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## NOMENCLATURE

|   |   |  |
|---|---|--|
| a, A  | = | Constant   |
| %ash  | = | Weight percentage of ash in biomass                      |
| b   | = | Radius of bonding neck                                   |
| B, B0, B1, B2   |   |  |
| B3, B4, B5  | = | Constant   |
| C   | = | Constant   |
| C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub> , C <sub>4</sub> | = | Constant   |
| C <sub>b</sub>  | = | Bulk oxygen concentration                                |
| C <sub>new</sub>  | = | Constant   |
| C <sub>p,f</sub>  | = | Fluid heat capacity                                      |
| d <sub>ag</sub>   | = | Agglomerate diameter                                     |
| d <sub>b</sub>  | = | Bubble diameter  |
| d <sub>p</sub>  | = | Particle/Bed particle diameter                           |
| d <sub>p,av</sub>   | = | Average bed particle diameter                            |
| d <sub>p,char</sub>   | = | Char particle diameter                                   |
| D   | = | Particle separation distance                             |
| D <sub>AB</sub>   | = | Gas molecular diffusivity                                |
| D <sub>b</sub>  | = | Bed diameter   |
| D <sub>b,eq</sub>   | = | Equivalent bed diameter                                  |
| D <sub>0,S</sub>  | = | Pre-exponential factor for surface diffusion coefficient |
| E <sub>S</sub>  | = | Activation energy for surface diffusion                  |
| E <sub>μ</sub>  | = | Activation energy for viscosity                          |
| E <sub>μ,s</sub>  | = | Activation energy for surface viscosity                  |
| f, f <sub>1</sub> , f <sub>2</sub> , f <sub>3</sub>               | = | Function   |
| f <sub>N</sub>  | = | Existing ratio of alkali in bed material                 |
| F <sub>ad</sub>   | = | Adhesive force   |
| F <sub>ad,total</sub>   | = | Total adhesive force                                     |
| F <sub>br</sub>   | = | breaking-up force  |
| F <sub>LB,S</sub>   | = | Static liquid bridge force                               |
| F <sub>LB,V</sub>   | = | Viscous force in liquid bridge                           |
| F <sub>seg</sub>  | = | Segregate force  |
| F <sub>VW</sub>   | = | van der Waals force                                      |
| g   | = | Average gravity; 9.8 m/s <sup>2</sup>                    |
| h   | = | Heat transfer coefficient                                |
| H <sub>b</sub>  | = | Static bed height  |
| H <sub>mf</sub>   | = | Bed height at minimum fluidization velocity              |
| k   | = | Boltzmann constant / constant                            |
| k(T)  | = | Kinetic constant of devolatilization process             |
| k <sub>c</sub>  | = | Combustion rate constant                                 |
| k <sub>f</sub>  | = | Fluid conductivity                                       |
| k <sub>g</sub>  | = | Gas conductivity   |
| k <sub>m</sub>  | = | Mass transfer coefficient                                |
| K, K <sub>2</sub>   | = | Constant   |
| m <sub>bed</sub>  | = | Bed inventory  |
| m' <sub>fuel</sub>  | = | Fuel feed rate   |
| m <sub>p</sub>  | = | Mass of a single particle/bed particle                   |
| M   | = | Average convective solid mass flux                       |
| n   | = | The number of particles/bed particles                    |

