The XXXVIII International School of Hydraulics, 21-24 May 2019, Łąck, Poland

A free-surface immersed-boundary Lattice Boltzmann method for porous-media flows

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ABSTRACT

Inspired by the simple nature of the immersed-boundary (IB) lattice Boltzmann method (LBM) proposed by Noble and Torczynski (1998), we introduce a novel representative elementary volume scale IB-LBM to model porous media flows. The proposed model allows, with the free surface (FS) formulations of LBM by Körner et al. (2005), to be applied to free surface flows through unconfined porous media. The liquid fraction values, l_f, representing the presence of void in porous media are used as the model parameter which explicitly relates to the model permeability as $k = l_f \nu_L/(2-2l_f)$, where $k(\cong 1.618\, K_p/\Delta x^2)$ is the model permeability, $\nu_L$is the lattice fluid viscosity, K_p is the intrinsic permeability of medium and Δx is grid spacing in geometric discretization. This exact relation of the liquid fraction and permeability is examined by the analytical and numerical computations of flows through a U-tube with a porous zone (see Fig. 1). The model with the permeability relation obtained provides good agreement with the analytical results in Fig. 1 (right) convincing the extended applicability to porous media flows. The model retains the inherent advantages for parallelization and the smooth treatment of a moving boundary. The model can also be applied to the force estimation on porous objects and application can be found in coastal engineering and river engineering as well as other engineering fields involving porous and flexible media.

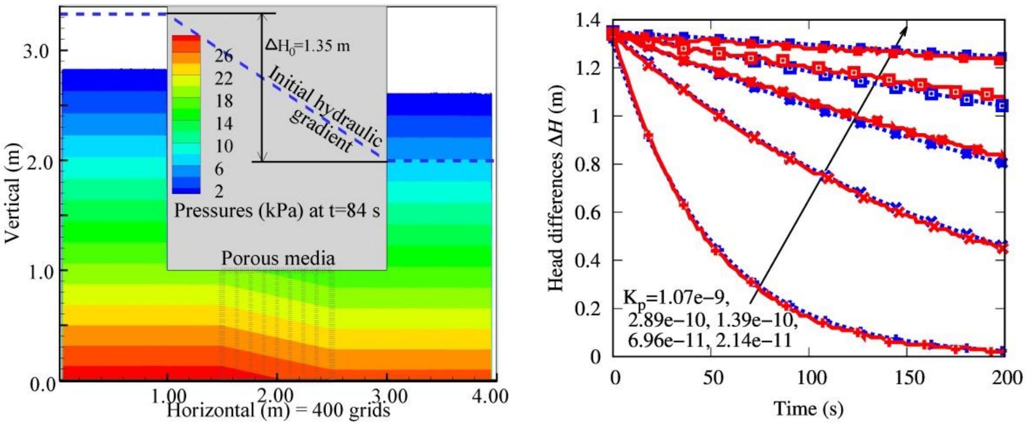

Fig. 1. Temporal hydrostatic pressure evaluation by the FS-IB-LBM at t = 84 s in case of $K_p = 1.07 \times 10^{-9}$ m^2 representing the U-tube porous media flow problem (left) and comparison between the analytically and numerically defined head differences in cases (right).