Bacherlor's / Master's thesis project:

Development of a new approach to simulate the electrostatic charging of particle-laden flows

The "Analysis and Simulation in Explosion Protection" group at Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig/Germany invites applications for a bachelor's/master's thesis project starting as soon as possible. The research of the group concerns a wide range of flows in the field of explosion protection. Hereby, we contribute to the prevention of explosions, or, where they occur, to the mitigation of their impact on humans, facilities and the environment. To this end we focus on experimental research, the development of new mathematical models and Computational Fluid Dynamics (CFD) simulations via high performance computing.

The proposed student project regards the numerical exploration of particle-laden flows. When powders are transported pneumatically they often gain an electrostatic charge that can lead to hazardous spark discharges which caused in the past numerous dust explosions. The research group has developed a code where the turbulent carrier flow is computed in an Eulerian framework either through direct numerical simulations (DNS) [1] or large-eddy simulations (LES) [2]. The trajectories of the particles and their electrostatic charging, on the other hand, are described in a Lagrangian framework. Thus, Newton's second law of motion is solved for each individual particle.

This methodology enabled the computation of a wide range of flows. However, since the computational effort of the Lagrangian description scales with the number of particles, the applicability of this approach is limited to a relatively small powder sample. The number of treatable particles can be significantly increased by describing the particulate phase in an Eulerian framework which facilitates the computation of real-scale powder flows. In Eulerian framework the particulate phase is considered to behave as a continuum which is characterized by the particle probability density function given by

$$\zeta = \zeta(\boldsymbol{u}_\mathrm{p}, r_\mathrm{p}, Q_\mathrm{p}; \boldsymbol{x}, t)\,. \tag{1}$$

This expression gives the probable number of particles having a velocity of $\boldsymbol{u}_\mathrm{p}$, a radius of r_p and carrying an electrical charge of Q_p. The evolution of ζ reads, analogous to Williams' spray equation [3],

$$\frac{\partial \zeta}{\partial t} + \frac{\partial(\boldsymbol{u}_\mathrm{p}\zeta)}{\partial \boldsymbol{x}} = -\frac{\partial(\sum \boldsymbol{f}\,\zeta)}{\partial \boldsymbol{u}_\mathrm{p}} - \frac{\partial(\dot{Q}_\mathrm{p}\,\zeta)}{\partial Q_\mathrm{p}}\,. \tag{2}$$

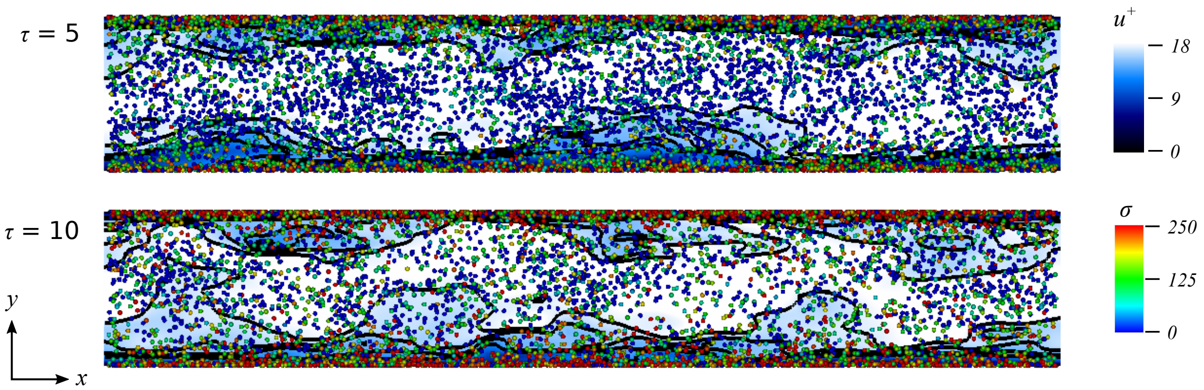

Figure 1: Instantaneous visualizations of the charging of particles in a channel flow. The black contours represent the isolines of the magnitude of the fluid velocity [1].

The first term on the right hand side of the above equations represents the sum of the external forces affecting ζ whereas $\dot{Q}$ denotes the change of the particle charge.

It is the aim of the proposed project to implement the Direct Quadrature Method of Moments (DQMOM) [4] to solve equation (2) in the existing CFD solver. DQMOM allows the accurate treatment of strongly polydisperse particle size distributions. This task also includes the suitable modeling of the source terms on the right hand side of equation (2).

The applicant should fulfill the following requirements:

- He/she is currently pursuing studies in computational engineering, applied mathematics, or similar
- He/she has basic skills in the fields of fluid mechanics and the programming language fortran
- He/she has a strong interest in numerical mathematics

The project will be based in the "Analysis and Simulation in Explosion Protection" group at Physikalisch-Technische Bundesanstalt in Braunschweig/Germany. Please send your application documents including a CV and certificates to Dr. H. Grosshans (holger.grosshans@ptb.de).

References

[1] H. Grosshans and M. V. Papalexandris. Direct numerical simulation of triboelectric charging in a particle-laden turbulent channel flow. *J. Fluid Mech.*, 818:465–491, 2017.

[2] H. Grosshans and M. V. Papalexandris. Large eddy simulation of triboelectric charging in pneumatic powder transport. *Powder Technol.*, 301:1008–1015, 2016.

[3] F. A. Williams. Spray combustion and atomization. *Phys. Fluids (1958-1988)*, 1(6):541–545, 1958.

[4] D. L. Marchisio and R. O. Fox. Solution of population balance equations using the direct quadrature method of moments. *J. Aerosol Sci.*, 36(1):43–73, 2005.