A Comprehensive Three-Dimensional Model of a Black Liquor Char Bed

Benjamin J. Ohran, Michael M. Choi, Larry L. Baxter

CFD Modeling Group, Brigham Young University

February 2004, ACERC Conference

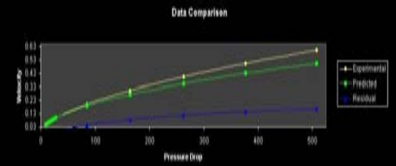
Abstract

A three-dimensional computer code is being developed to predict fluid mechanics, heat transfer and chemical kinetics within a black liquor char bed. Finite-volume equations are used to estimate pressure drop through porous media with the Ergun equation, a semi-empirical equation based on Darcy's law, to predict fluid flow. Gas and particle temperatures are calculated using established albeit mostly empirical heat transfer correlations together with heat released/absorbed by chemical reactions. The model predicts air flow including penetration depth into the bed, heat transfer between the bed and surrounding gases, and species concentrations and reaction rates. The model predictions will be compared with available experimental measurements in the literature.

Darcy's Law Approach to Flow Through the Bed

Darcy's law for flow through porous media is the underlying principle behind the flow scheme of the model. The Ergun Equation provides a semi-empirical form of the Darcy equation for transitional flow.

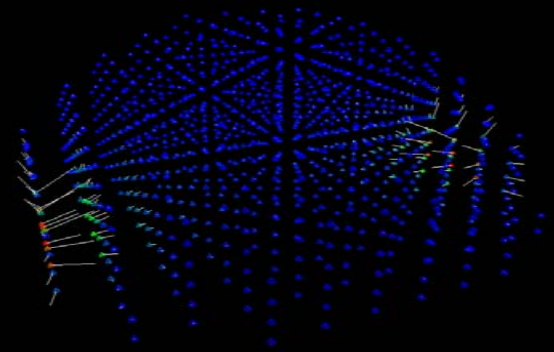
$$\nabla P = 150 \cdot \left(\frac{\mu \cdot \upsilon}{D_p^{\,2}}\right) \cdot \frac{(1-\varepsilon)^2}{\varepsilon^3} + \frac{7}{4} \cdot \left(\frac{\rho \cdot \upsilon^2}{D_p}\right) \cdot \frac{1-\varepsilon}{\varepsilon^3}$$



A plot of air velocity vs. pressure drop across a fixed bed of wood chips.

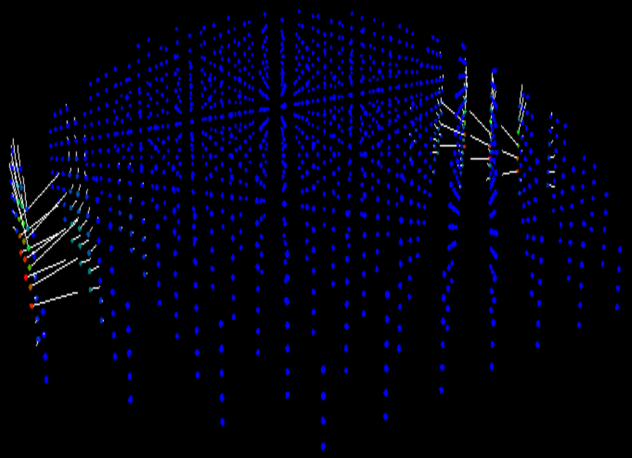
The model predicts

- •Pressure drop within a porous bed
- •Air penetration depth
- •Gas flow rates and their directions
- •Gas temperatures
- •Species concentrations
- •Gas density

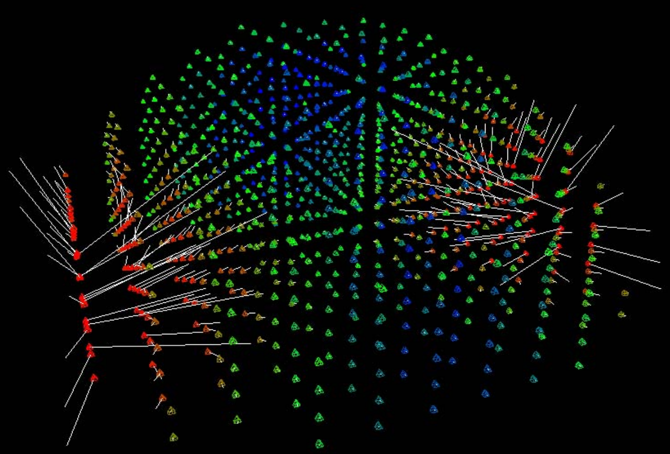


O2 concentration in the gas; assumed that only CO + ½O2 -> CO2 occur in the gas phase; uniform oxygen concentration of 0.05 mole fraction was assumed; the oxygen concentration near the jet was set to 0.21.

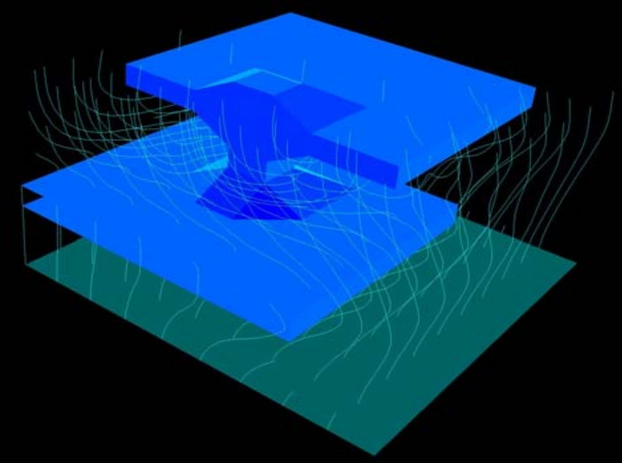
Sample model outputs



Example of airstreams entering hemi-spherical bed from two sides.



Gas temperature predictions: High temperature gas(1500K) entering porous bed at 1400K; based on uniform bed porosity of 0.3, constant outside temperature of 1500K; assumed that no reactions in the gas phase occur.



Gas flow responds to areas of low porosity