Modelling of Non-Spherical Particles

Berend van Wachem

This lecture will focus on modelling approaches for dispersed multi-phase flows with non-spherical particles. The analysis of flows with non-spherical particles is considerably more complicated than flows with spherical particles. While a sphere is characterised by its diameter only, even a very simple non-spherical particle like a disc or a fiber needs at least two parameters to be uniquely defined. This makes the rigid body dynamics of non-spherical particles more complex than the corresponding dynamics of spherical particles. Moreover, additional complexities arise in describing the interaction of a non-spherical particle with a fluid. In a uniform flow a sphere experiences only a drag force, whereas a non-spherical body is also affected by a transverse lift force, a pitching torque and a counter-rotational torque. A comprehensive overview of the available methods to describe the shape, the resulting drag force based on correlations and their associated behaviour of non-spherical particles is presented in Chhabra et al. (1999); Mando and Rosendahl (2010).

This lecture will start with deriving the rigid body dynamics for generally shaped objects, and discussing the various approaches for contact-detection, to account for collisions between two non-spherical particles. Also, the numerical implementation of these models will be discussed (Zhao and van Wachem, 2013).

Furthermore, the coupling between the motion of a non-spherical particle and a fluid is discussed. In studying the orientation of non-spherical particles with a slip velocity between the particle and the fluid, the application of the drag and torque model as put forward by Brenner (1964) and Jeffery (1922) is frequently used, but limited to particle Reynolds number much less than 1. For most applied gas-particle flows, these models are not realistic. Empirical models and models derived using DNS to describe the coupling between the fluid and a non-spherical particle (*e.g.* Zastawny et al. (2012)) will also be discussed. The large-scale application of such models can accurately predict the turbulent flows with non-spherical particles (van Wachem et al., 2015).

References

Brenner, H. (1964). The Stokes resistance of an arbitrary particle-IV Arbitrary fields of flow. *Chemical Engineering Science*, 19(9):631–651.

Chhabra, R., Agarwal, L., and Sinha, N. (1999). Drag on non-spherical particles: An evaluation of available methods. *Powder Technology*, 101(3):288–295.

Jeffery, G. B. (1922). The motion of ellipsoidal particles immersed in a viscous fluid. *Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character*, 102(715):161–179.

Mando, M. and Rosendahl, L. (2010). On the motion of non-spherical particles at high Reynolds number. *Powder Technology*, 202(1-3):1–13.

van Wachem, B., Zastawny, M., Zhao, F., and Mallouppas, G. (2015). Modelling of gas–solid turbulent channel flow with non-spherical particles with large Stokes numbers. *International Journal of Multiphase Flow*, 68:80–92.

Zastawny, M., Mallouppas, G., Zhao, F., and van Wachem, B. (2012). Derivation of drag and lift force and torque coefficients for non-spherical particles in flows. *International Journal of Multiphase Flow*, 39:227–239.

Zhao, F. and van Wachem, B. (2013). A novel Quaternion integration approach for describing the behaviour of non-spherical particles. *Acta Mechanica*, 224(12):3091–3109.