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A new design of ski-jump-step spillway*

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Abstract: A new kind of ski-jump-step spillway was reported. By means of the effects of the aeration basin, it supplies the sufficient aeration flow from the first step for stepped chutes, especially for large unit discharge. The physical model experiments demonstrated that, this spillway makes a far better hydraulic performance as regards energy dissipation and cavitation damage protection than the current and conventional stepped spillways, and the unit discharge can be enlarged from about 50 m^3/s-60 $m^3/s·m$ to 118 $m^3/s·m$ in order to significantly reduce the width of the spillways.

Key words: cavitation, energy dissipation, pre-aeration, ski-jump-step spillway

Over the last 30 years, several dozens of hydropower projects, characterized by high water head, large discharge and narrow valley, have been constructed within China. Stepped spillways, thanks to their simple structure and high energy dissipation, are widely used in the designs of the release works for high dams. However, there are the limits of unit discharge about 50 $m^3/s·m$-60 $m^3/s·m$ for those stepped spillways. Both low energy dissipation and cavitation damage risk, due to insufficient air entrained into the flow in several foregoing steps of the spillways, may be brought about if the discharge exceeds the limit. So, many investigations on the enlargement of the unit discharge of the stepped spillways have paid much attention to in order to reduce the width of the spillways, especially in arrangement of those release works in narrow valley.

Pfister et al.[1] and Wu et al.[2] proposed the bottom aeration method using an aerator device at the first step. But, non-aeration zones still appear in two sidewalls. Furthermore, Pfister et al.[3] and Zamora et al.[4] presented another aeration method through placing a deflector at the vertical wall of the first step. However, in common with the method of the bottom aerator device, there are also non-aeration zones in two sidewalls in the deflector method.

Here, we will report a kind of ski-jump-step spillway, developed in the present work (Fig.1), which can produce a sufficient aeration flow from the first step of the stepped chutes (i.e., no non-aeration zones) so that it could achieve high energy dissipation and low cavitation damage risk, especially under the operation conditions of large unit discharge.

Figure 1 shows the definition sketch of ski-jump-step spillway geometry, including five parts as an entrance section, a ski-jump, a pre-step section, an aeration basin, and a stepped chute. When the discharge is small, the flow passes through every part in turn, and it is the nappe flow regime that appears in each step of either the pre-step section or the stepped chute. In this flow regime, the flow energy is mainly dissipated by jet break in the air, jet impact and mixing on the step, and formation of full or partial hydraulic jump. Meanwhile, cavitation and atomization phenomena are virtually weak because of the low flow velocity.

With the continuously increasing discharge, the ski-jump and the aeration basin begin to play the role of pre-aeration. A large amount of air is entrained through ski-jump jet splashing in the air, and flow impact, diffusion and recirculation in the aeration basin. The sufficient aeration flow is formed by means of the pre-aeration effects of the aeration basin and is supplied to the stepped chute.

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Biography: Jian-hua WU (1958-), Male, Ph. D., Professor

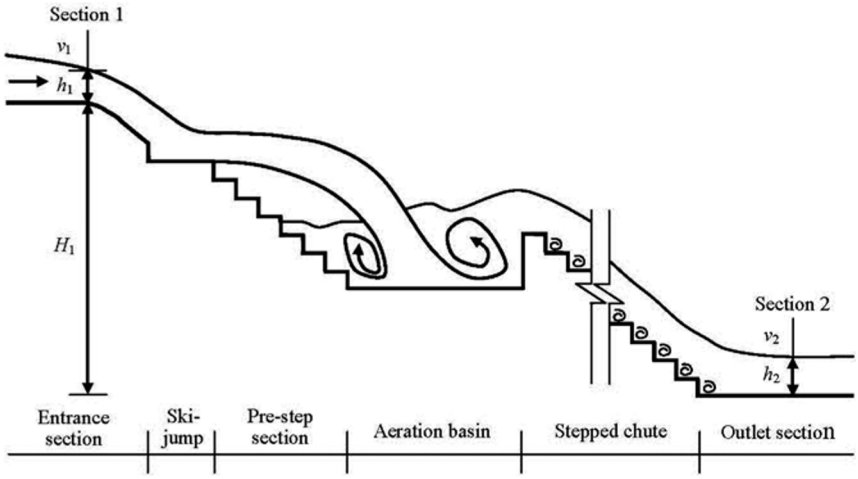

Fig.1 Definition sketch of ski-jump-step spillway geometry and flow regime at large discharge

