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LIST OF SYMBOLS

A_t, A_v	Cross-sectional area of bed, (m^2)
A_D	Area of distributor plate per hole, (m^2)
Ar	Archimedes number, $Ar = \frac{\rho_f (\rho_p - \rho_f) g d_m^3}{\mu_f^2}$ (dimensionless)
Bi	Biot number (dimensionless)
C_{Pa}	Average heat capacity of air (J/g^0C)
C_{Pv}	Average heat capacity of volatiles (J/g^0C)
C_{Pca}	Average heat capacity of char and ash (J/g^0C)
C_{Pds}	Average heat capacity of dry waste (J/g^0C)
C_{Pwv}	Average heat capacity of water vapour (J/g^0C)
$C_x H_y$	Hydrocarbon
D_c	Column diameter, (m)
D_b, d_b	Bubble diameter, (m)
D_G	Binary molecular diffusion coefficient of oxygen in air, (m^2/s)
d_{bo}	Initial bubble formed near the bottom of the bed, (m)
d_i	Diameter of the spherical fuel particle, (m)
d_m, d_p	Mean particle diameter (m), particle diameter (m)
d_t	Bed diameter, (m)
d_*	Dimensionless particle size, $d_* = d_{sph}\left[\frac{g\rho_f(\rho_s - \rho_f)}{\mu^2}\right]^{1/3}$
g	Gravitational acceleration, (9.81 m/s^2

g_c	Conversion factor, $\left(\frac{1kgm/s^2}{N}\right)$
$\hat{H}_i$	Specific enthalpy of the ith component at 25^{0}C, (kJ/kg)
h	Heat transfer coefficient, $\left(\frac{W}{m^2K}\right)$
k	Thermal conductivity, $\left(\frac{W}{mK}\right)$
L_{mf}	Height of bed at minimum fluidization, (m)
L_p	Pyrolysis endothermicity, (kJ/kg)
M	Mass of solid in bed, (kg)
M_a	Mass flow rate of air (g/min)
M_{ca}	Mass flow rate of residual char and ash (g/min)
M_{ds}	Mass flow rate of dry waste (g/min)
M_f	Mass flow rate of fuel (g/min)
M_v	Mass flow rate of volatiles (g/min)
M_w	Mass flow rate of water (g/min)
n_d	Total number of orifices
n_i	Moles of the ith component in the feed or product
p_s	Partial pressure of oxygen at the carbon surface, (atm)
Q_{rad}	Radiative heat loss (W)
q, q	Heat flux $\left(\frac{W}{m^2}\right)$, heat liberated (J/g)
Re	Reynolds number, Re = $\left(\frac{\rho_f U d_p}{\mu_f}\right)$ (dimensionless)
T_a, T_a	Inlet air temperature (^{0}C), temperature of flame (K)
T_0	Temperature of particle (K), temperature of the surroundings (K)
T_b	Bed temperature (^{0}C)
T_{ad}	Adiabatic flame temperature, (^{0}C)
T_s	Burning char particle surface temperature, (K)

T_v, t_v	De-volatilization time, (s)
t_b	Burn-out time, (s)
U, u	Fluidization velocity, $\left(\frac{m}{s}\right)$
U_b	Bubbles velocity in a bubbling fluidized bed, $\left(\frac{m}{s}\right)$
U_{br}	Single bubble velocity, $\left(\frac{m}{s}\right)$
U_0, u_0	Fluidization velocity at the distributor, $\left(\frac{m}{s}\right)$
U_{mf}, u_{mf}	Minimum fluidization velocity, $\left(\frac{m}{s}\right)$
U_t, u_t	Terminal-fall velocity, $\left(\frac{m}{s}\right)$
u_*	Dimensionless gas velocity, $u_* = u_t\left[\frac{\rho_f^2}{g\mu(\rho_s - \rho_f)}\right]^{1/3}$
z	Distance above the distributor, (m)
z_{b0}	Height of initial bubble formation, (m)
ΔP_b	Pressure drop across the bed, $\left(\frac{N}{m^2}\right)$
$\Delta \hat{H}_c$	Heat of combustion of the fuel at reference temperature 25^0C, $\left(\frac{kJ}{mol}\right)$
$\Delta \hat{H}_v$	Heat of vaporization of water at 25^0C, $\left(\frac{kJ}{mol}\right)$

Greek Letters

α	Thermal diffusivity $\left(\alpha = k\rho_i^{-1}C_p^{-1}\right)$
λ	Amount of heat required to raise the moisture from ambient conditions to the boiling point and to evaporate the moisture, (J/g)
σ	Stefan-Boltzmann constant ($5.67 \times 10^{-8} \frac{W}{m^2 K}$)
$\varepsilon, \varepsilon_{mf}$	Bed voidage, bed voidage at minimum fluidization
ε_m	Emissivity of the bed surface, (dimensionless)
ϕ_s	particle sphericity, (dimensionless)
μ_f , μ_g	fluid viscosity $\left(\frac{kg}{ms}\right)$, gas viscosity, $\left(\frac{kg}{ms}\right)$
ρ_b	Bulk density, $\left(\frac{kg}{m^3}\right)$
ρ_c	Carbon density of a char particle, $\left(\frac{kg}{m^3}\right)$
ρ_g	Density of fluidization gas, $\left(\frac{kg}{m^3}\right)$
ρ_p	Particle density, $\left(\frac{kg}{m^3}\right)$
ρ_f	Fluid density $\left(\frac{kg}{m^3}\right)$, gas density $\left(\frac{kg}{m^3}\right)$
ρ_i	Density of the initial fuel particle, $\left(\frac{kg}{m^3}\right)$
η_{CU}	Carbon utilization efficiency, (%)
η_{CQ}	Combustion quality efficiency, (%)
η_{TE}	Thermal efficiency, (%)

Abbreviation

2D	Two-dimensional
3D	Three-dimensional
AF	Air Factor
ASEAN	Association of South East Asian Nations
BFB	Bubbling Fluidized Bed
CH	Centre High
CFB	Circulating Fluidized Bed
CHS	Circular Hydrodynamic Studies
EF	Equal Flow
GI	Galvanized Iron
HHV	High Heating Value, (MJ/kg)
ITA	Investment Tax Allowance
LHV	Lower Heating Value, (MJ/kg)
LDPE	Low Density Polyethylene
LPM	Litre Per Minute
MSW	Municipal Solid Waste
OSH	One Side High
PS	Pioneer Status
PAH	Polycyclic aromatic hydrocarbon
ppm	part per million
RC – 1	Rectangular column – 1
RC – 2	Rectangular column – 2
RDF	Refused Derived Fuel
RHS	Rectangular Hydrodynamic Studies
SEM	Scanning Electron Microscope
SPP	Small Power Producers
SREP	Small Renewable Energy Programme
TDH	Transport Disengaging Height
TSH	Two Side High
UK	United Kingdom

APPENDICES

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