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Free surface flows modelling based on lattice Boltzmann method

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Free surface flow is an important physical phenomenon involved in many manufacturing processes, e.g. material transport, machining, casting [2] etc. This work deals with the numerical simulation of free surface flows using the lattice Boltzmann method (LBM) [3–5], famous for its simplicity to algorithmize, fastness and its efficiency in parallel computing.

Basically free surface flows are two-phase flows. In this work the flow behaviour is dominated by the denser phase and therefore the air flow is neglected and represented by appropriate boundary conditions at the interface. To capture the free surface in the simulations, we adopt the algorithm based on the volume of fluid method (VOF) [6].

In the VOF method the interface is captured via the fill level of a cell, which qualifies the amount of a cell which is filled with fluid. Value 0 indicates an inactive gas cell and 1 corresponds to a filled cell inside the fluid. Fluid and gas cells are separated by a closed interface layer with a fill level between 0 and 1.

The aim of this work is to improve the accuracy of the algorithm by incorporating the surface tension and wetting angle effects [1]. The developed computational algorithm is tested on three benchmarks. In the first case, we solved the Poiseuille flow inside the channel formed by two infinite plates. The comparison with the analytical solution is shown in Fig. 1 (right).

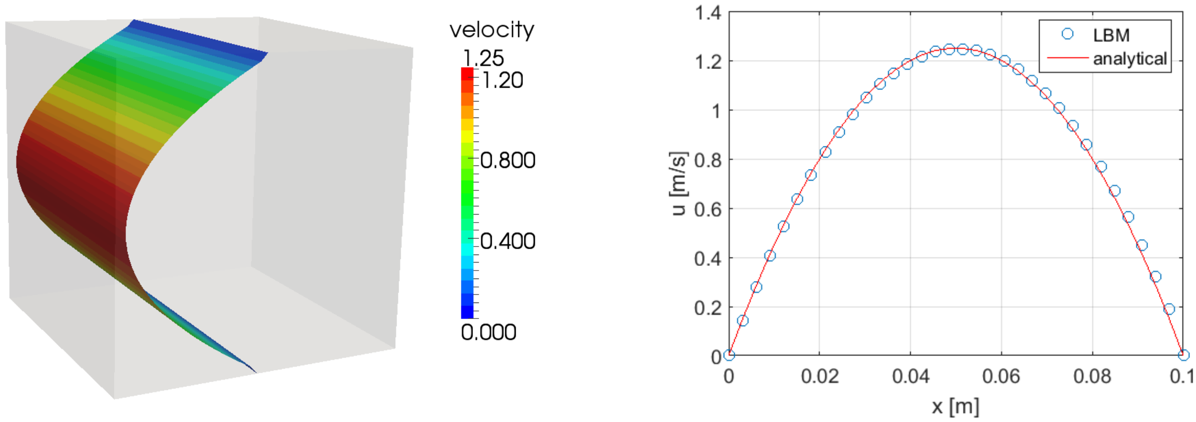

Fig. 1. Poiseuille flow between two infinite plates

The second case is focused on a validation of surface tension effect. We study the value of Laplace pressure, which is the pressure difference between the inside and the outside of a spherical water drop surface that forms the boundary between a gas and a liquid region. The error of the pressure inside the drop obtained by the numerical simulation on a relatively coarse mesh is 3.1 percent.

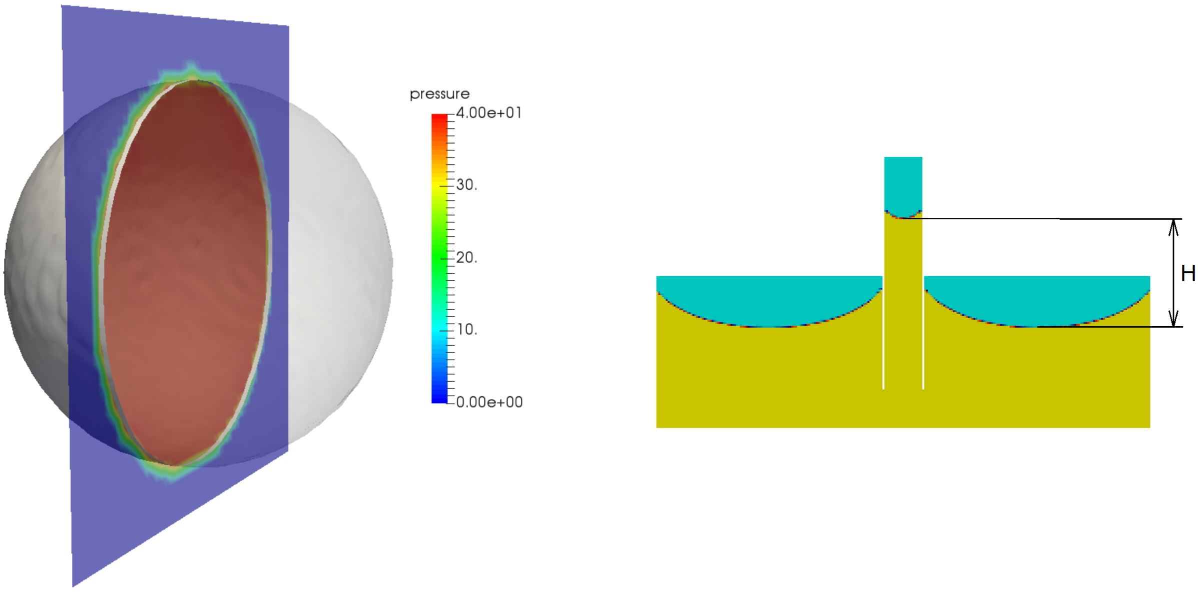

Fig. 2. Laplace pressure in a drop (*left*), capillary rise (*right*)

The third case deals with capillary action of a water between two infinite plates and serves for testing our implementation of wetting angle. The Fig. 2 (right) shows obtained increase of free surface H caused by the wetting angle and the surface tension. The error with respect to the analytical solution is below 5 percent.

The presented test cases are in a good agreement with the analytical data and show correctness of developed numerical algorithm for this kind of problems.

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