Improved one-dimensional numerical simulation of transient mixed flow in water pipes network.

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For environmental purpose, the necessity of treating efficiently waste water as well as storm water collected in urban drainage systems has increased in the last decades. As a consequence, administrations in most European countries are improving their sewer systems and pipe networks in terms of capacity and drained area. To design these hydraulic structures, practitioners should rely on an efficient and accurate one-dimensional numerical model, whose development remains challenging for two main reasons:

- Mixed flows, characterized by a simultaneous occurrence of free surface and pressurized flow, are frequently encountered in the case of the rapid filling/emptying of water pipe network and sewer systems. Now, pressurized flow and free-surface flow governing equations present an inherent dissimilarity which has to be mastered in order to create a unified framework of simulation.
- Furthermore, as a pump start-up in such pipes generates the propagation of transition bores, water hammers and even free surface surges, the model should be able to accurately simulate highly transient phenomena.

It is well known that the only difference between the Saint-Venant equations for open channel flow and the incompressible pressurized flows set of equations holds in the term of pressure gradient. Analytical developments, initially presented by Preismann (1961), show that this difference is overcame by adding a narrow slot at the top of the pressurized flows. By this way, pressurized flow can be equally calculated through the free-surface set of equation. In such shock-capturing model, the slot width reflects the pipe dilatation and the water compressibility under a pressure fluctuation and takes into account the steep change of the wave celerity across the transition bore.

Preismann's hypothesis gives a simple framework for mixed flow simulation (in association with shock-capturing method). However, its major shortcomings seem to be their inability to handle with sub-atmospheric pressure flow. To overcome this without losing the unified framework, the authors have successfully implemented an original negative Preismann slot.

In the one-dimensional set of equations describing free-surface flows, section geometry defines univocally the dependence of the flow section with the water height. In this paper, authors assess directly two different dependences to each geometrical section. The first one corresponds with the free-surface flow and the second one with the sub-atmospheric flow. The former relation is derived from the physical geometry of the section as the last one is obtained by adding a negative Preismann slot. In the simulation, the adequate relation is chosen based on the aeration rate of the considered section. On account of this, sub-atmospheric as well as free surface flows are simulated by a single numerical scheme.

Positive and Negative Preismann slots have been successfully implemented in the one-dimensional module of the software package WOLF (Generalisation of the original Wolf upwind scheme has been theoretically analysed). WOLF is a finite volume flow simulation software developed within the Laboratory of Applied Hydrodynamics and Hydraulic Constructions (HACH) of the University of Liege. Authors have validated the accuracy of their new methodology, especially the ability to simulate sub-atmospheric flows, on published benchmarks. In addition, the usefulness of the new model has been underlined through the design of a practical application.