|                        |   |  |
|------------------------|---|--|
| $p$                    | = | Constant   |
| $P$                    | = | Pressure in Pa   |
| $\Delta P$             | = | Different pressure between in bridge and the surrounding Pressure                        |
| $q$                    | = | Heat of reaction at complete combustion ( $C + O_2 \rightarrow CO_2$ )                   |
| $Q_{pp}$               | = | Polymer feed rate  |
| $r_p$                  | = | Particle/Bed particle radius   |
| $r_a$                  | = | Radius of curvature of asperities at a particle surface                                  |
| $r_{LB,c}$             | = | Liquid bridge meridional radius of curvature   |
| $r_{LB,n}$             | = | Liquid bridge neck radius  |
| $R$                    | = | Gas constant   |
| $S$                    | = | Adhesive stress / Bubble separation length   |
| $t$                    | = | Time   |
| $t_{def}$              | = | Defluidization time  |
| $T$                    | = | Operating temperature  |
| $T_{ag}$               | = | Agglomeration temperature  |
| $T_b$                  | = | Bed (combustion) temperature   |
| $T_{char}$             | = | Char surface temperature   |
| $T_S$                  | = | Sintering temperature  |
| $u_0$                  | = | Absolute velocity of a solid/bed particle at initial conditions                          |
| $u_b$                  | = | Bubble velocity  |
| $u_p$                  | = | Absolute velocity of a solid/bed particle  |
| $U$                    | = | Superficial gas/air velocity   |
| $U_{BB}$               | = | Bed breaking fluidizing velocity   |
| $U_D$                  | = | Defluidization velocity  |
| $U_f$                  | = | Fluid velocity   |
| $U_{mf}$               | = | Minimum fluidization velocity under normal conditions                                    |
| $U_{mf,S}$             | = | Minimum fluidization velocity under sintering conditions                                 |
| $U_S$                  | = | Limiting gas velocity  |
| $V$                    | = | Particle-Particle relative velocity  |
| $W$                    | = | Weight   |
| $W_{bed}$              | = | Weight of the bed particles in the bed   |
| $x_c$                  | = | Critical sintering neck radius   |
| $X^2$                  | = | Equivalent of neck contact area between particles  |
| $X_{ash}$              | = | Mass fraction of ash in the biomass  |
| $X_{K \text{ in Ash}}$ | = | Mass fraction of potassium in the ash  |
| $X_{K-Fuel}$           | = | Mass fraction of potassium in the fuel   |
| $X_{melt}$             | = | Ash melt fraction based on the initial ash compositions                                  |
| <b>Greek letters</b>   |   |  |
| $\pi$                  | = | Pi constant  |
| $\gamma$               | = | Surface tension  |
| $\phi$                 | = | Three-phase contact angle  |
| $\alpha$               | = | Half-filling bridge angle / ratio of volume of solids carried by bubble to bubble volume |
| $\mu_0$                | = | Pre-exponential factor for viscosity   |
| $\mu_f$                | = | Fluid viscosity  |
| $\mu_g$                | = | Gas/Air viscosity  |
| $\mu_s$                | = | Surface viscosity  |
| $\mu_{pp}$             | = | Polymer intrinsic viscosity  |

|                      |   |   |
|----------------------|---|---|
| $\mu_l$              | = | Viscosity of molten material  |
| $\rho_{\text{coat}}$ | = | Density of coating material   |
| $\rho_f$             | = | Fluid density   |
| $\rho_g$             | = | Gas/Air density   |
| $\rho_p$             | = | Particle/Bed particle density   |
| $\rho_{pp}$          | = | Polymer particle density  |
| $\rho_s$             | = | Solid density   |
| $\varepsilon$        | = | Bed void fraction / Emissivity  |
| $\varepsilon_{mf}$   | = | Bed void fraction at minimum fluidization                                   |
| $\psi$               | = | Sintering force function / alkali feed rate                                 |
| $\sigma$             | = | Stefan-Boltzmann constant, $5.670 \times 10^{-8} \text{ W/m}^2 \text{ K}^4$ |
| $\sigma_s$           | = | Yield stress of neck  |
| $\phi$               | = | Particle shape factor   |
| $\eta_0$             | = | Pre-exponential factor for surface viscosity                                |
| $\zeta$              | = | Specific surface free energy  |
| $\delta$             | = | Lattice constant for a crystalline solid / Coating thickness                |
| $\beta$              | = | Magnitude of relative contribution in MLR analysis                          |
| $\nu_f$              | = | Fluid kinematic viscosity   |

### Abbreviations

|                  |   |  |
|------------------|---|--|
| AI               | = | Alkali Index                                       |
| BAI              | = | Bed Agglomeration Index                            |
| EARS             | = | Early Agglomeration Recognition System             |
| FBC              | = | Fluidized Bed Combustion                           |
| FBG              | = | Fluidized Bed Gasification                         |
| K/Bed            | = | Potassium consumption to bed material weight ratio |
| M.P.             | = | Melting temperature                                |
| RDF              | = | Refuse Derived Fuel                                |
| R <sub>b/a</sub> | = | Base to Acid ratio                                 |

### Dimensionless group

|    |   |   |
|----|---|---|
| Ar | = | Archimedes number; $\frac{\rho_f(\rho_s - \rho_f)d_p^3 g}{\mu_f^2}$ |
| Co | = | Cohesive number; $\frac{6S}{(\rho_p - \rho_f)d_p g}$                |
| Ga | = | Galileo number; $\frac{gd_p^3}{\nu_f^2}$                            |
| Nu | = | Nussult number; $\frac{hd_p}{k_f}$                                  |
| Pr | = | Prandtl number; $\frac{c_{p,f}\mu_f}{k_f}$                          |

$$\text{Re}_p = \text{Reynolds number based on the particle; } \frac{\rho_f U_f d_p}{\mu_f}$$

$$\text{Sc} = \text{Schmidt number; } \frac{\mu_f}{\rho_f D_{AB}}$$

$$\text{Sh} = \text{Sherwood number; } \frac{k_m d_p}{D_{AB}}$$

$$\text{St} = \text{Stoke number; } \frac{2m_p u_0}{3\pi\mu_f r_p^2}$$