Machine Learning models for bubbly flows

Student

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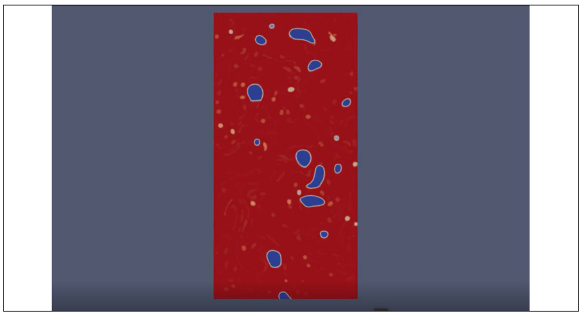
Introduction: The study of bubbly flows goes back to Leonardo da Vinci who tried to describe its patterns. Unlike da Vinci, computational fluid dynamics (CFD) is nowadays used to study the flow of bubbles in liquids, however the topic remains challenging. Bubbly flows are important in the chemical industry, where large reactors exploit bubbly flows for high yields. In this preliminary study, we combine CFD and machine learning to alleviate the simulation cost of large reactors.

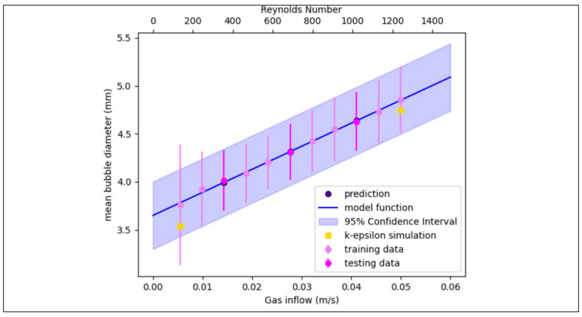
Approach: CFD simulations of large-scale chemical reactors with small bubbles are very time consuming due to the small mesh size required to resolve the bubbles and the size of the computational domain. This can make some models impractical or impossible to execute. However, in many processes only small parts of the reactor need to be simulate din detail, e.g. perforated trays used to manage bubble size, and large sections of the reactor are characterized by "free" bubbly flows, in the sense that bubbles flow without interaction to solid obstacles other than the reactor walls.
This report aims at using machine learning models of bubbly flow statistics in this regions to reduce the cost of simulating them. If successful, this approach replaces a costly CFD simulation with the evaluation of an algebraic model, which is order of magnitudes faster then the simulation. This approach is sometimes called "emulation" or "surrogate models " in the literature.

Result: In this report we showed how CFD simulations of gas bubbles in liquid can be quantified by extracting different bubble statistics and generating effective models for them. We used the the PyVista library to extract the data and machine learning models, i.e. Gaussian Processes, were trained on the extracted data using the Scikit-learn library. For the generation of the data we performed many simulations sweeping the parameter space of a simplified model. We also compared simulations using a laminar and a turbulent (k-epsilon) transport model.

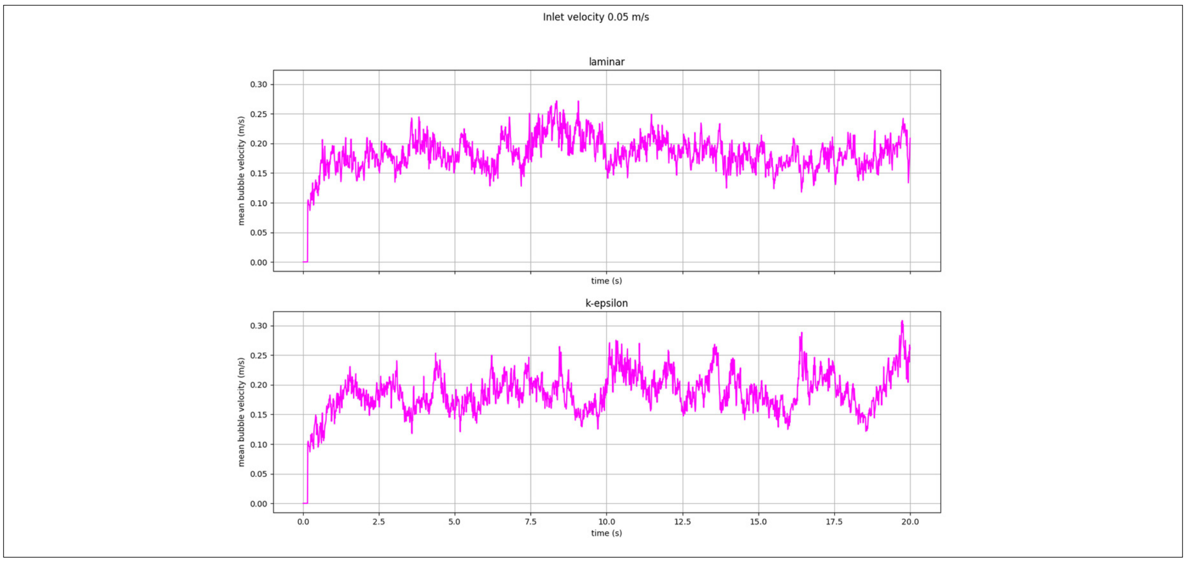
Snapshot of a bubble flow simulation in OpenFoam v12. The fraction of gas is shown, red (liquid) and blue (gas).
Own presentment



Mean bubble diameter at different gas inlet velocities and the corresponding inlet Reynolds number.
Own presentment



Mean bubble velocity comparison of laminar and k-epsilon simulation.
Own presentment



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Subject Area
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