

# COMPUTATIONAL FLUID DYNAMICS SIMULATIONS OF BIOMASS FAST PYROLYSIS IN A GAS-SOLID VORTEX REACTOR

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## Keywords

*Biomass fast pyrolysis, gas-solid vortex reactor, process intensification, thermal degradation kinetics.*

Gas-solid vortex reactors (GSVR) are a new generation of multiphase reactors, differing from the current state of the art as they maintain a rotating fluidized bed in a static geometry via high gas injection at high tangential velocities ( $\sim 80\text{-}120\text{ m s}^{-1}$ ). Centrifugal force instead of the gravitational force counteracts the drag force, allowing denser beds and higher slip velocities ( $5\text{-}6\text{ m s}^{-1}$ ) compared to conventional fluidized bed reactors. Due to the overall higher gas velocities, the residence time of the gas phase is also lower, reducing undesired gas-phase secondary reactions in the pyrolysis product mixture. With these advantages, a GSVR makes a suitable candidate to perform fast pyrolysis of lignocellulosic biomass. At the Laboratory for Chemical Technology, we operate a GSVR demonstration unit for biomass fast pyrolysis. Earlier 2D computational fluid dynamics simulations on a similar reactor geometry showed biomass reaching pyrolysis conditions rapidly, reducing the secondary reactions and limiting production of char. These simulations also predicted high convective heat transfer coefficients ( $\sim 500\text{-}800\text{ W m}^{-2}\text{ K}^{-1}$ ). Additionally, bio-oil yields as high as 70 % are shown to be achievable via this novel technology (Ashcraft et al., 2012).

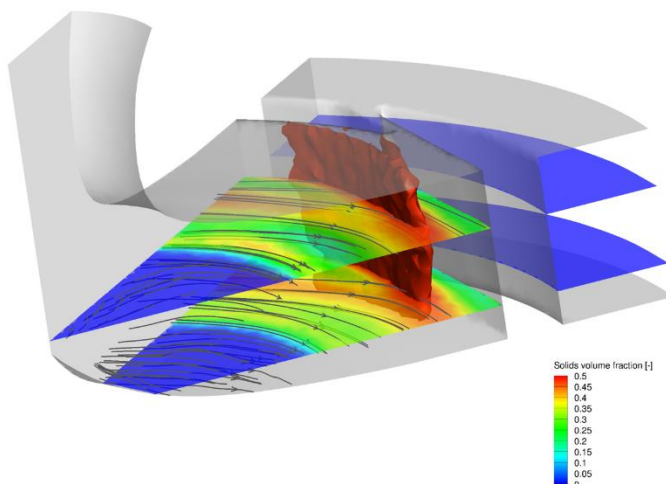


Figure 1. Time averaged Solids volume fraction [-] across two axial planes, isosurface of solids volume fraction and streamlines indicating flow of the gas phase.

However, these 2D simulations did not take into account the end wall effects which could substantially influence the hydrodynamics and hence the yields in the GSVR. Hence, 3D Eulerian-Eulerian simulations have been carried out using a biomass pyrolysis model that considers thermal degradation of biomass constituents (cellulose, hemicellulose and lignin) into products (bio-oil, non-condensable gases and solid char) via an *activated* state. (Xue et al., 2011). Figure 1 shows a densely packed circulating bed of solids particles with good uniformity in the axial direction and swirl-dominated gas flow maintaining the rotating fluidized bed behavior of the solid phase.

Ashcraft, R.W., Heynderickx, G.J., Marin, G.B., (2012). Modeling fast biomass pyrolysis in a gas–solid vortex reactor. *Chemical Engineering Journal* 207-208, 195-208.

Xue, Q., Heindel, T.J., Fox, R.O., (2011). A CFD model for biomass fast pyrolysis in fluidized-bed reactors. *Chemical Engineering Science* 66, 2440-2452.