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Population Balance Equation for Porous Media: Upscaled Dynamics and Evolution

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Evolution and dynamics of particles have great importance in environmental, industrial and biological applications. One of the most known way to model their behaviour is through the Population Balance Equation (PBE). The PBE describes the evolution of the size ℓ of a population of particles, $f(\mathbf{x}, \ell; t)$, through the reciprocal interactions of the particles within the population (e.g., collisions) and the interaction of the particles with the environment (e.g., shear-induced breakage). Thanks to its extreme flexibility to account for different mechanisms in different systems, it was applied with great success for several problems in chemical engineering, such as the precipitation of polymer nanoparticles in micro-reactors (Di Pasquale et al., 2012,2013).

Population Balance Equation (PBE) successfully describes particle evolution in different flow conditions (Di Pasquale et al., 2012). However, despite predictive macroscopic models for polydisperse particulate flows are relevant for many Porous Media applications (Municchi and Icardi, 2020; Municchi et al., 2020) such as subsurface (water, oil) reservoirs, industrial filtration, there is still little penetration of the PBE framework into PM community.

Our main goal is to present a general population balance model for particle transport at the pore-scale, which includes the main mechanisms of particle evolution, such as aggregation, breakage and surface deposition. Using dimensional analysis we consider the different terms in the PBE and we propose to split the various mechanisms considered for particle interactions into one- and two-particles processes, defining for each different aggregations and breakage mechanisms a Damköhler number, Da, which, along with the Peclet number, Pe, describes the relative importance of the particle evolution mechanisms with respect the time-scale of the fluid.
In this work, we are also considering fractal aggregates, with fractal dimension ϕ.

One open problem remains the upscaling of the PBE (via volume averaging and homogenisation) to a macroscopic (Darcy-scale) description which requires closures assumptions.

Here, we show how to obtain such closure for some specialised case where we show, for arbitrary periodic geometries, accurate upscaled models in particular for the upscaled breakage and collision frequencies, starting from a non-linear power-law dependence on the local fluid shear rate. This work represents the foundation of a new general framework for multiscale modelling of particulate flows in PM.

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Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

Online

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