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What Waterfalls and Kitchen Sinks have in Common:

A Comparison between Vertical and Horizontal Supported Jets

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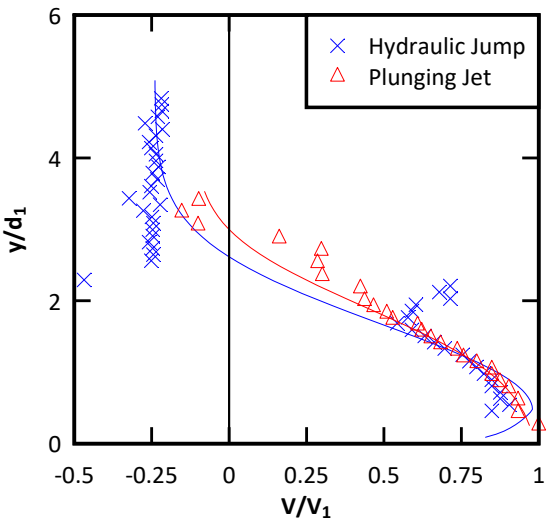
Introduction

Both plunging jets and hydraulic jumps are examples of singular air entrainment. They occur in vast forms, such as water falls and kitchen sinks (figure to the right). Key physical similarities and differences between horizontal (hydraulic jump, HJ) and vertical supported jets (plunging jet, PJ) were analysed based upon air-water flow experiments, carried out under identical inflow conditions in terms of inflow depth and inflow velocity.

Methodology

Detailed air-water flow measurements were carried out with intrusive double-tip phase detection probes. Experiments were carried out at relatively large-scale facilities at Froude numbers between 6.5 and 13.5 and Reynolds numbers of ~10^4.



Velocity profiles in plunging jet and hydraulic jump at a distance of 0.062m from impingement for V_1 = 4.50 m/s – comparison with analytical solutions

Air entrainment at (a) a waterfall, (b) a vertical supported jet, (c) a horizontal hydraulic jump and (d) a circular hydraulic jump in a kitchen sink. (Experimental flow conditions: V_1 = 4.50 m/s, Fr_1 = 13.5, Re_1 = 5.14E+04)

Key results

Similarities were found in terms of local air entrainment at the impingement point and void fraction distributions in the turbulent shear layer, the latter following a Gaussian profile with a pseudo-exponential decay in maximum air content.
Key differences between the two flow situations could be summarized as follows:

- Remarkably larger maximum amplitudes of the impingement perimeter fluctuations in the HJ
- Velocity profile (figure above): Marked boundary layer and important negative velocities in the recirculation region of the HJ, following closely a wall jet solution. Velocity profiles in the PJ corresponded to a free shear layer.
- Difference in buoyancy force direction
- Substantial interfacial aeration and de-aeration in the upper flow region in the HJ
- Interplay between momentum transfer and air-bubble diffusion in the HJ, momentum transfer always dominant over air-bubble diffusion in the PJ

Conclusion

The findings of the present study provided new knowledge about similarities between hydraulic jumps and plunging jets. However, substantial differences brought up fundamental questions about the applicability of an in-depth analogy between hydraulic jump and plunging jet.