Discrete bubble modeling of a wire-mesh bubble column reactor

View abstract data

Abstract title	DISCRETE BUBBLE MODELING OF A WIRE-MESH BUBBLE COLUMN REACTOR
Author	Jain , Deepak, TUe, Eindhoven, Netherlands (Presenting author)
Co-author(s)	Kuipers, Hans, TUe, Eindhoven, Netherlands Deen, Niels, TUe, Eindhoven, Netherlands

Reactors involving gas-liquid mass transfer are often facilitated with a solid catalyst phase for chemical reactions. Such arrangements are quite frequently found in industries involving hydrogenation, oxidation and Fischer-Tropsch synthesis. Conventionally, two reactor types are widely used in large scale production, slurry bubble column reactors and trickle bed reactors. Slurry bubble column reactors suffer from pronounced bubble coalescence at high solids fractions, which reduces the interfacial mass transfer area. Trickle bed reactors are limited by low gas throughput and poor heat removal characteristics. To overcome the aforementioned disadvantages, a novel reactor type, a micro-structured bubble column is proposed.

This reactor type consists of an array of static wire-meshes stacked inside the column at various heights. These wire meshes serve as catalyst carriers, facilitate the cutting of larger bubbles into smaller ones, and save the extra cost of an external filtration unit for catalyst particles. In recent studies it has also been observed that such arrangements may help in reducing liquid phase backmixing.

Detailed modeling of bubble column reactors has been successfully undertaken by Darmana et al. [1] using a Discrete bubble model (DBM) based on a Eulerian-Lagrangian framework. In this work we have extended the previous work by accounting for the presence of a solid phase (wires) and bubble cutting due to presence of wires. Drag closures for i) bubble swarms as proposed by Roghair et al. [2] and, ii) immersed cylindrical wires by Segers et al. [3] are included. The bubble break-up model of Lau et al. [4] is used to incorporate the effect of bubble break-up.

The simulation model was verified extensively before the effect of geometrical and physical parameters on the bubble size distribution was studied. Results show that the bubbles experience pronounced cutting due to the presence of the wires, leading to a higher specific gas-liquid interfacial area. An increase in mesh opening results in the reduction of bubble cutting. However, too small openings are not useful, as they lead to gas pocket formation below the mesh. Thus, an optimal opening depending on bubble sizes is necessary. Gas superficial velocity affects the bubble coalescence and break-up phenomena and hence is also an important factor in deciding about the mesh dimensions.

References:

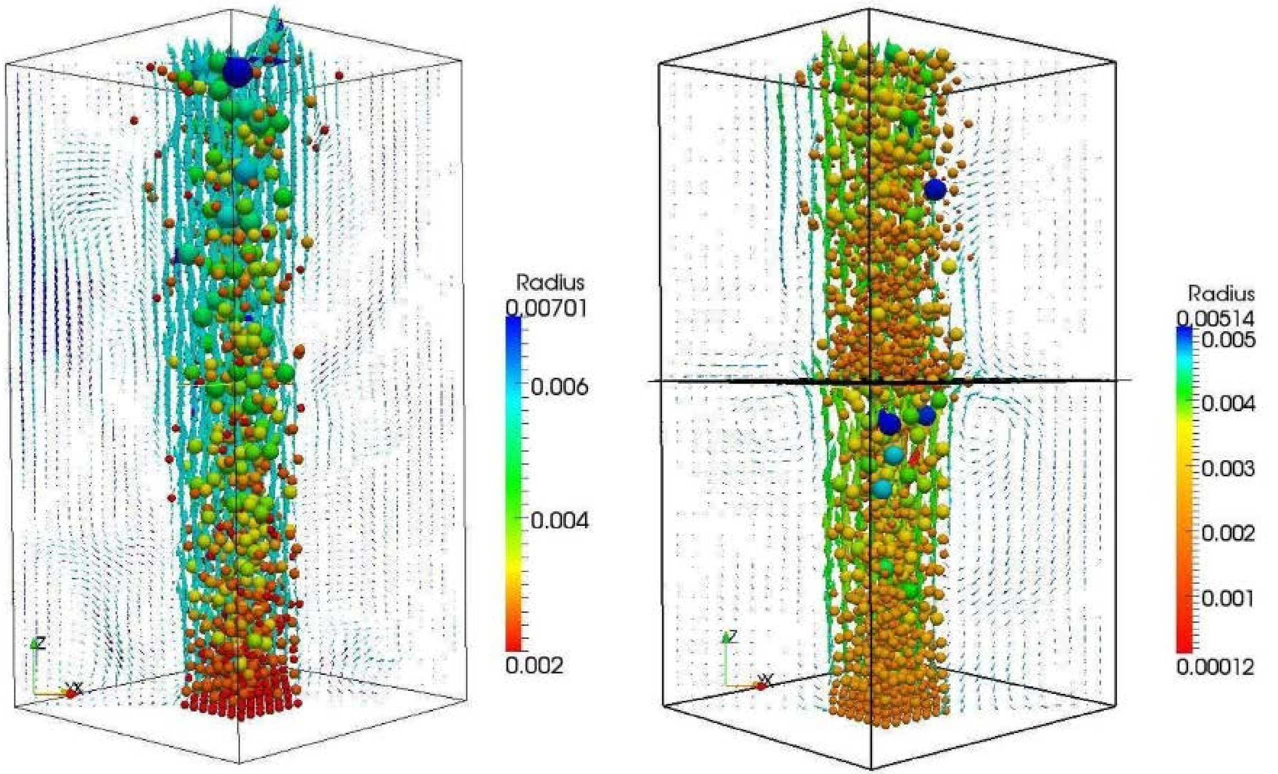
1. Darmana, D., Henket, R., Deen, N., & Kuipers, J. (2007). Detailed modelling of hydrodynamics, mass transfer and chemical reactions in a bubble column using a discrete bubble model: Chemisorption of CO_{2} into NaOH solution, numerical and experimental study. Chemical Engineering Science, 62 , 2556–2575.

