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Table 1. Experimental parameters in Xiangjiaba Hydropower Station.

Test	s (m)	q (m^2 s^{-1})	V_1 (m s^{-1})	F$_1$	d_1 (m)	s/d_1	d_2 (m)	V_b (ms^{-1})
T-1	8.0	321.7	40.7	4.63	7.9	1.01	38.0	12.20
T-2	9.0					1.14	38.0	11.48
T-3	10.0					1.27	38.0	10.63
T-4	16.0	269.8	38.5	4.65	7.0	2.29	40.5	6.86
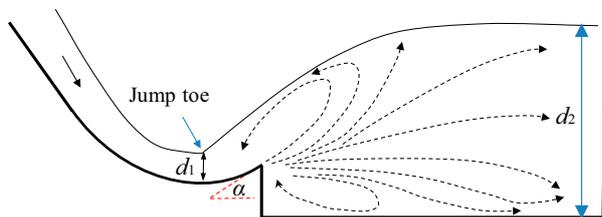
Figure 2. Sketch of hydraulic jump in stilling basin with an upward angle at the entrance.

jet will be raised compared to that downstream of a flat step. The upward approach angle also enhances the expansion of the turbulent shear layer in the vertical direction, resulting in reducing velocity near the stilling basin bed. Besides the required depth of the bottom drop, the length of the stilling basin will be also shortened, thus lowering the investment costs. For the sloping upstream spillway in Figure 2, the hydraulic jump toe will be located on the slope or the curved section upstream of the bottom drop. In order to generate a steady B-type hydraulic jump, it is necessary to specify the negative-step slope angle α and the drop height s with different downstream water levels d_2. For larger upward angles and smaller downstream water levels, the flow will become a ski jump jet. The favourable inflow conditions and the air–water flow properties including free-surface breaking and undulations will be investigated for this new bottom drop configuration in future studies.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notation

d_1	approach flow depth (m)
d_2	downstream conjugate depth (m)
F$_1$	inflow Froude number (-)
g	gravity acceleration (m s^{-2})
s	abrupt drop height (m)
q	flow rate (m^2 s^{-1})
V_1	mean approach velocity (m s^{-1})
V_b	bottom velocity (m s^{-1})
$V_{b\max}$	maximum bottom velocity (m s^{-1})
α	jump front slope (°)

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References

Chen, J. G., Zhang, J. M., Xu, W. L., & Li, S. (2013). Particle image velocimetry measurements of vortex structures in stilling basin of multi-horizontal submerged jets. *Journal of Hydrodynamics*, 25(4), 556–563. doi:10.1016/S1001-6058(11)60396-0

Chen, J. G., Zhang, J. M., Xu, W. L., & Peng, Y. (2014). Characteristics of the velocity distribution in a hydraulic jump stilling basin with five parallel offset jets in a twin-layer configuration. *Journal of Hydraulic Engineering*, 140(2), 208–217. doi:10.1061/(ASCE)HY.1943-7900.0000817

Chen, J. G., Zhang, J. M., Xu, W. L., & Wang, Y. R. (2010). Scale effects of air-water flows in stilling basin of multi-horizontal submerged jets. *Journal of Hydrodynamics*, 22(6), 788–795. doi:10.1016/S1001-6058(09)60117-7

Zhang, J. M., Chen, J. G., Xu, W. L., and Peng, Y. (2013). Characteristics of vortex structure in multi-horizontal submerged jets stilling basin. *Proc ICE-Water Manage*, 1.

Closure to 'Air entrainment and free-surface fluctuations in A-type hydraulic jumps with an abrupt drop'

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The Authors thank the Discussers for their interest in the abrupt drop hydraulic jump study. The Discussers provided constructive comments on two aspects of this study, namely, the characterization of the bottom roller dynamics, and a design modification for the bottom-drop or negative-stepped stilling basin to improve bottom velocity reduction and hydraulic jump stabilization.

The Authors appreciate the supportive discussion and the new configuration presented by the Discussers. The Discussers pointed out that the slope of the upstream step surface is set at an upward angle at the entrance to the stilling basin. The inflow jet is then deflected upward, leading to increased elevations of maximum flow velocity compared to the bottom drop

or negative-stepped stilling basin design. According to the velocity distributions in the lower turbulent shear region of hydraulic jumps, the new configuration may improve the bottom velocity reduction, which is a key consideration while assessing the risk of structural damage to stilling basin bed.

In our study of hydraulic jumps with an abrupt drop, observations show that a deeper stilling basin is needed to reduce the bottom velocity, costing enormous investment. The new configuration proposed by the Discussers may reduce the bottom velocity with a lesser length and depth of the stilling pool. Nevertheless, there are several points to note:

(1) In order to form a stable submerged hydraulic jump under a wide range of discharges, a suitable upward angle must be selected. A too large upward angle hinders the formation of hydraulic jump, while a too small upward angle fails to reduce the critical flow velocity.

(2) Due to the upward angle of the flow, the maximum flow depth at the upwelling point increases and may not be directly linked to the tailwater depth. It is necessary to accurately calculate the maximum depth for all possible flow conditions, to avoid overtopping the training walls of the stilling pools.

(3) Downstream conjugate depth should be accurately calculated for hydraulic jumps with an upward angle. If the downstream water depth is less than the conjugate depth, flow separation will occur. In practical engineering operations, a B-jump type on a slope is more common and stable (Bai et al., 2021; Hager, 1988). Attention should be given to the conditions for formation of B-jumps with different upward angles.

(4) By considering the synergistic effects of upward angle and drop height at the entrance to the stilling pool, this approach does not only effectively reduce the critical flow velocity at the bottom of the stilling pool, but also shortens its length, thus contributing to an enhanced investment efficiency, especially for high dams in mountain-valley areas.

Hence, the optimization design necessitates a comprehensive consideration of various factors, including different downstream water levels, upward angles, and drop heights, to achieve optimal energy dissipation of B-type hydraulic jumps. The authors are interested in the optimization suggestions put forth by the Discussers and emphasize the need for further research on this topic.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Bai, Z., Bai, R., Tang, R., Wang, H., & Liu, S. (2021). Case study of prototype hydraulic jump on slope: Air entrainment and free-surface measurement. *Journal of Hydraulic Engineering*, *147*(9), 05021007. https://doi.org/10.1061/(ASCE)HY.1943-7900.0001916

Hager, W. H. (1988). B-jump in sloping channel. *Journal of Hydraulic Research*, *26*(5), 539–558. https://doi.org/10.1080/00221688809499192

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