**Reinterpretation of the Geldart A Powder Classification Based on Eulerian-Eulerian CFD Simulation**

**Supporting Information Document**

**Table S1.** Eulerian-Eulerian TFM governing equations of the form implemented in ANSYS FLUENT 17.0 solver

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| **Conservation of mass for gas phase:**$$\frac{1}{ρ\_{rg}}\left(\frac{δ}{δt}\left(ε\_{g }ρ\_{g}\right)+ ∇. \left(ε\_{g }ρ\_{g}\vec{v\_{g}}\right)=\sum\_{p=1}^{n}\left(\dot{m\_{sg}}-\dot{m\_{gs}}\right)\right)$$ | (1) |
| **Analogous Conservation of mass for solid phase:**$$\frac{1}{ρ\_{rs}}\left(\frac{δ}{δt}\left(ε\_{s }ρ\_{s}\right)+ ∇. \left(ε\_{s }ρ\_{s}\vec{v\_{s}}\right)=\sum\_{p=1}^{n}\left(\dot{m\_{gs}}-\dot{m\_{sg}}\right)\right)$$ | (2) |
| **Solid volume fraction constraint :** $ε\_{s }+ε\_{g }=1$ | (3) |
| **Momentum conservation equation for gas phase:**$$\frac{δ}{δt}\left(ε\_{g }ρ\_{g} \vec{v\_{g}}\right)+ ∇. \left(ε\_{g }ρ\_{g}\vec{v\_{g}} \vec{v\_{g}}\right)=-ε\_{g }∇p+∇.̿\_{g}+ε\_{g }ρ\_{g}\vec{g } +\sum\_{p=1}^{n}\left(K\_{sg}\left(\vec{v\_{s}}-\vec{v\_{g}}\right)+\dot{m\_{sg} }\vec{v\_{sg}}-\dot{m\_{gs} }\vec{v\_{gs}}\right)$$ | (4) |
| **Analogous momentum conservation equation for solid phase:**$$\frac{δ}{δt}\left(ε\_{s }ρ\_{s} \vec{v\_{s}}\right)+ ∇. \left(ε\_{s }ρ\_{s}\vec{v\_{s}} \vec{v\_{s}}\right)=-ε\_{s }∇p-∇p\_{s}+∇.̿\_{s}+ε\_{s }ρ\_{s}\vec{g } +\sum\_{p=1}^{n}\left(K\_{gs}\left(\vec{v\_{g}}-\vec{v\_{s}}\right)+\dot{m\_{gs} }\vec{v\_{gs}}-\dot{m\_{sg} }\vec{v\_{sg}}\right)$$ | (5) |
| **Conservation of granular energy:**= *Generation of energy by solid stress tensor*= *Energy diffusion (is diffusion coefficient of the particles)*= *Collision dissipation of energy*= *Energy exchange between gas and solid phase*Under steady state convection and diffusive terms are usually neglected to give: | (6) |
| **Solids pressure :** (Lun C.K.K. et al., 1984)(Syamlal M. et al., 1993)*= pressure due to kinetic energy of particles, neglected in Syamlal model**= pressure due to particle collision* | (7)(8) |
| **Radial distribution function:**(S. Ogawa A.U., N. Oshima, 1980) and later by (Syamlal M. et al., 1993) | (9) |