2. Roghair, I., Lau, Y., Deen, N., Slagter, H., Baltussen, M., Van Sint Anna- land, M., & Kuipers, J. (2011). On the drag force of bubbles in bubble swarms at intermediate and high reynolds numbers. Chemical Engineering Science,66, 3204–3211.

3. Segers, Q., Kuipers, J., & Deen, N. (2013). Immersed boundary method applied to single phase flow past crossing cylinders. Chemical engineering science, (submitted).

4. Lau, Y., Deen, N., & Kuipers, J. (2010). Bubble break-up in Euler-Lagrange simulations of bubbly flow. In International Conference on Multiphase Flow.

Images



(a) without mesh

(b) with mesh

Figure 1: Instantaneous liquid velocity vectors in a square bubble column a) without mesh, b) with mesh inside the column. Less backmixing is observed with mesh, as separate liquid circulation patterns are visible above and below mesh.

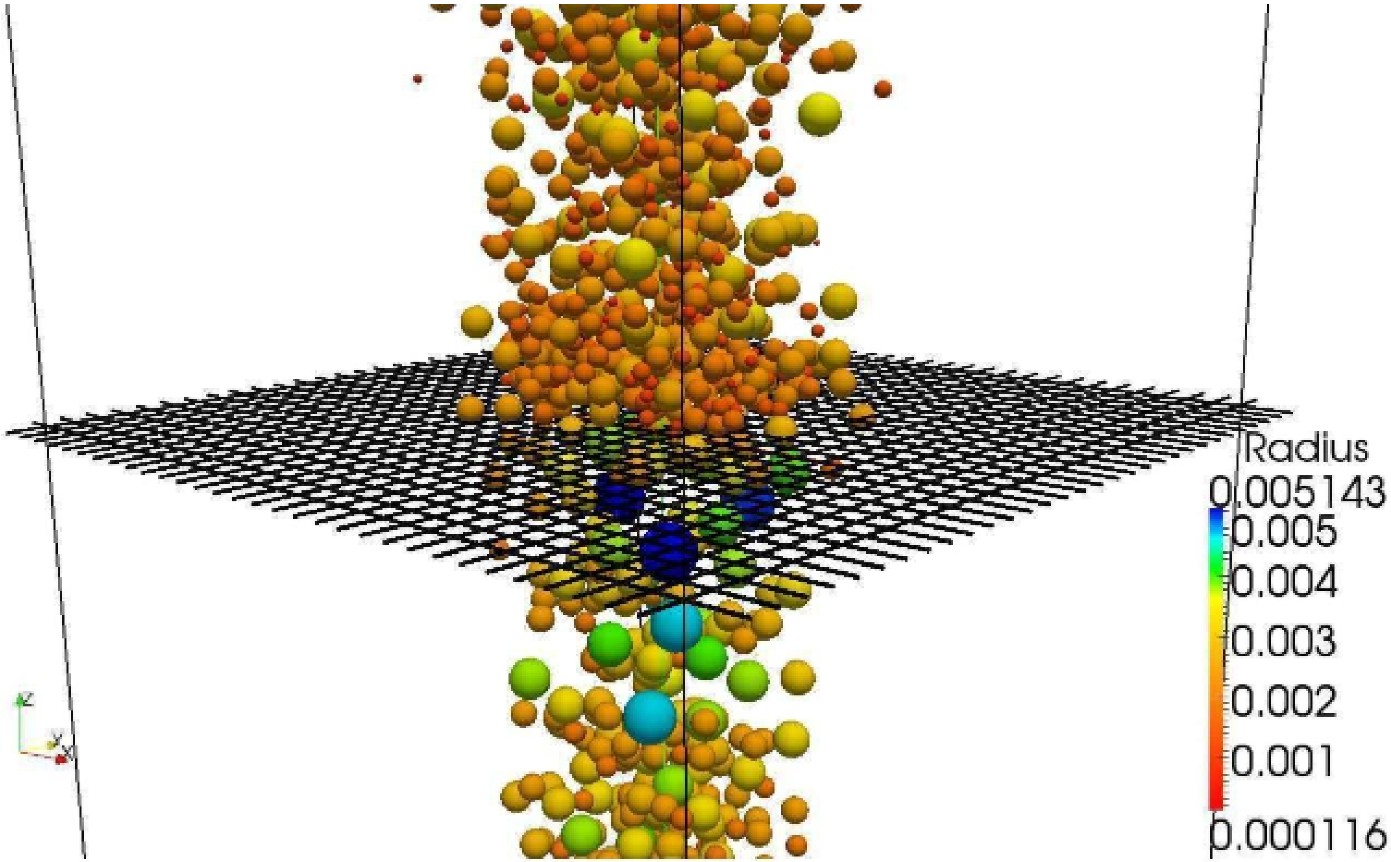


Figure 2: Close-up of bubble cutting through the wire-mesh. As the bigger bubbles pass though the mesh, they are cut in smaller ones by the wires.

Cutting of bubbles through wire-mesh