Discussion of:

Modeling and Prototype Testing of Flows over Flip-Bucket Aerators

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Discussers:

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The Authors propose an interesting comparison between physical scale modeling, CFD modeling and field observations related to a unique spillway with flip buckets and built-in aerators. Despite the field observations are mainly qualitative, the Discussers would like to thank the Authors for sharing with the scientific community these results. Indeed, such analysis are very valuable but are too rare. Physical models and CFD are both modeling tools. They both suffer limitations and, consequently, their results need to be carefully and objectively discussed and validated. Comparison to quantitative prototype data is the only way to proof the validity of a modeling technique for real projects. However, such validation data remain sparse and rare, in particular considering large hydraulic structures.

In the following, the Discussers aim to raise one issue in the Authors' research and to highlight recent contributions and existing datasets, which are of direct relevance for the interpretation and discussion of the Authors' results.

Comparison of models and prototype results

Differences are reported by the Authors in terms of flow aeration, jets stability and jets trajectory between the physical model and both the CFD results and the field observations. The Authors explain these discrepancies mainly by the lower air entrainment in the jets on the physical model, because of too small (scaled) flow velocities. Consequently, the jets breakup is not reproduced on the model and the air pressure decrease in the cavities below the jets is large and affects both the jets trajectory and stability. On the contrary, the jet breakup observed on both the prototype and the CFD results enable air to enter the cavities. This implies a lower air pressure decrease.

The Discussers think that this explanation is not supported by the data provided by the Authors. For the CFD model, Fig. 18 and Fig. 19 show fluctuations of the relative pressure variation in the centroid of the side and middle aerator air cavities. In their comparison section, the Authors mention time-averaged values of 100 N/m² (case A) and 155 N/m² (case B) for the middle aerator cavity. The corresponding values for the air cavity of the side aerator are 180 N/m² and 245 N/m², respectively.

Fig. 6 shows the same parameter measured during the 1:40 physical model tests. A value around 60 and 75 N/m² is provided for the middle aerator cavity for Q/Q_0=0.89 (case A) and Q/Q_0=1 (case B), respectively. Corresponding values in the side aerator cavity have to be extrapolated from the graph but are roughly equal to 150 and 200 N/m².

Pressure variations measured on the physical model are then lower than the ones computed with the CFD model, contrary to the explanation of the Authors.

The Discussers think that the smaller air pressure variations in the scale model cavities are logical as air entrainment is lower in the physical model.

Consequently, the cause of discrepancies in terms of jets trajectory and stability is more complex. The low velocity jets on the physical model are probably more sensitive to pressure variations than the higher velocity ones on a prototype. This might be related to the Weber number *W*, i.e. the ratio between inertia and surface tension, whose values are 40 times smaller on the 1:40 physical model than on the prototype in case of Froude similitude.

To further explain this effect, the Discussers encourage the Authors to apply CFD to model the physical model. Comparison of results from both modeling approaches would be a good way, first, to quantitatively validate the CFD model and, second, to assess physical model limitations and measurement uncertainties. Indeed, it is easy, in process-oriented numerical models, to carry out sensitivity analysis on parameters such as surface tension or roughness (Camnasio *et al*., 2013). Comparison of CFD results gained on the same structure geometry considered at different scales is another way to look at possible scale effects affecting physical models.

Similarity to flow over Piano Key Weirs

The Authors do a parallel between the Gallejaur spillway flow and the flow over a Piano Key weir because both cases exhibit "air cavities with potential depressive air pressure". They mention that, on Piano Key weirs, "jet oscillations due to air pressure depression were truly observed in many scale model tests". Finally, they say "no measurements of air entrainment on aeration devices have ever been made in the existing prototypes". The Discussers would like to highlight recent contributions and existing datasets, which contradict or complement these statements.

Jet oscillations occur on a large range of hydraulic structures, from flap and crest gates to fixed thin weirs, linear or not (Piano Key and Labyrinth weirs). Low head operation of flap and crest gates has been well known for decades to be prone to produce jet (or nappe) oscillations critical for the gate integrity (Naudascher and Rockwell, 1994). Occurrence of these oscillations is classically avoided by jet division and thus air cavity aeration using splitters added to the gate crest (Naudascher and Rockwell, 1994; Lodomez *et al*. 2019a). It is also known that this phenomenon is not properly scaled on physical models, which are usually less prone to experience jet oscillations (Lodomez *et al*. 2019b).

Piano Key weirs, and also Labyrinth weirs, operate under lower heads than conventional linear weirs. Their limited crest length makes them similar to crest gates. That's why the risk of jet oscillation occurrence has been considered seriously during the design of the first Piano Key weirs, despite physical model tests showed stable jets and natural aeration of the air cavities (Laugier et al., 2017) thanks to the specific geometry of the structures and early jet breakup (Fig. 1). As a consequence, and because crest splitters are not recommended on fixed weir crest to avoid debris collection, aeration systems have been added to most Piano Key weirs built to date in order to supply air between the most downstream face of the structure (inlet overhang invert) and the jet (Fig. 2).

Air velocity measurements on the Malarce Piano Key weir prototype (Vermeulen et al., 2017) show a limited but non negligible air demand, decreasing with the discharge over the weir (Fig. 3) and confirm the early jet breakup observed on prototypes (Fig. 4).

All the data gathered to date on Piano Key weirs physical models and prototypes open the door to air-water CFD models validation, which is strongly encouraged by the Discussers.

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