Drag models for the spherocylinder CFDEM model

In this document, $\vec{u}$ is used to denote the relative velocity between particle and fluid.

$$\vec{u} = \vec{u}_f - \vec{u}_p$$

Holzer and Sommerfeld, Di Felice

The drag force on a single particle is given by

$$\vec{F}_{D0} = \vec{u}|\vec{u}|C_D \frac{1}{2}\rho\frac{\pi}{4}d_s^2$$

Where the drag coefficient is given by Holzer and Sommerfeld [1]:

$$C_D = \frac{8}{\mathrm{Re}}\frac{1}{\sqrt{\phi_\parallel}} + \frac{16}{\mathrm{Re}}\frac{1}{\sqrt{\phi}} + \frac{3}{\sqrt{\mathrm{Re}}}\frac{1}{\phi^{\frac{3}{4}}} + 0.4210^{0.4(-\ln\phi)^{0.2}}\frac{1}{\phi_\perp}$$

Where

$$\mathrm{Re} = \frac{\epsilon|\vec{u}|d_s}{\nu}$$

$$\phi_\perp = \frac{A_{s,\perp}}{A_{p,\perp}}$$

$$\phi_\parallel = \frac{2A_{s,\parallel}}{A_{p,tot} - 2A_{p,\parallel}}$$

The drag force on a particle in presence of other particles is given according to Di Felice [2]:

$$\vec{F}_D = \vec{F}_{D0}\epsilon^{2-\beta}$$

$$\beta = 3.7 - 0.65\exp\left(-\frac{(1.5 - \ln\mathrm{Re})^2}{2}\right)$$

Ergun Equation

The pressure drop over a CFD cell is given by the Ergun equation [3]

$$\frac{\Delta P}{L} = 150\frac{\mu\vec{U}_0(1-\epsilon)^2}{(\phi d_s)^2\epsilon^3} + 1.75\frac{\rho|\vec{U}_0|\vec{U}_0(1-\epsilon)}{\phi d_s\epsilon^3}$$

The total force on all particles in a cell is given by

$$F_{tot,cell} = \frac{\Delta P}{L}V_{cell}\epsilon$$

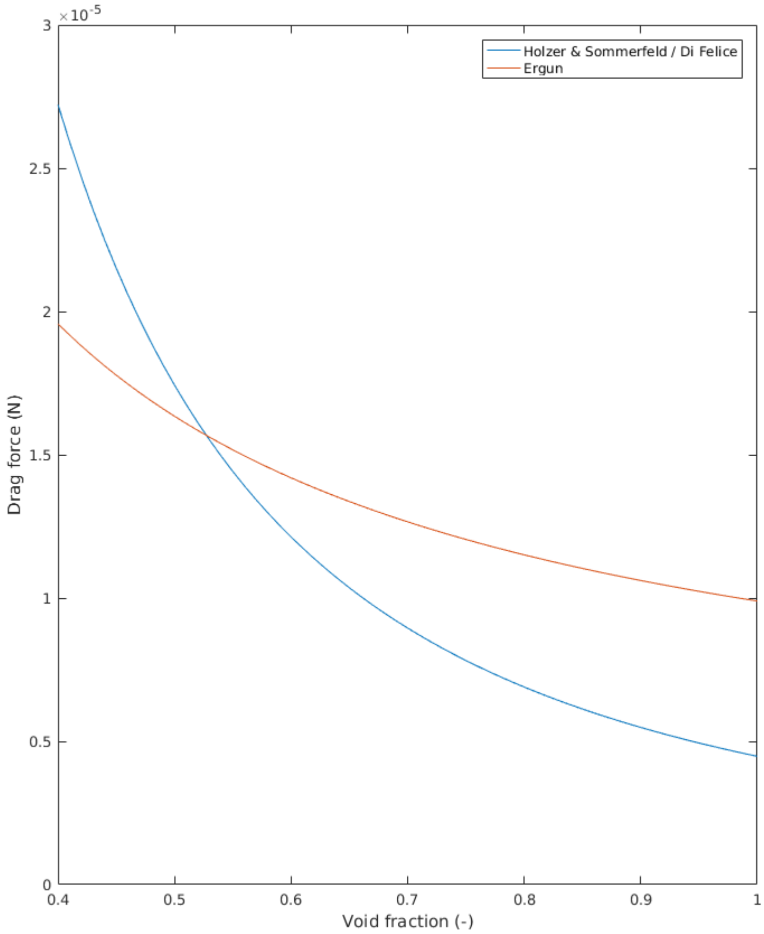
The force on each particle is given by [4]

$$F_{part} = \frac{F_{tot,cell}}{n_{part}} = F_{tot,cell}\frac{V_{part}}{V_{cell}(1-\epsilon)} = \frac{\Delta P V_{part}\epsilon}{L(1-\epsilon)}$$

$$\frac{F_{part}}{V_{part}} = 150\frac{\mu\vec{U}_0(1-\epsilon)}{(\phi d_s)^2\epsilon^2} + 1.75\frac{\rho|\vec{U}_0|\vec{U}_0}{\phi d_s\epsilon^2}$$

For μ we substitute $\nu\rho$, for $\vec{U}_0$ we substitute $\epsilon\vec{u}$.

$$\vec{F}_{part} = \frac{\vec{u}V_{part}\rho}{\phi d_s}\left(150\frac{\nu(1-\epsilon)}{\epsilon\phi d_s} + 1.75|u|\right)$$



In order to decide which drag model to use, the minimum of the Holzer & Sommerfeld / Di Felice and the Ergun drag is taken. This ensures that the Ergun drag is used in dense regions.

$$\vec{F}_D = \min(\vec{F}_{D,H\&Z/DF}, \vec{F}_{D,Ergun})$$

References

1. HÃ¶lzer, A., & Sommerfeld, M. (2008). New simple correlation formula for the drag coefficient of non-spherical particles. Powder Technology, 184(3)

2. Di Felice, R. (1994). The voidage function for fluid-particle interaction systems. International Journal of Multiphase Flow, 20(I)

3. Ergun, S. (1952). Fluid flow through packed columns. Chem. Eng. Prog., 48

4. Gidaspow, D. (1994). Multiphase Flow and Fluidization: Continuum and Kinetic Theory Descriptions. London: Academic Press Inc.