EGU21-7978
https://doi.org/10.5194/egusphere-egu21-7978
EGU General Assembly 2021

Hydrodynamic instability of downslope flow with respect to two-dimensional perturbations

Julia Zayko and Margarita Eglit
Lomonosov Moscow State University, Faculty of Mechanics and Mathematics, Moscow, Russian Federation
(m.eglit@mail.ru)

Hydrodynamic instability of open flows down inclines is an important phenomenon which leads perturbation growth, turbulence, roll waves formation etc. It has been widely studied for flows of Newtonian rheology with respect to longitudinal perturbations (perturbations that spread along the flow velocity vector), for example, see works [1 - 4]. From mathematical point of view, the study of the stability of open flow down an inclined planes with respect to two- or three-dimensional perturbations (i.e., with respect to oblique perturbations, spreading under an arbitrary angle to the flow velocity vector) is quite difficult, especially, if the fluid has non-Newtonian rheological properties, which can be important in the context of geophysical applications. Nonetheless, works exist, where these two factors (non-Newtonian rheology of the moving medium and arbitrary angle of spreading of perturbations) are taken into account, e.g., [5,6]. In more recent work [5], the problem of downslope flow linear stability is solved in complete formulation (continuity and momentum equations are used with no averaging over the depth, stability with respect to 3D perturbations is studied); this significant work uses complex mathematics, and can be difficult for applications.

This abstract is based on the work [6], where linear stability analysis was first conducted for the downslope flow that is described by hydraulic equations, but 1) the rheology of the flow and flow regime (laminar or turbulent) were arbitrary, 2) oblique perturbations were taken into account. The stability criterion is obtained analytically, it contains basic flow characteristics and can be applied to the flow if it's depth-averaged velocity $\boldsymbol{u}$, depth h, relation between the bottom friction and h, u (u is the velocity modulus), slope angle are known. It is shown that the flow can be unstable (i.e., small perturbations grow, and this can lead, for example, to roll waves formation, or turbulisation of the flow) to oblique perturbations, even if standard stability criterion for longitudinal 1D perturbations is satisfied. This takes place, e.g., for dilatant fluids with power law index greater than 2).

The result is important not only for experimentalists, but for researchers who use numerical modeling, because knowledge of the flow behavior (for example, possible roll waves development) plays crucial role when choosing a computational scheme that will allow one to get the correct result.

[1] Benjamin T.B. Wave formation in laminar flow down an inclined plane. J. Fluid Mech. 1957. V. 2.

P. 554 – 574.

[2] Yih C-S. Stability of liquid flow down an inclined plane. Phys. Fluids. 1963. V. 6(3). P. 321 – 334.

[3] Trowbridge J.H. Instability of concentrated free surface flows. J. Geophys. Res. 1987. V. 92(C9). P. 9523 – 9530.

[4] Coussot P. Steady, laminar, flow of concentrated mud suspensions in open channel. J. Hydraul. Res. 1994. V. 32. P. 535 – 559.

[5] Mogilevskiy E. Stability of a non-Newtonian falling film due to three-dimensional disturbances. Phys. Fluids. 2020. V. 32. 073101.

[6] Zayko J., Eglit M. Stability of downslope flows to two-dimensional perturbations. Phys. Fluids. 2019. V. 31. No. 8. 086601.