OPTIMIZATION OF PROCESS PARAMETERS OF FLUIDIZED BED BIOMASS COMBUSTOR USING CFD MODELING

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Degree of Master of Science

Department of Chemical & Process Engineering

University of Moratuwa

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science in fulltime research in Chemical & Process Engineering

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Abstract

The present work is focused on mathematical modelling of fluidized bed combustion of biomass by means of computational fluid dynamics (CFD). Introducing a stable CFD solver for combustion of solid fuel with Large-Eddy Simulation (LES) turbulence modeling and diffusion corrective velocity is the novelty of this study. A great part of the work is devoted to development of a reliable algorithm to solve the fluidized bed combustion model and to improve the accuracy of simulation results. A three-dimensional transient model is developed with a special emphasis on the conservativeness property of energy and mass.

The second part of the work is devoted to development of C++ libraries for the open source CFD tool kit OpenFOAM for coupling fluidized bed model with gas phase combustion. The created CFD solver has capability to adept with wide range of application of fluidized bed combustion. The presented results contribute to better understanding of numerical modelling and simulation of fluidized bed combustion, especially optimizing of combustor geometries.

The performance of fluidized bed biomass combustor depends on the turbulence of freeboard. The optimum amount of secondary air ratio is 1.6%, which gives higher freeboard temperature while maintaining minimum emission. The optimum excess air ratio is 10% for 0.1125 kg/h. In the case of suspension combustion, maximum combustor temperature has been obtained for optimum airflow, which was 5.5 ms^{-1} of inlet air velocity for a 0.00171 kg/s of fuel feeding rate (65% amount of excess air).

Keywords

Computational Fluid Dynamics, fluidized bed, biomass, Large-Eddy Simulation, Combustion

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NOMENCLATURE

C_d	Drag coefficient
D_i	Effective mass diffusion coefficient for species i (m^2/s)
d	Particle diameter (m)
f_g	Drag force acting on particle (N)
f_p	Contact force acting on particle (N)
g	Gravitational acceleration (m/s^2)
h_s	Sensible enthalpy of gas phase (J/kg)
m_p	Particle mass (kg)
P	Pressure (Pa)
Re	Reynolds number
S_h	Enthalpy source term due to homogeneous reaction (W/m^3)
$S_{p,h}$	Enthalpy source term from particle phase (W/m^3)
$S_{p,mom}$	Momentum source term (N/m^3)
$S_{p,m}$	Mass source term ($kgm^{-3}s^{-1}$)
S_{p,Y_i}	Species source term from particle phase ($kgm^{-3}s^{-1}$)
S_{rad}	Radiation source term (W/m^3)
S_{Y_i}	Species source term due to gas phase reactions ($kgm^{-3}s^{-1}$)
T	Temperature (K)
u_g	Gas velocity (m/s)
v_p	Particle velocity (m/s)
V_p	Particle volume (m^3)
V_c	Correction velocity (m/s)
Y_i	Mass fraction of species i
ε_g	Volume fraction of gas
ρ_g	Gas density (kg/m^3)
τ_{eff}	Effective stress tenor (Pa)
α_{eff}	Effective thermal diffusivity ($kgm^{-1}s^{-1}$)
β	Inter-phase momentum exchange coefficient ($kgm^{-3}s^{-1}$)
μ	Viscosity ($kgm^{-1}s^{-1}$)

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