VALIDATION OF A THREE-DIMENSIONAL NUMERICAL MODEL FOR RIVER FLOW BASED ON POLYHEDRAL FINITE VOLUMES

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Today's numerical simulation models for river flow in three spatial dimensions usually employ computation grids consisting of hexahedra, tetrahedrons or wedges. Tritthart (2004) recently introduced a novel grid type based on arbitrarily shaped polyhedrons. This grid is derived by a Voronoi decomposition algorithm from a set of base points distributed in the horizontal plane (Fig. 1). Afterwards, the resulting grid regions are vertically sliced into a number of cells. During the simulation process, the base points act as storage locations for all flow properties.

A numerical model based on this grid type and solving the Reynolds-averaged Navier-Stokes equations by means of the Finite Volume Method was developed at Vienna University of Technology. It utilizes a Second Order Upwind technique for discretizing the convective term and the SIMPLE method for pressure-velocity coupling. Pressure values are interpolated by Rhie and Chow's (1983) technique, and turbulence is modeled with the standard $k-\varepsilon$ closure approach. The model was validated using experimental data from two steady-state test cases: air flow in a curved rectangular duct of Kim and Patel (1994) and water flow in a sharp 180° bend by Rozovskii (1961). For the second test case, two different cell shapes have been used to assess their respective performance: a grid based on quadrilateral regions and one constructed on hexagonal regions.

The resulting longitudinal velocity profiles indicate a reasonable agreement between computed and measured data for both test cases. The computed profiles yield a better match with the experimental data near the center of the flow domain than in wall regions. However, it was found that the model performance in near-wall regions was enhanced when a grid based on hexagonal regions was used. This behavior is credited to the fact that the actual flow directions in the vicinity of side walls of a bend are rarely parallel to the channel axis, giving rise to numerical diffusion in grids based on quadrilateral regions.

From the computed transversal velocity profiles it can be seen that the model underestimates the magnitude of the secondary motion, even though the profiles otherwise exhibit reasonable accordance with the measurements. This observation has also been made by Sotiropoulos and Patel (1995) who credit this effect to simplifications in the $k-\varepsilon$ turbulence closure.

An analysis of the computed water surface elevations for Rozovskii's experiment shows that the numerical model is capable of reproducing the measured superelevation pattern in the bend with small differences near start and end of the curve that were also observed in previous numerical studies of this experiment (Lien et al., 1999). The result obtained using the grid based on hexagonal regions exhibits water depths along the inner wall of 1mm below those computed using quadrilateral regions, while no significant differences were found along the outer bank.

After a final assessment the validity of the model was accepted based on the results presented in this study.

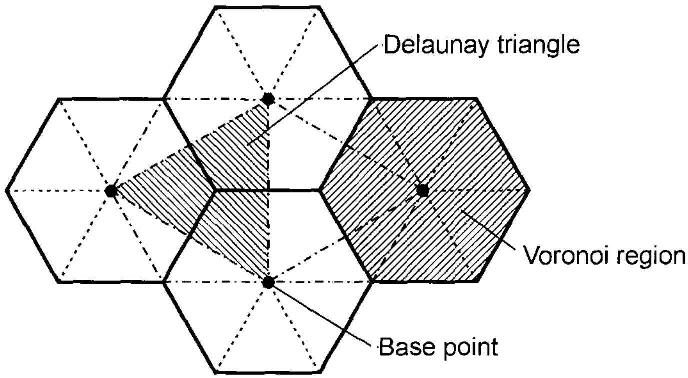

Fig. 1 Detail of a sample computation grid based on hexagonal Voronoi regions.

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