Simulations of Heat and Mass Transport During Biomass Conversion Processes Using 3D Biomass Particle Models with Realistic Morphology and Resolved Microstructure

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Abstract

I will describe the use of Constructive Solid Geometry (CSG) methods to produce more realistic biomass particles based on direct microscopic measurements of particle morphology and microstructural dimensions. A schematic illustrating the image analysis and model construction methods is presented in Figure 1. The resultant 3D models are imported into COMSOL Multiphysics® software via the CAD Import Module and serve as the simulation geometry. An example of a meshed particle model constructed from microstructural parameters for Quaking Aspen, a Poplar sub-species is presented in Figure 2. The particle model is highlighted in blue in this figure, and the remaining domains are filled with nitrogen gas.

We have performed conjugate heat transfer simulations (using the CFD Module) based on these complex biomass particle models. A Dirichlet boundary condition is imposed on the exterior of the bounding cylinder by specifying a temperature that corresponds to that of the bulk fluid within a pyrolysis reactor. Heat is transferred by conduction and convection to the biomass particle. A snapshot of one such transient heat transfer simulations is presented in Figure 3. We have used this simulation approach to predict particle heating times for biomass feedstocks over a range of sizes from two different species of origin.

Our continuing efforts are centered on multiphysics simulations that incorporate devolatilization and char formation reactions with heat and mass transport. Our initial simulations predict that the concentration of primary vapors becomes orders-of-magnitude higher inside biomass particles than outside during fast pyrolysis. This is an important observation in that secondary recondensation reactions which lead to undesired coke formation are greatly accelerated within the particle due to mass transport limitations.

Figures used in the abstract

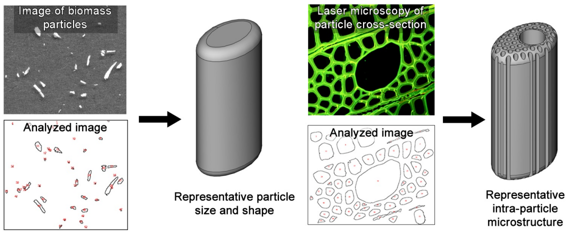

Figure 1: Schematic showing quantitative image analysis coupled to model construction algorithm.

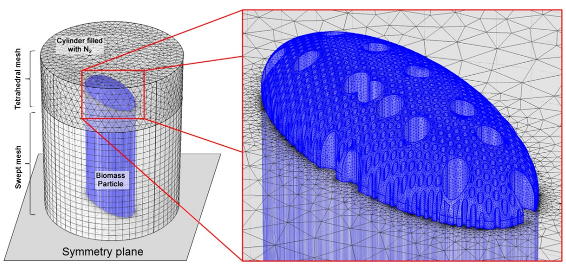

Figure 2: Example of simulation geometry.

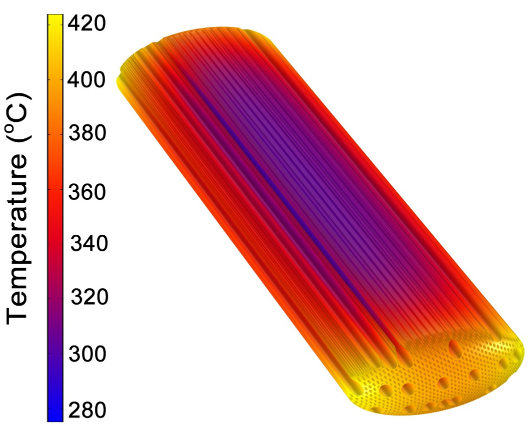

Figure 3: Snapshot of conjugate heat transfer simulation.