AIR ENTRAINMENT AND VELOCITY REDISTRIBUTION IN A BOTTOM OUTLET JET FLOW

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In large dams, bottom outlets are commonly used for reservoir drawdown, sediment flushing, river diversion and environmental flow releases. A typical example is a bottom outlet when a high-velocity supercritical flow discharges past an abrupt drop (Fig. 1). Such high-velocity free-surface flows are extremely turbulent flows, and interfacial aeration is commonly observed. In Fig. 1, the flow Reynolds number is about 8 E+8. Little research has been conducted systematically in the air-water flow properties of the high-velocity waters discharging at the downstream end of the tunnel. This paper aims to provide some new understanding of the air-water flow properties in high-velocity water jets discharging past an abrupt drop. New experimental investigations were conducted systematically in the free-jet. The data are compared with analytical solutions of the air bubble diffusion equation and with a wake flow model. The results provide new insights into the interactions between the high-velocity water jet and the surrounding air.

Downstream of the abrupt drop, the free-jet entrained air at both upper and lower air-water interfaces, as well as along the sides. An air-water shear layer developed at the lower nappe interface. Measured air-concentration distributions within the shear layer showed good agreement with an analytical solution of the basic diffusion equation for air-bubbles, based on the continuity equation for air The turbulent boundary layer upstream of the step brink was partially developed. Downstream of the brink, friction forces from the step invert were no longer present and the velocity field at the lower nappe was subjected to a strong redistribution. Experimental results showed a negligible loss of momentum from the free-falling jet to the surrounding air. The velocity redistribution within the jet was successfully modelled by integrating numerically the Navier-Stokes and continuity equations. Beyond a certain distance from the step brink, the velocity field was found to be similar to that in two-dimensional wake flow.

The results highlighted two distinct flow regions. Close to the brink ($We_X < 5000$), the flow was dominated by momentum transfer as the result of the step brink singularity. Further downstream ($We_X > 5000$), the results implied a strong competition between air bubble diffusion and momentum exchanges.

Keywords: Bottom outlet; Interfacial aeration; Velocity redistribution; Wake flow; Water jets

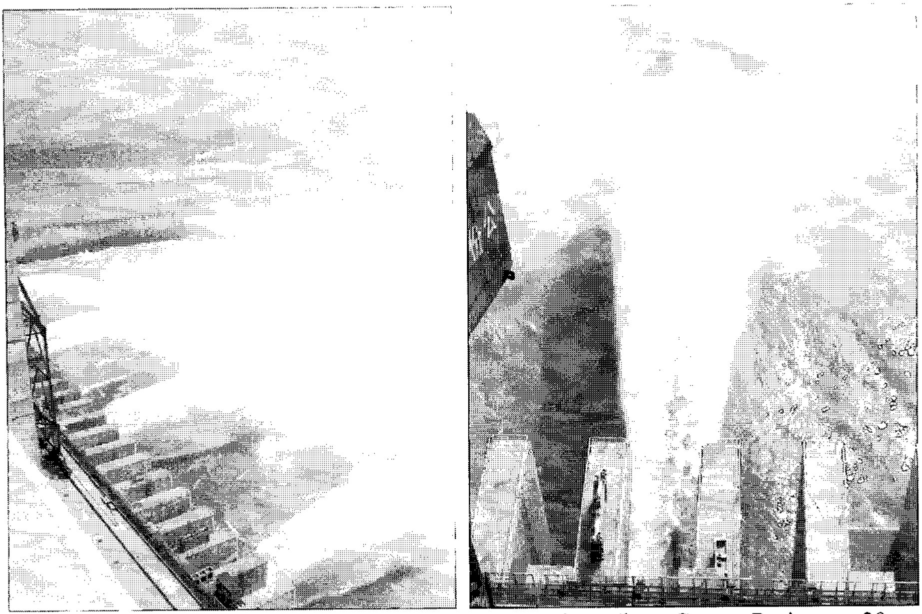

Fig. 1 Photographs of air-water flow at bottom outlet - Three Gorges Project on 20 October 2004, V_o = 35 m/s, Q = 1700 m^3/s per outlet, W_o = 9 m (per outlet)