One Dimensional Mathematical Model for Packed Bed Biomass Combustion Using MATLAB

UDESHIKA PRIYADARSHANI

149262L

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Department of Chemical and Process Engineering

University of Moratuwa
Sri Lanka

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Supervisor Date

Dr. M. Narayana

Senior Lecturer

Abstract

Packed bed biomass combustion is widely used thermal conversion process which contributes major portion of energy fulfillment around the globe. This process is usually involving higher operation cost due to low efficiency and high emissions. Hence there is a huge room for improvements in the process and needs to be optimized as well as modernized. This thesis presents two-phase one-dimensional mathematical model with MATLAB solver which can be used for diagnosis and optimization of packed bed combustion process under low computing resources and less cost. The mathematical model uses the discretized equations to develop the ordinary differential equations which are solved using implicit method. Free-board region is not taken into account. Only the biomass bed is considered here to solve the combustion system by applying conservation equations into gas and solid phase separately. The main model is consisting with different sub models with subjected to four stages of combustion as drying, pyrolysis, Char oxidization and char combustion. The biomass batch is initially ignited by continuous preheated gas inlet and higher gas flow rate. Radiation heat transfer is assumed to be negligible due to high temperature gas flow at the inlet. Combustion is occurred in batch wise. Particle diameter and bed porosity is considered with a mean value for the simplicity of the model. The developed model is used to find the solid temperature profile and generation of CO_2 and CO gases. By using walking column approach, industrial moving grate furnace was represented and required optimum grater length for a particular mass flow rate can be calculated with the fixed bed simulation results.

Keywords—Biomass combustion, Mathematical model, Layer-lumped model, MATLAB simulation

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Nomenclature

A	Specific surface area of packed bed (m^{-1})
A_p	Specific surface area of particle (m^{-1})
A_w	pre exponential factor (s^{-1})
C_g	Heat Capacity of gas phase (J kg^{-1} K^{-1})
C_S	Heat Capacity of solid phase (J kg^{-1} K^{-1})
$D_{g,i}$	Diffusion coefficient of gas species i (m^2 s^{-1})
d_p	Particle Diameter (m)
E_w	Activation Energy (J/mol)
H	Heat transfer coefficient (W m^{-2} $K^{-1)}$
k_g	Thermal Conductivity of gas phase (W m^{-1} K^{-1})
k_S	Thermal Conductivity of solid phase (W m^{-1} K^{-1})
M_i	Molecular weight of species i (kg mol^{-1})
Nu	Nusselt number
P	Pressure (Pa)
Pr	Prandtl Number
$Q_{S,g}$	Convective Heat transfer rate (W m^{-3})
Re	Reynolds Number
R_{Drying}	Rate of Drying reaction i (kg m^{-3} s^{-1})
R_{pyr}	Rate of pyrolysis reaction i (kg m^{-3} s^{-1})
$R_{g,pyro}$	Rate of release of pyrolytic volatiles (kg m^{-3} s^{-1})
r_{char}	Rate of char combustion reaction i (kg m^{-3} s^{-1})
r_i	Rate of reaction i (kg m^{-3} s^{-1})
$r_{i,hetero}$	Rate of heterogeneous reaction i (kg m^{-3} s^{-1})
$r_{i,homo}$	Rate of homogeneous reaction i (kg m^{-3} s^{-1})
$r_{t,i}$	Rate of turbulent mixing limitation in reaction i (kg m^{-3} s^{-1})
r_{out}	Reactor outer radius (m)
S_{sg}	Heterogeneous reaction rates involving for mass transfer (kg m^{-3} s^{-1})
T_g	Gas phase temperature (K)
T_s	Solid Phase temperature (K)
U_g	Gas phase velocity (m s^{-1})
U_S	Shrinkage Velocity (m s^{-1})
$Y_{g,i}$	Mole fraction of gas species i
$Y_{i,S}$	Mass fraction of solid species i
ε_b	Bed porosity
ρ_g	Gas Density (kg m^{-3})
ρ_S	Solid Density (kg m^{-3})
$\emptyset$	Stoichiometric ratio
μ	Kinematic Viscosity (Pa S)
$\sigma_{i,air}$	Average Collision diameter (A)
$\Omega_{i,air}$	Diffusion collision integral
ΔH_i	Enthalpy of reaction i (J kg^{-1})

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