Production of metallurgical charcoal from biomass pyrolysis: pilot-scale experiment

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Replacement of fossil coal with biomass fuel is a key strategy to decrease CO_2 emission in the Nordic industry. Charcoal produced from pyrolysis of forest residue is expected for the application in metallurgical process. Quality of charcoal can reach the requirement, i.e. high carbon content, low volatile, low ash content, and high heating value at high pyrolysis temperature. Nevertheless, to produce charcoal with such high quality, the products distribution may shift toward pyrolysis oil and gas. We have suggested to increase the charcoal yield while keeping its quality by adsorbing large molecule fractions of pyrolysis oil on the pore structure of charcoal produced at relatively high temperature (>600 °C). This study aims at demonstrating the suggested pyrolysis process to produce metallurgical charcoal with high efficiency. The effect of various operation parameters was investigated in batch operations with ca. 130 kg dry wood chips for this purpose.

The experiment was conducted in a pilot-scale auger-type pyrolysis reactor. Two cylindrical pipes with screw conveyers and external heating/cooling media are connected for pyrolysis and vapor adsorption. In the pyrolysis reactor, woodchips are heated indirectly with flue gas generated from a propane burner. In the vapor adsorption pipe, charcoal and volatiles are cooled down and part of pyrolysis volatile is condensed and absorbed on the surface of charcoal. The experiment was carried out with various process conditions such as residence time and temperature of both pyrolysis and vapor adsorption pipes as well as moisture content and types of original biomass. All the mass and energy flows were carefully monitored to perform mass and energy balances over the process. Ultimate analysis and heating value were measured to characterize charcoal. The composition of pyrolysis gas was analyzed to determine the potential to utilize the pyrolysis gas as a heating source instead of propane.

In a preliminary trial, pine chips with moisture content of 45.5% (m/m) were fed to the reactor at the feeding rate of 19 kg hr^{-1}. Wood particles passed through the reactor at temperature from 200 ˚C to 650 ˚C with residence time of 73 minutes, meaning that heating rate was approximately 8.5 ˚C min^{-1}. Process temperature and pyrolysis gas composition reached steady condition at 220 minutes after feeding woodchips. Charcoal obtained from this trial has yield of 40.2% (m/m) on dry basis with average carbon content of 89.5% and higher heating value of 32.4 MJ kg^{-1}. The characterization shows that charcoal produced from this reactor has the comparative quality to pulverized coal used in metallurgical application. Pyrolysis gas averagely contained with 36.6% (vol.) CO, 24.5% CO, 24.5% CO_2, 19.6% H_2, 14.7% of CH_4, and 4.6% of other hydrocarbon gases. Maximum flame temperature calculated from the gas composition is 1140 ˚C, which show the possibility to recirculate pyrolysis gas to supply heat to the process.

Process sensitivity will be performed to define the optimal condition of this process. The outcome of this work is expected to provide knowledge for upscaling pyrolysis process to produce metallurgical charcoal.