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An Experimental Investigation of Reaeration and Energy Dissipation in Hydraulic Jump

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ABSTRACT

Hydraulic jump constitutes at the transition from supercritical regime to subcritical regime and characterized by highly turbulent flow, macro-scale vortices, kinetic energy dissipation and bubbly two-phase flow due to air entrainment. In the literature, there are lots of studies concerned with the hydraulic jump flow patterns. However, hydraulic jumps self-aeration aspect took less attention. The term self-aeration means transfer of oxygen from air into water and it has important environmental and ecological implications for polluted streams. Hydrodynamic processes which ensure the self-aeration mechanism such as: (i) hydraulic jump, (ii) plunging jet or water fall, and (iii) stepped channels have other common property: they are also used as energy dissipaters at hydraulic structures. These hydraulic processes generate sufficiently large disturbances on water surface which lead to suction of air and then the entrapped air volume is broken into air bubbles by the turbulence structure of the flow. By this self-aeration, air is mechanically mixed with the water, what leads to an increase of Dissolved Oxygen (DO) concentration in the water up to a saturation limit. It could be suggested that the macro-scale eddies which are responsible for the mixing and energy dissipation; also could be responsible for the suction of air into water and oxygen transfer too.

The experiments were carried out in a horizontal rectangular flume 0.50 m wide, 0.45 m deep and 13.15 m long with glass sidewalls and a concrete bottom. The hydraulic jumps were generated with the aid of sluice and tail gates. DO measurements were conducted simultaneously upstream and downstream of the hydraulic jump with a manual oxygen meters. The air calibration technique was used in the experiments with Cs values measured in the air. The turbulence quantities were collected by a Nortek 10 MHz type Acoustic Doppler Velocimeter (ADV) at 25 Hz during a sampling time of two minutes. In this study, it is expected to find a positive correlation between the aeration efficiency and energy dissipation. For this purpose, aeration efficiency E_{20} values were plotted against head loss ΔH, which is thought to be indicator for turbulence level , including the oxygen transfer data at the V-notch weir of the experimental set-up. Figure 1 depicts the E_{20} dependence on ΔH but data were scattered around a linear line suggesting another parameter influence on the process. This parameter thought to be unit discharge.

Moreover, In Fig. 2, vertical Reynolds shear stress variation through the hydraulic jump is shown. Figure 2 shows the intensive vertical mixing and momentum transfer near the free-surface of the hydraulic jump. The experimental data revealed that turbulent kinetic energy and Reynolds shear stress took their maximum values at the toe of the jump and exhibited a longitudinal decay. We related macro-scale turbulent length scale with upstream flow depth. The average energy dissipation rate has been correlated with the 1.5 power of the maximum turbulent kinetic energy in a dimensionally homogeneous form.

It is shown that functional relationship between rearation and energy dissipation rate exists both for unifom and nonuniform flow conditions. At site conditions, measuring energy dissipation is much easier than measuring turbulence quantities. The functional dependence between the reaeration and energy dissipation rate can provide engineers to estimate gas transfer coefficients in the field. The authors believe that the present results bring a fresh perspective towards better understanding of hydraulic jump reaeration process. The overall contribution of this study thought to be that we showed the macro turbulence main role in self-aeration and energy dissipation mechanisms. Consequently, experimental findings suggest that hydraulic jump can be used as a self-aerator device in waste water treatment plants to enhance the DO levels of an effluent.

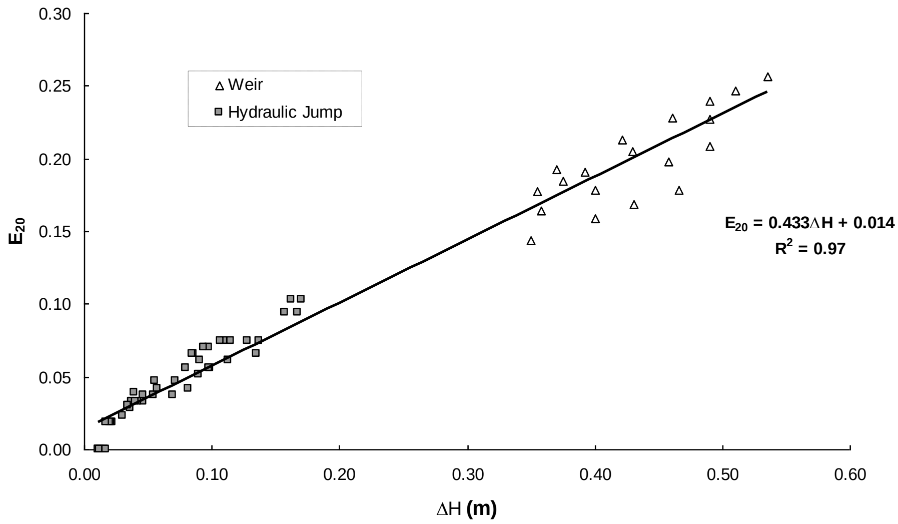

Fig. 1. Variation of aeration efficiency as a function of head loss at a hydraulic jump and weir

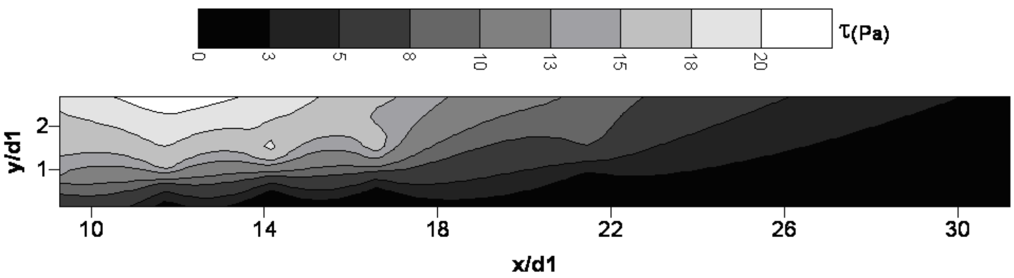

Fig. 2. Reynolds shear stress contour in a hydraulic jum for Fr_1=3.35; *Re*=86,100