Time Extrapolation of Multiphase Flow Simulations by Recurrence CFD - Offline Simulations and Explicit Online Approaches

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ABSTRACT

In typical multi-scale particulate flows (e.g. gas solid fluidized beds) slow processes evolving at large time-scales (e.g. heating of particles) depend on rapidly changing flow topologies (e.g. bubble dynamics). Considering such strongly separated time-scales within the framework of deterministic CFD-DEM simulations might render impossible due to the excess number of (very small) time-steps.

With the concept of recurrence CFD (**rCFD**), we replace the (pseudo-)deterministic time-marching procedure of CFD-DEM simulations by a generic composition of a multiphase flow candidate based on pre-calculated flow fields.

To realize this, we first analyse an expensive CFD-DEM simulation with respect to recurring flow patterns. As a result we obtain a recurrence matrix, which describes the correlation between individual flow patterns. Based on this information, we chose a candidate for an unsteady flow by stitching sequences of existing flow patterns accordingly [1]. Finally, slow processes (e.g. heating of particles) can be traced on top of this generic flow by solving for a transport equation or by tracking particle trajectories on pre-defined flow fields. In a first part of this talk I will show that such a flow based **rCFD** simulation of particle cooling in a fluidized bed deliver highly accurate results at only 1/300 of the computational time of corresponding full CFD-DEM simulations [2].

In a second part of this talk we further develop **rCFD** by switching from considering recurring flow patterns to analysing recurring transport patterns. In this step we omit the composition of a generic flow candidate but directly address transport processes themselves. With this modelling shortcut, we can boost **rCFD** simulations by another two orders of magnitude, which in case of particle heating/cooling in a fluidized bed yields an overall speed-up of 99.000 (i.e. compared to full CFD-DEM simulations). Still, individual gas cell temperatures and discrete particle temperatures are obtained at the same spatial resolution as in the original simulation (i.e. 57.000 particles and 23.100 grid cells). Furthermore, those fast (i.e. five times faster than real-time) **rCFD** simulations delivered astonishingly accurate results.

I will conclude my talk by wrapping up the main idea of flow based and transport based **rCFD** and by explicitly discussing existing limitations of our approach. Finally, I will provide an outlook towards online simulations of particulate processes by transport based **rCFD** simulations.

REFERENCES

[1] T. Lichtenegger and S. Pirker, “Recurrence CFD – A novel approach to simulate multiphase flows with strongly separated time scales”, *Chem. Eng. Sci.*, **153**, 394-410 (2016).

[2] T. Lichtenegger, E.A.J.F. Peters, J.A.M. Kuipers and S. Pirker, “A recurrence CFD study of heat transfer in a fluidized bed”, *Chem. Eng. Sci.*, **172**, 310-322 (2017).