Numerical Study of the Flow and Heat Transfer in Supercritical Water Based Fluidized Bed Reactor

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The full report contains confidential information.

This public version is therefore limited to the summary.
Summary

Supercritical water gasification (SCWG) is a novel process for the thermochemical conversion of wet organic waste to gas and minerals. It is an alternative to the anaerobic digestion process, dewatering followed by drying and incineration and conventional dry gasification. Its advantages include no requirement for drying, higher syngas yield and much shorter residence time. From societal aspect, SCWG offers a solution to environmental problems caused by wet waste and fossil fuels, through the production of renewable gas and minerals.

TU Delft and Gensos B.V. collaborate in fundamental research on supercritical gasification using a fluidized bed reactor concept. This study focuses on the hydrodynamics and heat transfer of the fluidized bed reactor of the supercritical gasification process. It aims to develop CFD models that can correctly predict the main heat transfer and fluidization phenomena in the supercritical fluidized bed reactor. CFD models are developed to conduct numerical studies of single-phase heat transfer without fluidization, multi-phase fluidization without heat transfer and fluidization with heat transfer. The CFD models are validated by using experimental data from Yamagata, Mokry and Lu et al.

A literature study was carried out to review the fundamental theories and existing scientific knowledge for modeling heat transfer and fluidization at supercritical conditions. Particular physical models and boundary conditions for supercritical water were selected and established. For single-phase-heat-transfer study, the standard k-epsilon low-Reynolds number turbulence model with low y+ wall treatment were selected and a polyhedral type grid was chosen. For multiphase fluidization study, the Euler-Euler approach with the Gidaspow drag force model and standard k-epsilon turbulence model was selected.

For both the heat transfer and fluidization studies, the numerical results are generally in good agreement with the experimental data from literature. As expected, heat transfer deterioration for single-phase supercritical upward flow cannot be predicted.
well by these models. Numerical results agree well with existing semi-empirical correlations for the minimum fluidization velocity at supercritical conditions.

From the heat transfer study, it is found that fluidization is beneficial for the supercritical gasification process. The heat transfer coefficient is orders of magnitude higher in case of fluidization. Heat transfer is greatly enhanced due to particles disrupting the boundary layer and improving radial mixing and transfer of mass and energy. This also avoids large temperature variations at the wall.

To improve accuracy of the simulations, more accurate turbulence models, like LES and DNS, and multiphase approaches such as Euler-Lagrange or Discrete Element Method are needed. Furthermore, 3D model is also necessary for the future study, since it is easy to observe the radial movement in the reactor.