**Table S2.** Notation used for TFM equations in Table S1

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| $ρ\_{rg}= refernce density or volume averaged density of gas phase$ *(kg/m3)*$ε\_{g }=volume fraction of gas phase $*(-)*$ε\_{s }=volume fraction of solid phase $*(-)*$ρ\_{g}=density of gas phase $*(kg/m3)*$ρ\_{s}=density of solid phase $*(kg/m3)*$\vec{v\_{g}} =velocity of gas phase $*(m/s)*$\vec{v\_{s}} =velocity of solid phase $*(m/s)*$\dot{m\_{sg}}=mass transfer rate from solid to gas phase$ *(kg/s)*$\dot{m\_{gs}}=mass transfer rate from gas to solid phase$*(kg/s)*$p=gas pressure$ *(Pa)*$p\_{s}=solids pressure$ *(Pa)*$̿\_{s}=solid phase stress tensor$ *(N/m2)*$\vec{g }=acceleration due to gravity$ *(m/s2)*$$\vec{v\_{gs}}=interphase velocity .If \dot{m\_{gs}}>0, \vec{v\_{gs}}= \vec{v\_{g}} else if \dot{m\_{gs}}<0, \vec{v\_{gs}}= \vec{v\_{s}} $$$$\vec{v\_{sg}}=interphase velocity .If \dot{m\_{sg}}>0, \vec{v\_{sg}}= \vec{v\_{s}} else if \dot{m\_{sg}}<0, \vec{v\_{sg}}= \vec{v\_{g}} $$$$K\_{gs}= K\_{sg}=momentum exchange coefficient between gas and solid phase$$Ѳ = *Graular temperature(m2/s2)**= restitution coefficient for particle collisions (-)**= radial distribution function(-)* |

**Table S3.** Closure for stress tensor

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| --- | --- |
| **Stress tensor for solid phase** | (10) |
|  **Analogous stress tensor for gas-phase** | (11) |
| **Solid bulk viscosity** (Lun C.K.K. et al., 1984) | (12) |
| **Components of solids shear viscosity** appearing in Eq. (2.11) are collisional, Kinetic and frictional:  | (13) |
| **Collision shear viscosity** given by the combined Gidaspow and Syamlal models(D.Gidaspow, 1994., Syamlal M. et al., 1993) | (14) |
| **Kinetic shear viscosity** given by the Syamlal model(Syamlal M. et al., 1993) | (15) |
| **Frictional viscosity**  (Schaeffer D.G., 1987) | (16) |
| **Frictional pressure**(Syamlal M. et al., 1993) | (17) |

**Table S4.** Closures for drag coefficient implemented

|  |  |
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| **Gidaspow drag law**$$If ε\_{g }<0.8 $$$K\_{gs}=\frac{3}{4} C\_{D}\frac{ε\_{s } ε\_{g }ρ\_{g}\left|\vec{v\_{s}}-\vec{v\_{g}}\right| }{d\_{p}}ε\_{g }^{-2.65} $ (Ergun S., 1952)$$C\_{D}=\frac{24}{ε\_{g }Re\_{p}}\left[1+0.15\left(ε\_{g }Re\_{p}\right)^{0.687}\right]$$$$Re\_{p}=\frac{ d\_{p}ρ\_{g}\left|\vec{v\_{s}}-\vec{v\_{g}}\right| }{μ\_{g}}$$ | (18)  |
| $If ε\_{g }>0.8 $(C.Y. Wen Y.H.Y., 1966)$$K\_{sg}=150 \frac{ε\_{s } \left(1-ε\_{s }\right)μ \_{g}}{ε\_{s }d\_{p}^{2}}+1.75\frac{ ε\_{s }ρ\_{g}\left|\vec{v\_{s}}-\vec{v\_{g}}\right| }{d\_{p}}$$ | (19) |

**Table S5.** Notation used for TFM equations in Table S3 and S4

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| = *Shear viscosity of solids (Pa s)**= Bulk viscosity of solid (Pa s)**= Unit stress tensor (-)**= Divergence of solid velocity vector (-)**= Transpose of divergence of solid velocity vector(-)* *= Solids pressure due to friction (Pa) to be added to of Eq. 2.7**= Angle of internal friction (common value is 30o)**= Second invariant of deviatoric stress tensor(-)*= *Minimum bed solid volume fraction for frictional stress consideration(-)*= *Maximum allowable bed packing (packed bed state)(-)*= *Empirical material constants required to calculate frictional pressure* = *Material constant required to calculate frictional pressure of typical value 1025* $$K\_{gs}=Interphase drag exchange coefficient$$$$C\_{D}=Drag function$$ |

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