Multiphase flow simulations using the meshfree Smoothed Particle Hydrodynamics method

C. Hoefler*, S. Braun, R. Koch, H.-J. Bauer
Institute of Thermal Turbomachinery, Karlsruhe Institute of Technology, Germany
corina.hoefler@kit.edu

Abstract

In order to numerically model primary atomization a fully three-dimensional code based on the meshless Lagrangian Smoothed Particle Hydrodynamics method has been developed. The present paper focuses on the capability of our code to accurately capture multiphase flow phenomena.

Within the scope of this work a fully three-dimensional code based on the meshless Lagrangian Smoothed Particle Hydrodynamics (SPH) method [1][2] has been developed and validated for various test cases. The long-term objective is the development of a so called virtual atomizer test rig in order to avoid the cumbersome, time-consuming and costly iterative process of nozzle design and repeated manufacturing. This SPH approach was chosen to overcome the difficulties inherent to meshbased techniques such as the Volume of Fluid or Level Set method. Those methods suffer from complex and often inaccurate reconstruction of three-dimensional interfaces and mass loss, respectively. Inaccurate reconstruction of the interface causes deficiencies of the predicted interface curvature, which in turn results into erroneous surface tension forces and thus inaccurate modeling of the primary atomization process. In addition, gridbased methods require enormous computational resources to accurately capture the phenomena occurring during primary atomization.

As a promising alternative the Smoothed Particle Hydrodynamics method is based on the Lagrangian description of the governing equations at movable spatial discretization points. The flow quantities at a certain location in space are interpolated from the neighboring discretization points via a weighing function. Different phases can be modeled by assigning an appropriate marker function and the according fluid properties to the corresponding discretization points. A huge benefit is the inherent advection of the phase interfaces, as the discretization points or so called particles move with the velocity field of the fluid flow. Thus, there is no need for any interface tracking or capturing techniques. The SPH method has already been successfully validated for shear-driven single phase flows and a qualitative comparison between the modeling of free surface flows and experiments has been conducted [3]. Within the present paper we focus on the capability of the method concerning multiphase flow simulations with particular emphasis on surface tension.

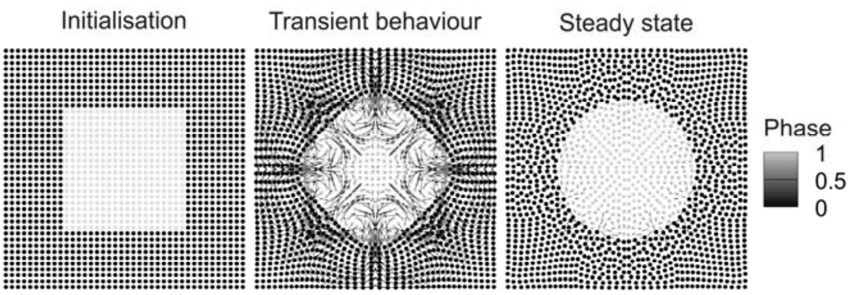

Fig.1: Droplet formation

As depicted in Fig. 1, the formation of a droplet from non-equilibrium state and its transient behaviour could be modeled successfully. The pressure jump across the curved interface of the droplet depending on the surface tension coefficient has been reproduced in excellent agreement with theory. Moreover, the promising first step towards the modeling of planar sheet disintegration at an airblast atomizer edge is presented. Test cases performed so far demonstrate the capabilities of the Smoothed Particle Hydrodynamics method for simulating multiphase flows and the initial stage of numerically predicting primary atomization.

* Corresponding author: corina.hoefler@kit.edu

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