Numerical Investigation of the Deformation and Break-Up Mechanisms of Droplets in a High-Pressure Emulsification Orifice with a Coupled Volume-of-Fluid/Level-Set Method

Kathrin Kissling, kissling@imvt.uni-stuttgart.de **Steffen Schütz**, schuetz@imvt.uni-stuttgart.de **Manfred Piesche**	Institute of Mechanical Process Engineering, University of Stuttgart 70199 Stuttgart, Germany

Abstract

The aim of the current study is the investigation of deformation and break-up mechanisms of droplets in high pressure emulsification orifices.

To physically capture the effects at the interface a sharp representation is needed. This is achieved by implementing a coupled Level-Set and Volume-of-Fluid (CLSVOF) method, which was first published by Sussman [3] in OpenFOAM®. To track the phase distributions and the interface, an additional state variable α is introduced, which describes the volumetric phase fraction in a computational cell and the phase continuity equation

$$\frac{\partial \alpha}{\partial t} + \nabla \cdot (\mathbf{U}\alpha) = 0$$

is solved. In the Level-Set approach the interface is captured by introducing the Level-Set variable ϕ, which describes the distance from the interface and solving the transport equation:

$$\frac{\partial \phi}{\partial t} + \nabla \cdot (\mathbf{U}\phi) = 0$$

Both methods follow a mixture approach. Hence a phase averaged momentum equation

$$\rho \frac{d(\mathbf{U})}{dt} + \rho \mathbf{U} \nabla \mathbf{U} = -\nabla p + \mu \nabla^2 \mathbf{U} + \rho \mathbf{g} + \mathbf{F}$$

is solved to model the flow field. The advantage of the Volume-of-Fluid method lies in the conservation of mass while the Level-Set Method is a priori not mass conservative. On the other hand the Level-Set method gives a sharp interface, while the Volume-of-Fluid Methods tends to smear it. The idea now lies in coupling both methods to achieve a sharp interface while preserving mass conservation. An algorithm is presented which couples the Level-Set variable and the volumetric phase fraction by error minimations and geometrical calculations [2].

To adequately capture the jump conditions in density, viscosity and pressure at the interface the Ghost Fluid method [1] is implemented in OpenFOAM®.

The behaviour of the new interCLSVOFFoam solver is presented on testcases (Figure 1) and on real emulsification orifice geometries.

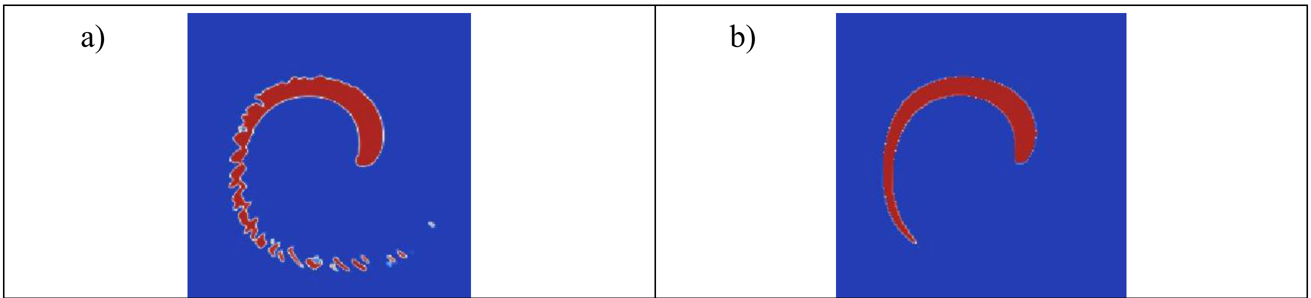

Figure 1: Performance of interFoam (a) and interCLSVOFFoam (b) on the circle in a vortex testcase

Key words: Coupled-Volume-of-Fluid-Level-Set Method, Ghost Fluid Method, High Pressure Emulsification

References

[1] **Fedkiw, R.P.; Aslam, T.; Merriman, B.; Osher, S.:** *A non-oscillatory Eulerian approach to interfaces in multimaterial flows (the ghost fluid method).* Journal of Computational Physics 152 (1999), 457-492.

[2] **Menard, T.; Tanguy, S.; Berlemont, A.:** *Coupling levelset/VOF/ ghost fluid methods: Validation and application to 3D simulation of the primary break-up of a liquid jet.* International Journal of Multiphase Flow 33 (2007), 510-524.

[3] **Sussman, M.; Puckett, E. G.:** *A coupled level set and volume-of-fluid method for computing 3D and axisymmetric incompressible two-phase flows.* Journal of Computational Physics 162 (2000), 301-337.