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Implicit and explicit integration of the resistance force in non-Newtonian free surface flows

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SUMMARY

In the context of 2D models for free surface flows, depth-averaged rheological models relate the basal shear stress exerted by the bottom surface on the fluid layer to the depth-averaged local flow features. The resistance force play a key role on the mobility of non-Newtonian shallow flows but their numerical integration in 2D frameworks when dealing with large-scale long-term scenarios is still a challenging issue. In this work, two new approaches for the explicit integration of turbulent and visco-plastic resistance terms in 2D numerical models are proposed. These novel approaches, called integral and differential strategies respectively, ensure the integrated resistance force satisfies the rotation invariance property in any mesh topology, allowing upwind computation of the frictional momentum contribution. Benchmark tests are performed in orthogonal, triangle structured and triangle unstructured meshes. The obtained results have been compared with the classical strategy for the upwind computation of the resistance force [1]. Results demonstrate that the alignment of the flow with the mesh main-directions, which has been previously attributed to faults of the Finite Volume (FV) numerical methods and the insufficient mesh refinement, is directly related to the erroneous procedure for including the 2D resistance term into the local flux balance at the cell edges. Furthermore, a novel implicit centered method for the integration of the 2D resistance force has also been derived for the quadratic-type non-linear resistance formulation [2]. This method allows to compute implicitly the flow linear momentum using only current-state flow variables, improving the computational performance respect to the classical iterative models. Implicit and explicit formulations have been compared in terms of accuracy, robustness and computational efficiency. Despite the implicit procedure fails to converge to steady uniform flow states, the novel explicit upwind and the implicit centered methods show similar level of accuracy, robustness and computational efficiency for transient 2D frictional visco-plastic flows.

Keywords: Geophysical shallow flows, Resistance force integration, Rheological models, Rotational invariance

AMS Classification: 76-10, 76A05, 76M12

References

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