energies

Supplementary Materials

A Phenomenological Model of a Downdraft Biomass Gasifier Flexible to the Feedstock Composition and the Reactor Design

The following are the stoichiometric coefficients of the devolatilization reaction, obtained from the balance equations of the products yields [20]:

$$\alpha_2 = \eta_W \cdot (100 - A)/12 \quad \text{(S1)}$$

$$a = \eta_{H2} \cdot (100 - A)/2 \quad \text{(S2)}$$

$$b = \eta_{CH4} \cdot (100 - A)/16 \quad \text{(S3)}$$

$$c = \eta_{CO} \cdot (100 - A)/28 \quad \text{(S4)}$$

$$d = \eta_{H2O} \cdot (100 - A)/18 \quad \text{(S5)}$$

$$e = (\gamma_1 - c - d)/2 \quad \text{(S6)}$$

$$f = \varepsilon_1 \quad \text{(S7)}$$

$$g = 0.5 \cdot \delta_1 \quad \text{(S8)}$$

$$m = \alpha_1 - \alpha_2 - b - c - e \quad \text{(S9)}$$

$$n = \beta_1 - 2a - 4b - 2d - 2f \quad \text{(S10)}$$

where the devolatilization yields η_i are obtained from literature data [20] while α_1, β_1, γ_1, δ_1, ε_1 derive from the brute biomass formula:

$$\alpha_1 = 1 \quad \text{(S10 a)}$$

$$\beta_1 = (y_H \cdot M_C)/(y_C \cdot M_H); \quad \text{(S10 b)}$$

$$\gamma_1 = (y_O \cdot M_C)/(y_C \cdot M_O) \quad \text{(S10 c)}$$

$$\delta_1 = (y_N \cdot M_C)/(y_C \cdot M_N) \quad \text{(S10 d)}$$

$$\varepsilon_1 = (y_S \cdot M_C)/(y_C \cdot M_S) \quad \text{(S10 e)}$$

being y_i and M_i respectively the species mass fraction and molecular mass.

The devolatilization kinetic rates used as right-hand term in each of the eqs. (6 – 14) are reported in Table S1, while the kinetic constants in Table S2 are expressed as a function of the Reynolds and Schmidt number of each species, while D_i expresses the species diffusivity coefficient.

Table S1. Devolatilization products kinetic rates used within the present model.

R_{char}	$2 \cdot (M_c/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)
R_{H2}	$a \cdot (M_{H2}/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)
R_{CH4}	$b \cdot (M_{CH4}/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)
R_{CO}	$c \cdot (M_{CO}/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)
R_{TAR}	$(M_{CmHn}/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)
R_{H2O}	$d \cdot (M_{H2O}/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)
R_{CO2}	$e \cdot (M_{CO2}/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)
R_{H2S}	$f \cdot (M_{H2S}/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)
R_{N2}	$g \cdot (M_{N2}/M_{coal}) \cdot R_{dev}$	kg/(m^3·s)

Table S2. Kinetic constants used in the present model [22].

P1	$k_{diff,O2}$ [m/s]	$D_{O2} \cdot [(2 + 1.1 \cdot Re^{0.6} \cdot Sc^{0.33})/d_{p0}]$
	$k_{ash,O2}$ [m/s]	$2 \cdot D_{O2} \cdot \varepsilon^{2.5}/d_{p0}$
	$k_{reaz,O2}$ [m/s]	$2.3 \cdot T_S \cdot \exp(-11100/T_S)$
P2	$k_{diff,CO2}$ [m/s]	$D_{CO2} \cdot [(2 + 1.1 \cdot Re^{0.6} \cdot Sc^{0.33})/d_{p0}]$
	$k_{ash,CO2}$ [m/s]	$2 \cdot D_{CO2} \cdot \varepsilon^{2.5}/d_{p0}$
	$k_{reaz,CO2}$ [m/s]	$589 \cdot T_S \cdot \exp(-26800/T_S)$
P3	$k_{diff,H2O}$ [m/s]	$D_{H2O} \cdot [(2 + 1.1 \cdot Re^{0.6} \cdot Sc^{0.33})/d_{p0}]$
	$k_{ash,H2O}$ [m/s]	$2 \cdot D_{H2O} \cdot \varepsilon^{2.5}/d_{p0}$
	$k_{reaz,H2O}$ [m/s]	$k_{reaz,CO2}$
P4	$k_{diff,H2}$ [m/s]	$D_{H2} \cdot [(2 + 1.1 \cdot Re^{0.6} \cdot Sc^{0.33})/d_{p0}]$
	$k_{ash,H2}$ [m/s]	$2 \cdot D_{H2} \cdot \varepsilon^{2.5}/d_{p0}$
	$k_{reaz,H2}$ [m/s]	$k_{reaz,CO2} \cdot 10^{-3}$