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Liquid-Solid **Fluidisation**

Experimental and numerical insights into heterogeneous liquid-solid behaviour in drinking water softening reactors

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Fig. 2: Full-scale pellet-softening reactors located at Waternet (Amsterdam, the Netherlands). The unit consists of 12 reactors with a column diameter 3 meter

Abstract

Liquid-solid fluidisation is frequently encountered in drinking water treatment processes, for instance in seeded crystallisation softening processes. For modest superficial fluid velocities, liquid-solid fluidisation systems (LSF) are generally considered to be homogeneous, as reported in literature. However, during fluidisation experiments with calcite grains, open spaces of water can be observed between the fluidised particles, even at relatively low fluid velocities. Moreover, significant heterogeneous particle-fluid patterns are detected at higher fluid velocities. Such heterogeneous behaviour can beneficially or adversely affect the chemical crystallisation efficiency. To obtain information about voids in bulk regions, complementary Computational Fluid Dynamics - Discrete Element Method (CFD-DEM) simulations were performed and compared with the experimental results for validation. Simulations were performed using different water inlet velocities and fractionised calcite granules obtained from full-scale reactors. Here, the results are analysed using the bed height, voidage and pressure drop of the system. Furthermore, images of the experiments and simulations are visually compared for the formation of voids. The simulations showed distinct differences in void fraction in the cross-section of the column. It is shown that throughout the range of considered water velocities, heterogeneous behaviour exists and cannot be neglected. The heterogeneity and onset of fluidisation behaviour obtained from the simulations and experimental observations were compared and found to agree reasonably well.

Background

Water softening is an important process in water treatment. The removal of calcium carbonate has multiple benefits, for example to counteract limescale. The softening process is frequently performed using LSF bed reactors. In the Netherlands, more than 400 million m³ water is softened annually in drinking water treatment plants employing fluidised bed pellet reactors.

Experiments and modelling

Fluidisation characteristics were measured for calcite pellets at room temperature for five different superficial fluid velocities. In this study, we used a high-speed camera to make video recordings of the collective motion of calcite pellets in the expansion columns. The mean bed voidage for calcite pellets was predicted on the basis of the CFD-DEM simulations and compared with the experimentally determined voidages.

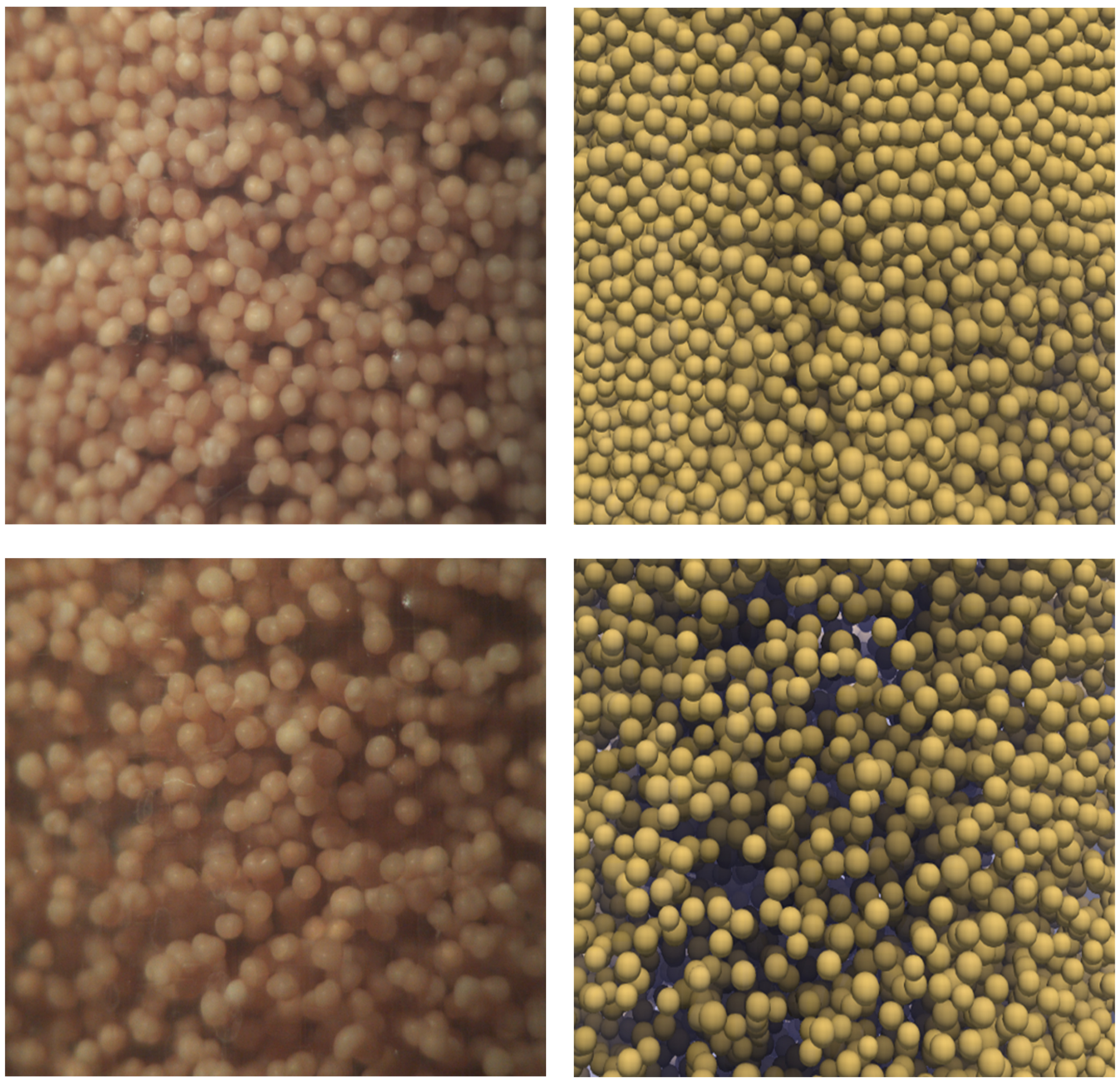

Fig. 2: Visual comparison between experiments (left) and simulations (right), showing void development with increasing fluid velocity.

