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Investigation of a Single Feedstock Particle during Pyrolysis in Fluidized Bed Reactors via X-Ray Imaging Technique

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Abstract : Fluidized bed reactor technologies are one of the most valuable pathways for thermochemical conversions of biogenic fuels due to their good operating flexibility. Nevertheless, there are still issues related to the mixing and separation of heterogeneous phases during operation with highly volatile feedstocks, including biomass and waste. At high temperatures, the volatile content of the feedstock is released in the form of the so-called endogenous bubbles, which generally exert a “lift” effect on the particle itself by dragging it up to the bed surface. Such phenomenon leads to high release of volatile matter into the freeboard and limited mass and heat transfer with particles of the bed inventory. The aim of this work is to get a better understanding of the behaviour of a single reacting particle in a hot fluidized bed reactor during the devolatilization stage. The analysis has been undertaken at different fluidization regimes and temperatures to closely mirror the operating conditions of waste-to-energy processes. Beechwood and polypropylene particles were used to resemble the biomass and plastic fractions present in waste materials, respectively. The non-invasive X-ray technique was coupled to particle tracking algorithms to characterize the motion of a single feedstock particle during the devolatilization with high resolution. A high-energy X-ray beam passes through the vessel where absorption occurs, depending on the distribution and amount of solids and fluids along the beam path. A high-speed video camera is synchronised to the beam and provides frame-by-frame imaging of the flow patterns of fluids and solids within the fluidized bed up to 72 fps (frames per second). A comprehensive mathematical model has been developed in order to validate the experimental results. Beech wood and polypropylene particles have shown a very different dynamic behaviour during the pyrolysis stage. When the feedstock is fed from the bottom, the plastic material tends to spend more time within the bed than the biomass. This behaviour can be attributed to the presence of the endogenous bubbles, which drag effect is more pronounced during the devolatilization of biomass, resulting in a lower residence time of the particle within the bed. At the typical operating temperatures of thermochemical conversions, the synthetic polymer softens and melts, and the bed particles attach on its outer surface, generating a wet plastic-sand agglomerate. Consequently, this additional layer of sand may hinder the rapid evolution of volatiles in the form of endogenous bubbles, and therefore the establishment of a poor drag effect acting on the feedstock itself. Information about the mixing and segregation of solid feedstock is of prime importance for the design and development of more efficient industrial-scale operations.

Keywords : fluidized bed, pyrolysis, waste feedstock, X-ray
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