EFFICIENT DESIGN OPTIMIZATION AND INVESTIGATION BY COMBINING NUMERICAL AND PHYSICAL MODELS

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In areas like mechanical or aerospace engineering computational fluid dynamics (CFD) has almost completely replaced experimental investigations. Corresponding techniques have also become popular in hydraulic engineering. However the investigations are usually restricted to 1D or 2D computations. Three dimensional computations accounting for a pressure free water surface and for a complex turbulence model are computationally intensive and therefore still rare even though they are often required to achieve satisfactory results.

Experiments of the spilling structures of a large dam have been conducted in a 2.2 m wide and 1.85 m high flume made out of glass and steel profiles at the Institute of Hydraulic Engineering of the University of Innsbruck. The hydraulic model represented a detail from a larger spillway structure. One Ogee weir and two low-level outlets were reproduced and investigated. The experiments have been accompanied by numerical studies to compare the results and to explore the potential of hybrid models for future investigations. Because of the combination of low-level outlets and Ogee weir the flow in the vicinity of the spillway has a strong three-dimensional nature. Therefore a 3D flow simulation was required and the commercial software Flow-3D was chosen.

For a validation of the numerical model stage discharge curves and pressures were compared with experimental data. The comparison of the stage discharge curves with the experimental rating curves comprised four numerical runs using various discharges and gate opening conditions. For the first test case (c1) a maximum discharge with completely open gates both for Ogee weir and low-level outlets was used. In the second test case (c2) the discharge was reduced and the Ogee partially closed (gate opening α=21°). In test case three (c3) the Ogee was even further closed (gate opening α=18°) and thus spilling discharge was further reduced and for test case four (c4) the Ogee was completely closed and the low-level sluices partially closed (gate opening α=49°). The fit of the numerical results was almost perfect especially for fine mesh computations, see figure 1. Computed pressures were also compared with experimental data for one geometrical configuration of the low-level outlet nose at four different measuring positions and the results of this comparison are presented. This structure was well suited for a comparison due to the fact that quite high negative pressures were observed and the variation of pressures along the nose was considerable. Initially a geometrical configuration of the nose like illustrated in figure 2, termed type 1 low-level outlet nose, was experimentally investigated and numerically verified. One can see that the minimum pressure is quite well captured and also the characteristics of the distribution however in neighbouring pressure drillings the error is larger. Due to the high sub atmospheric pressure of type 1 low-level outlet nose an improvement was sought only by

means of numerical computations. Type 2 low-level outlet nose according to Knapp (1960) showed much better results over the entire length of the nose.

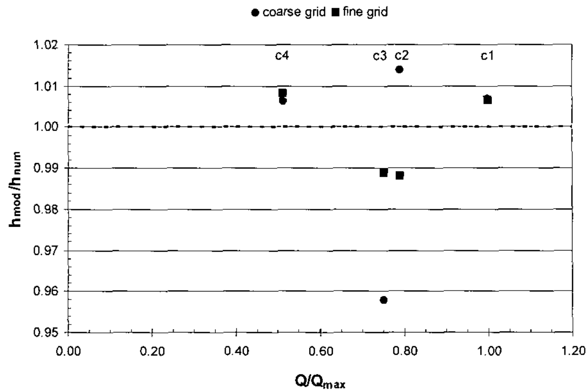

Fig. 1 Validation of flow rating curves for coarse and fine mesh.

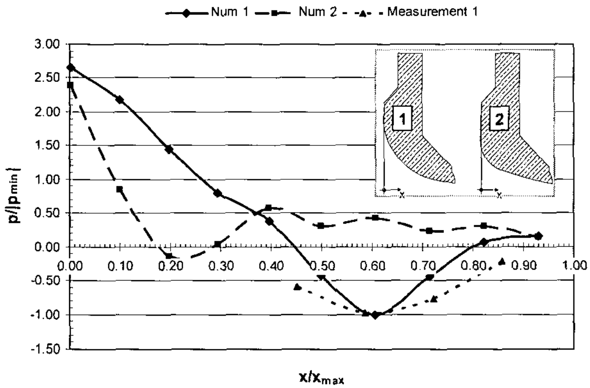

Fig. 2 Comparison of the pressure distributions along two different types of nose at the right low level outlet (Q_{max}), measured values (1), calculated values (1) and (2).

Numerical computations have the advantage that not only one single point can be verified but that at the same time very detailed information on the flow in the entire computational domain is available. Thus a hybrid approach combining numerical and physical models helps to save times and costs.

For future model testing we shall optimize critical designs numerically to start hydraulic model testing with an almost perfect geometry reducing the effort for modifications in the hydraulic model.

REFERENCES

Knapp, F.H. (1960). *Abfluss, Überfall und Durchfluss im Wasserbau*, G. Braun, Karlsruhe, Germany (in German).