Steam-Oxygen Gasification of Refuse Derived Fuel in Fluidized Beds: Modeling and Data Validation

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Abstract

The problems associated with municipal solid waste disposal and the requirement of a reliable and constant source of renewable energy are the pillars of the current environmental agendas of many developing and developed countries. The global interest has been polarized towards a combined and unique solution represented by the use of waste as a source of renewable energy or chemical feedstock. One possible way to achieve this is by intensifying the use of advanced thermochemical technologies and, amongst all the available options, gasification represents the most promising in terms of waste reduction, energy efficiency, and a large number of possible applications. Gasification can be accomplished through several reactors configuration, but feedstocks containing high ash and moisture fractions, such as refuse derived fuel (RDF), are mostly treated in fluidized bed reactors, which are particularly suitable due to their flexibility with respect to feedstock and operating conditions.

Despite this growing attention to steam-oxygen gasification of biogenic residues and waste feedstock, literature and industrial reference to this technology are still very scarce, both from modelling and experimental perspectives. To investigate and overcome all the challenges related to the process, a one-dimensional kinetic model for steam-oxygen gasification of refuse derived fuel in a bubbling fluidized bed reactor has been developed. The model incorporates the complex reaction network of gasification with the fluid dynamics of a bubbling fluidized bed to estimate the performance of the process. The model is validated by comparing outlet products composition and temperature profile with experimental data from a pilot-scale fluidized bed gasifier, operated at different conditions.

In particular, the entire modelled reactor is divided into a finite number of compartments of appropriate height; any variations are assumed to occur only along the axial direction. The initial devolatilization has been investigated and an ad hoc kinetic equation has been developed for standard RDF and included in the model. The bed zone is modelled according to the two-phase theory, with both heterogeneous and homogeneous reactions accounted and the enhanced mass transfer between the phases considered. The freeboard zone is modelled as a non-isothermal plug flow reactor to describe variation of syngas quality at different heights.

The model proved to be reliable in the estimation of the output of the gasifier, despite the assumption of mono-dimensional axial variation, which in turn provided ease of computation and less time of simulation. The effects of the operating conditions on gas yield and process efficiency were evaluated and the most appropriate fuel feeding height, equivalent ratio and the relative amount of steam to inject were identified.

Steam-oxygen gasification of RDF has proved to be a valid option to convert waste materials into a more valuable product, representing a possible solution to both the management of unrecyclable waste and alternative fuels production, especially for emerging applications, such as bioSNG and biohydrogen production.