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Travelling waves above the canopy of aquatic vegetation

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When fluid moves over a saturated porous medium with high permeability and porosity, the flow partially involves the fluid in porous medium, however, because of the great resistance force there arises sharp drop of tangential velocity. This leads to the development of instability similar to the Kelvin-Helmholtz instability on discontinuity surface of the tangential velocities of homogeneous fluids. Analogy becomes even more complete if we take into account the deformability of porous medium under the influence of pressure changes. Intensive vortices above the canopy of aquatic vegetation can lead to the coherent oscillations of vegetation, such traveling waves are called monami [1]. In the present paper we investigate stability of steady flow over a saturated porous medium. The importance of this problem is related to the applications to the dynamics of pollutants in the bottom layer of vegetation: the accumulation at low flow and salvo emissions with increasing velocity.

We consider a two-layer system consisting of a layer of a viscous incompressible fluid and porous layer saturated with the same fluid located underneath. The lower boundary of the system is assumed to be rigid, the upper boundary - free and non-deformable. Weak slope of the river is taken into account. The problem is solved within the framework of single approach in which a two-layer system is described by a single system of equations for saturated porous medium and the presence of two layers is modeled by introducing variable permeability and porosity, depending on vertical coordinate. The flow in a saturated porous medium is described by the Brinkman model.

Solution of the problem for steady flow shows that the velocity profile has two inflection points, which leads to the instability. The neutral curves are obtained for different values of the ratio d of porous layer thickness to full thickness. It is found that the dependence of critical Reynolds number on d is non-monotonic and the wave number of most dangerous perturbations increases monotonically with d. The effect of the deformability of porous medium on linear stability conditions is also investigated.

Non-linear flow regimes are studied numerically by finite difference method. The calculations are performed for the rectangular domains whose length is taken to be equal to the wavelength of most dangerous perturbations according to linear stability theory. The calculations show that for low values of Reynolds number the stationary uni-directional flow is realized. Starting from a certain Reynolds number, the stationary oscillations are established with amplitude and frequency depending on the parameters. Analysis of the velocity fields corresponding to different phases of the oscillation period, shows that the observed waves travel in the direction of the basic flow.

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1. Ghisalberti, M., Nepf, H.M., 2002, Mixing layers and coherent structures in vegetated aquatic flows, J. of Geophysical Research. 107, C2.