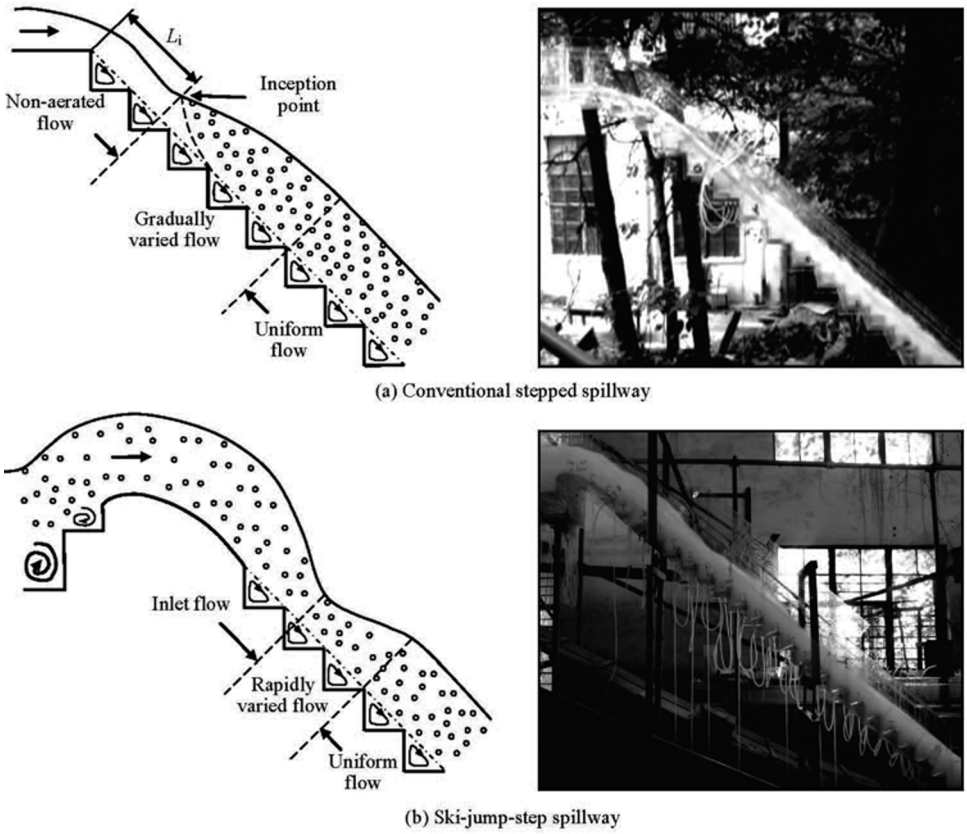

Fig.2 Description and photos of skimming flow

In order to verify the advantages of the ski-jump-step spillway presented in this work, the experiments were conducted in the High-speed Flow Laboratory of Hohai University in Nanjing, China. The physical model was designed according to the gravity similarity criterion at a scale of 1:40 in order to obtain the unit discharge in prototype[5].

For the test physical model, the entrance section, with the horizontal length and vertical height of 0.33 m and 0.21 m, consisted of three parts as WES, tangent and drop. At the pre-step section and the stepped chute, each step was of the length $a = 0.11$ m and of the height $b = 0.09$ m. The ski-jump was 0.33 m in length and connected to the aeration basin by the pre-step section with 6 steps. The aeration basin was 0.88 m in length and 0.27 m in height, and the stepped chute downstream contained 16 steps.

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