contaminating liquid and gas such as methane during its degradation and eventually causing spontaneous fire.

Approximately 85 % of the acai (/ˌæs.aɪˈiː/, Euterpe oleracea) is made up of seed, and it is a fruit typically found in the Amazon region (more than 90 % of the world's production of this fruit comes from Para) [1]. The literature still lacks technical data and experience in terms of its energy characterization, transformation into biomass and combustion in sizeable high-pressure boilers. This fact, combined with Alunorte's objective of converting current coal-fired boilers to renewable fuel instead of acquiring new equipment, brings technical complexity to the project. Therefore, in partnership with the Federal University of Para (UFPA), a mid-term work plan was elaborated for the cofiring of acai seed and mineral coal in the existing BFB boilers aiming to mature and enable the use of this biomass with the quantity and quality necessary for the definite conversion of one or more coal boilers by 2030.

Firstly, both fuels were characterized in the laboratory, as well as the combustion of pure biomass and mixed with mineral coal in different blend percentages. The implications of inserting biomass into boilers were evaluated based on computer simulations, equipment design information, and operational history, with the aim of identifying whether there were limiting factors for the mixture fraction. Finally, industrial cofiring tests with a gradual increase in the contribution of biomass to the blend were carried out in bubbling fluidized bed boilers, maintaining constant monitoring.

2. Equipment

The two boilers used in this work are bubbling fluidized bed boilers manufactured by Alstom in 2006 [2]. The dense bed cross-section is 21.65 × 8.09 m with a height of one meter. Above the freeboard are two risers. Afterward, the flow passes through a battery of cyclones that removes and returns suspended solids to the dense bed and directs the gases to the cleaning system and chimney, as shown in Figure 1.

In regular operation, the boilers are fed exclusively with bituminous mineral coal, which enters the combustion chamber above the dense bed. Along with coal, limestone is injected into the combustion chamber to sequester sulfur and nitrogen. Primary air is injected through the base of the dense bed, which is responsible for fluidizing the bed and starting volatiles combustion. Secondary air is introduced into the furnace at a height of 1.8 m. The maximum furnace temperature expected in these boilers is 950 °C.

boilers and adaptation of peripheral equipment to the renewable fuel. For instance, one of the main challenges that will be solved involves the inventory of inert materials in the BFB boilers and the inventory of fines for the CFB one.

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