
Comparison of direct numerical simulation and experimental investigation of droplet breakup inside a high-pressure homogenizer outlet chamber

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Objective

Emulsification is an essential unit operation in the food industry. High-pressure homogenizer (HPH) is the typical emulsification device used for low to medium viscosity ratio emulsions (e.g., pasteurized milk). While there is little consensus on the detailed mechanism of breakup in these devices, turbulence is considered to play a major role. This study is part of a larger project aiming for generating the fundamental understanding necessary for designing more efficient devices. The objectives of this specific study is to compare and validate the two commonly used methods for studying individual turbulent drop breakup: numerical in silico experiments and high-speed in vitro visualizations, with special emphasis on finding the limitations of the different techniques.

Methods

A cuboidal scale-up model of an HPH valve is designed and used both for the numerical and experimental investigations. For the numerical investigation of the breakup, direct numerical simulation (DNS) coupled with a highly resolved interface tracking VOF method is used. For the experimental studies, high-speed photography is carried out (using a 19000 fps camera with fluorescent marking of the drops).

Results

The results of the numerical breakup experiments are compared to the high speed visualizations in different aspects, including the position and the morphology of the breakup. The main limitations of the in vitro high-speed visualization technique are in only allowing for the investigation of a 2D-projection of the drop and in a limited spatial and temporal resolution. The main limitation of the numerical in silico experiment is in only allowing for a relatively simplistic description of how surface active species interplay with external stress (i.e., assuming an interfacial tension that is constant over space and time).

Conclusions

The combination of numerical experiments (high temporal and spatial resolution) and high-speed visualizations provides a powerful approach for studying the mechanism of drop breakup in turbulent emulsification devices. The verification of the DNS results by the experiments paves the road to use the detailed information provided by the DNS to study breakup on modified designs impossible to study by the experimental framework (i.e., in the axisymmetrical geometry of a production scale HPH).