Results

In this work, both experiments and simulations were employed to gain insight into the heterogeneous behaviour of drinking water softening reactors. In the literature, LSF systems are often considered to be homogeneous at modest velocities. Nevertheless, in the experiments with calcite grains, local voids were observed at relatively low fluid velocities and significant heterogeneous particle-fluid patterns at higher fluid velocities. A CFD-DEM simulation model was used, and its results compared with expansion measurements and high-speed videos and images. From this combination of experiments and simulations, it was concluded that homogeneous fluidisation virtually does not occur.

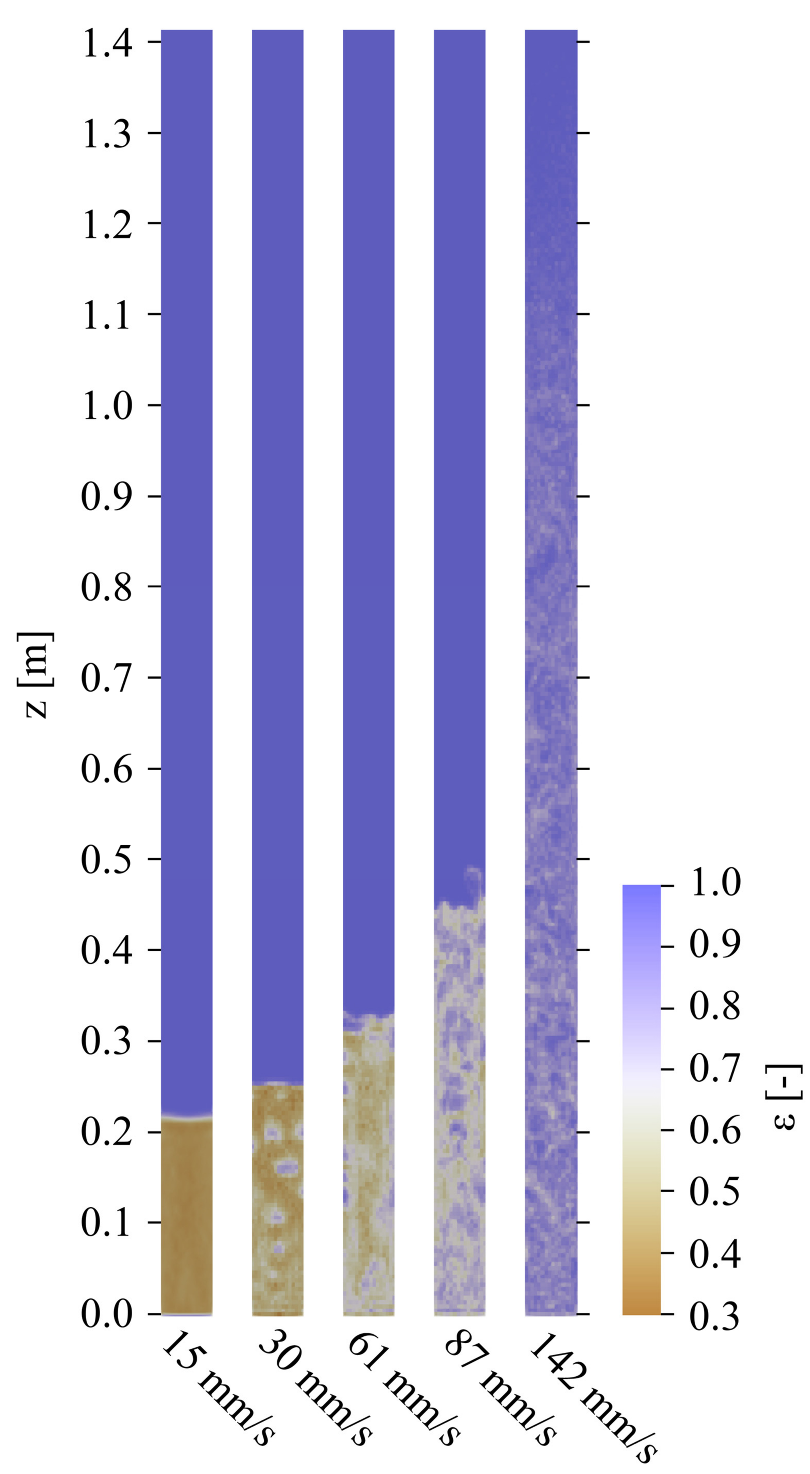

Fig. 3: Instantaneous cross-sectional void fraction snapshots for increasing superficial liquid velocity (15, 30, 61, 87 and 142 mm/s, respectively). Videos can be accessed at doi.org/10.4121/13663619 or by scanning the QR code.

References
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