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Numerical Simulation of 3D Foam Dynamics

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Introduction

Due to their highly structured geometry (liquid films bounded by plateau borders and junctions, see figure 1) and mechanics at film level, liquid foams show rich rheological behavior and have wide practical applications. This is mainly due to the presence of a relatively large interfacial area and, correspondingly, thin liquid films. Most of the existing theoretical results, however, are limited to dynamics of 2D wet foams or 3D dry-film foams, see [1].

Objective

To develop a computational method for a 3D simulation of the dynamics of wet polydisperse foams.

Mathematical method

The mathematical model is based on the assumptions that inertia is negligible and interfaces are pure (no surfactant). The model consists of:

- Stokes equations in all liquid regions;
- continuity of the velocity across the interfaces;
- normal stress balance on the interfaces which take into account the capillary as well as disjoining pressure;
- the evolution is governed by the kinematic condition;
- simple shear flow is considered as an example of external flow, see figure 2.

Numerical method

The numerical method is based on a boundary integral formulation [2] and is extended with the following features (see also [3]):

- non-singular contour integration of the singular layer potentials which improves the accuracy;
- multiple step integration which improves the numerical stability and increases the performance;
- high order approximation of the interfaces which allows simulation of films with thickness of order $10^{-3}$;
- dynamic mesh-size optimization, see figure 3.

Results

Subjected to the shear flow, the foam-drop undergoes significant topological changes: The inner drops move inside the whole drop, see figure 4, which is related to topological transitions between films, plateau borders and junctions. Such complex dynamics of the foams determines their elastic-plastic behavior.

Conclusions

A boundary integral method is developed for the simulation of the dynamics of wet polydisperse foam. It can resolve interface-to-interface distances of a few orders of magnitude smaller than the drop size. An extension of the method to the case of insoluble surfactants will be a topic of future work.

References:


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