ANALYSIS OF WOOD CHIP COMBUSTION SYSTEM FOR HOT AIR GENERATION IN THE INDUSTRIAL DRYING PROCESS

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of
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by

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Declaration

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To my parents Charlotte Gamage and late Siripala Jayawickrama

Abstract

A two-dimensional steady state packed bed CFD model is developed for the combustion of wood chip in a moving grate.The model is validated using an industrial moving bed hot air generator used in Tea industry.Various empirical models have used for thermophysical property modeling.For this purpose free-board region of the hot air generator is also simulated including volatile reactions and turbulent combustion.Modeling and simulation carried out using open source CFD software OpenFOAM.Radiation heat incident on the packed bed is unknown and it is assumed in the first packed bed simulation.Therefore, CFD simulation involves number of iterative runs of the packed bed model and free board model to obtain the radiation temperature incident on packed bed due to free board heat.According to the validation results the developed packed bed model can be used to predict temperature of the packed bed wood chip combustion of thermally thin wood particles. The gas compositions could not be validated using the model.Further improvements to the model have suggested.

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Nomenclature

Abbreviations

Bi	Thermal Biot number
CFD	Computational Fluid Dynamics
FV	Finite Volume
NERDC	National Engineering Research and Development Centre
OpenFOAM	Open Source Field Operation and Manipulation CFD tool box
Pa	Pascal
PaSR	Partially Stirred Reactor
PDEs	Partial Differential Equations
Pr	Prandlt number
PSR	Perfectly Stirred Reactor
Re	Reynolds number
toe	tonnes of oil equivalent

Subscripts

0	initial,reference (temperature in degrees Rankine)
a	Activation
b	bed
c	convective

char	char combustion
dry	drying reaction
G	grate
g	gas phase
i	i-th component
mix	mixing due to turbulence
p	particle
pyr	pyrolysing
s	solid phase
surf	surface
vol	volatile
x	x-direction(horizontal)
y	y-direction(vertical)

Symbols

ℓ	length scale (m)
λ	thermal conductivity (W/mK)
$\lambda_{e,0}$	effective thermal conductivity of a quiescent bed(without fluid flow) (W/mK)
λ_e	effective thermal conductivity of bed (W/mK)
μ	dynamic viscosity (kg/ms)
μ_0	reference viscosity in centipoise at reference temperature To (kg/mms)

μ_t	eddy viscosity (kg/ms)
ν	kinematic viscosity (m2/s)
ω	reaction rate (kg/m3s)
Ω_D	Diffusion collision integral
ρ	density (kg/m3)
$\S_{ij}$	rate of deformation (m2/s)
σ_{AB}	Binary pair characteristic length(dimensionless)
τ	integration time step (s)
$\tilde{u}_i$	density weighted mean velocity (m/s)
ε	rate of dissipation of turbulent kinetic energy per unit mass (m2/s3)
ϑ	velocity scale (m/s)
ξ	mixture fraction
c_p	specific heat capacity (J/kgK)
$\in$	porosity of the bed
A	pre-exponential factor(1/s)
A	volumetric particle surface (m2/m3)
c	concentration (kg/m3) or (mol/m3)
D	mass diffusion coefficient (m2/s)
d	particle diameter (m)
E	Energy (J/mol)
H	evaporation heat (J/kg)

h	specific sensible enthalpy/heat transfer coefficient (J/kg,W/m2K)
J	Joule
K	Kelvin/Equilibrium constant
k	Thermal conductivity (W/mK), turbulent kinetic energy (m2/s2)
kg	kilogram
M	moisture content(wet basis)
M	molecular weight (g/mol)
P	pressure (kg/m/s2)
Q	heat transferred to the solid phase by convection and radiation (W/m3)
R	universal gas constant (J/molK)
r	reaction rate (kg/m3s)
T	temperature (K)
t	temperature (K)
U,V	velocity vector (m/s)
V	volume (m3)
v	velocity component (m/s)
Y	mass fraction