A DEM modeling of biomass fast pyrolysis in a double screw reactor

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Biomass is an abundant renewable resource that has been used for thousands of years to provide heat and energy in rural areas. More efficient thermochemical conversion ways of utilizing biomass such as fast pyrolysis are introduced in recent studies [1, 2, 3]. Screw reactors are one of the commonly used reactors for biomass fast pyrolysis [3, 4, 5]. In a screw reactor, mechanical forces are provided to the bed to enhance particle mixing and heat transfer, and achieve particulate matter transport for continuous operation. The pyrolysis process in the screw reactor configuration is a reactive granular flow system which involves particle flow, heat transfer and biomass devolatilization reactions at the same. However, reactor-scale evaluation of heat and mass transfer effects on the biomass fast pyrolysis is very limited. Efforts are needed to discover the underlying physical phenomena and the interplay between the physical transport phenomena and chemical reactions for reactor design and optimization. Numerical simulation is capable of predicting the granular flow and heat transfer behavior in the reactor and providing useful information of particle flow such as particle residence time, particle mixing degree, and heat transfer coefficient [6].

In this research, we proposed an extended DEM method for modeling the reactive granular flow in a double screw reactor. A semi-detailed biomass devolatilization kinetics is adopted in the simulation and the decomposition dynamics of the major biomass components and pyrolysis products are analyzed at different operating conditions. The heat transfer coefficient information is extracted from the DEM simulation and provided as heat transfer boundary conditions for a single particle model. The intra-particle heat and mass transport phenomena are modeled and the effects on the biomass pyrolysis process are evaluated. We report that the heat transfer coefficient in the double screw reactor varies within a wide range of 20 to 90 W/(m^2K) for different operating conditions. Results also indicate the particle-fluid-particle conductive heat transfer pathways are the dominant contributors to the total heat flux, which accounts for 70%-80% in the total heat flux. Radiation heat transfer contributes 14%-26% to the total heat flux. The reported result is helpful for reactor performance evaluation and reactor design optimization.

Reference

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