

STUDY OF OPENFOAM VOF METHOD CAPABILITIES FOR NUMERICAL SIMULATION OF DROPLET IMPACT ON THICK LAYER AT LARGE FROUDE NUMBERS

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Modelling of droplet impact hydrodynamics is the key element in many industrial applications. It is necessary to simulate drop impacts when designing of ink-jet printers, combustion chambers (e.g., for internal combustion engines), microchips manufacturing, in different meteorological observations, *etc.* Therefore, the droplet impact modelling is a very important problem both from scientific and practical point of view.

There are number of problems for investigation in this area. The most ‘popular’ directions of research are the modelling of droplet impact on a deep pool [1, 2], on a thin liquid film [1, 3, 4] or on a liquid layer which depth is of the same order as the droplet diameter [5] and the modelling of droplet impact on the dry solid surface, which can be hydrophilic or hydrophobic [1, 3]. There are also some papers devoted to the thermal convection and external factors (e.g., magnetic field) influence on the liquid behaviour after the droplet impact [1]. The mentioned problems are well-investigated both experimentally and numerically.

In this present research the problem of droplet impact on the deep pool is considered. The drop and the pool consist of the same liquid. The depth of pool assumed to be extremely large compared with the diameter of initial droplet, so it is possible to consider the pool to be infinitely deep. We also consider that the space above the surface of the liquid in the pool is filled by gas. In the simplest case the liquid and the gas are considered to be incompressible, the surface of the liquid in the pool is quiescent, and there are no disturbances and external forces.

In this work the capability of Volume of Fluid (VOF) method implemented in OpenFOAM code have been investigated for modeling of different effects which can appear in fluid flow after the droplet impact: crown and Rayleigh column (high-speed jet) formation, the secondary drops tearing from the crown and from the top of the jet, bubbles entrapment and various small-scale effects. For numerical simulation the `interFoam` solver has been used. Different utilities for mesh refinement (`snappyHexMesh`, `refineMesh`, `makeAxialMesh`, *etc.*) can be used to decrease the mesh size and to accelerate computations.

Droplet impact can be modelled in OpenFOAM both for full 3D and axisymmetric cases. The difference between the results of simulation in these cases increases when some instabilities appear, for example, the instability of the crown border is the reason of waves and spikes appearance.

Number of validation cases have been considered. It was found that the correct simulation of macroscopic effects (formation of crater, high-speed jet, secondary drops which diameter is more than 10 % of initial drop diameter) requires the mesh, which cell size corresponds to 20 cpd or more (20 mesh cells per diameter of initial droplet). For high-quality simulation of small-scale effects with high resolution the mesh should be finer than 100 cpd, in some complicated cases — more than 1000 cpd.

The liquid behaviour after the droplet impact can be described by three dimensionless parameters: the Reynolds number, the Weber number and the Froude number. It is interesting to investigate the influence of the Weber number and the Reynolds number when the Froude number is large, i.e. when gravity forces are negligible. In this study the Weber number is in range 100 . . . 10 000, the Reynolds number is in range 400 . . . 3 000.

The series of droplet impacts on the deep pool was simulated by using OpenFOAM. The regime map dependency of the qualitative liquid behaviour after the droplet impact on the Weber and Reynolds numbers was obtained. The dependency of the appearance of these regimes on the gas-liquid densities ratio also has been investigated. It was found that if gas-liquid densities ratio decreases, the Weber number should be increased in order to obtain the regime which corresponds to the tearing of the secondary drops from the top of the jet.

Only a few researches are known, which are devoted to generalization of such regime maps. For example, the regime map for crown is presented in [4]. Also, in [2] there is the regime map for appearance of different kinds of high-speed jets when the Froude number is small.

To validate the results obtained by using OpenFOAM, the similar simulations have been carried out by using open-source code Gerris [6]. The regime maps computed by using OpenFOAM and Gerris are in good agreement.

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