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FINITE ELEMENT HYDROPOWER RESERVOIR FLOW SIMULATOR

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ABSTRACT

Is the flooding of soils, consecutive to the creation of water reservoirs, a significant anthropic source of GHG emissions? Can hydroelectricity be considered a clean energy in a mid and long term perspective? The answers from the scientific and industrial communities to these and other important questions are not conclusive [1,2]. In order to participate to this discussion, we have been developing a numerical simulator for studying water physico-chemical properties during the flooding of hydroelectric plants reservoirs.

The simulation of the complex fluid flow and transport in hydropower plant reservoirs requires the solution of the Navier-Stokes equations coupled, through the physical properties of the fluid, to the transport equation of chemical species and the energy equation. The purpose of this study is to develop a numerical simulator, based on the Finite Element Method [3], for the three-dimensional simulation of the filling of hydropower plant reservoirs, in order to asses the environmental effects of the formation of the reservoirs and analyse possible strategies for remediation.

The domains are discretized employing Tetrahedral meshes, based on a two-dimensional Delaunay algorithm, to guarantee good properties in the element mesh. Spatial discretization of the diffusion and pressure terms is made through the Galerkin method whereas the material derivatives are treated through a semi-Lagrangian technique that presents natural stability. The time discretization is done through a first-order backward Euler implicit scheme. The large systems of coupled linear equations are solved through the discrete projection method based on the block LU decomposition [4], resulting in symmetric positive-definite system matrices. The method proved to be stable at all CFL and Reynolds conditions, not showing spurious oscillations or excessive numerical diffusion even under large Reynolds number conditions.

The simulator treats independently the different compartments of a reservoir. This approach allows a finer analysis of the water quality during the flooding. Nonetheless, the resulting linear systems are

huge, and iterative methods are mandatory. For certain boundary conditions, the matrices were symmetric and positive definite and we have used the preconditioned conjugate gradient (PCG) method [5]. In other situations the matrices were nonsymmetric and nonsingular then we applied the generalized minimum residual method (GMRES)[6] and the bi-conjugate gradient stabilized method (BI-CGSTAB)[7].We present the comparison of some well-known preconditioners and reorderings for both methods. We also present another preconditioner and discuss its performance. We address the simulator mathematical and numerical models, and some numerical experiments.

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