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A Non-Oscillatory FEM–Conservative Level-Set Method Applied to the Simulation of Air Cavities in Ducts

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Intrusion of air cavities into filled ducts is a physical event which often occurs in sewer systems during a storm. Analytical solutions of this motion in horizontal ducts can be obtained for simplified configurations, including a weir situated at the end of the duct [1]. Nevertheless, full analytical solution for inclined ducts is not available, mainly due to gravity effects in the cavity formation and propagation (see e.g. [2]).

Numerical solutions are obtained by using one of the most successful interface-capturing methods, the conservative Level-Set (CLS). We propose a methodology consisting of a second order non-oscillatory finite element method (NFEM) [3] applied to the phase function transport step and of a reinitialization step formulated as a non-linear diffusion equation. Reinitialization is completed by the use of the NFEM sign-preserving correction to obtain the final solution. Moreover, in this work we propose a simplified local computation of interface normals with substantial savings on computational cost. Concerning hydrodynamics solution, we employ an improved NFEM for incompressible flows.

Air cavities propagation is a stringent problem, mainly due to zones where the interface is well-defined, combined with zones where the interface is a diffuse transition region between both phases. Moreover, there are regions where the interface is steady along with others where the interface is highly transient. Experiments illustrate the suitability of our model, both in terms of error norms and in terms of enclosed volume conservation error.

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