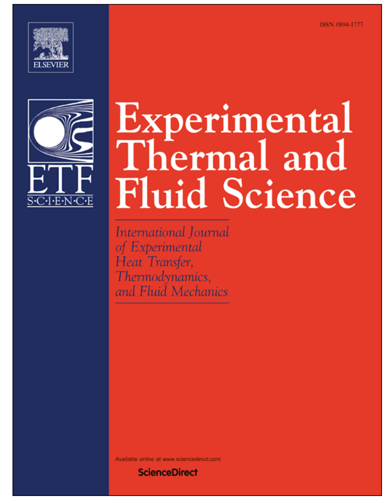
Accepted Manuscript



Characterisation of transverse turbulent motion in quasi-two-dimensional aerated flow: application of four-point air-water flow measurements in hydraulic jump

Hang Wang, Hubert Chanson

PII: S0894-1777(18)31500-0
DOI: https://doi.org/10.1016/j.expthermflusci.2018.09.004
Reference: ETF 9600

To appear in: *Experimental Thermal and Fluid Science*

Received Date: 29 December 2017
Revised Date: 22 July 2018
Accepted Date: 9 September 2018

Please cite this article as: H. Wang, H. Chanson, Characterisation of transverse turbulent motion in quasi-two-dimensional aerated flow: application of four-point air-water flow measurements in hydraulic jump, *Experimental Thermal and Fluid Science* (2018), doi: https://doi.org/10.1016/j.expthermflusci.2018.09.004

Characterisation of transverse turbulent motion in quasi-two-dimensional aerated flow: application of four-point air-water flow measurements in hydraulic jump

Hang Wang[(1)(*)] and Hubert Chanson[(1)]
[(1)] The University of Queensland, School of Civil Engineering, Brisbane QLD 4072, Australia
[(*)] Corresponding author: hang.wang@uqconnect.edu.au

Abstract
The measurement of turbulent velocity in highly aerated flow is difficult because of the presence of air bubbles. The characterisation of three-dimensional velocity field in highly aerated flows is even more challenging using existing phase-detection techniques. This paper presents an attempt on a quantification of transverse velocity and velocity fluctuations in quasi-two-dimensional hydraulic jumps with relatively high Froude and Reynolds numbers. A four-sensor phase-detection probe array was developed to measure the bubble convection in both streamwise and spanwise directions. A characteristic instantaneous transverse velocity component was derived together with a measure of its fluctuations. The transverse velocity component characterised the three-dimensional turbulent structures, although the time-averaged flow pattern was two-dimensional and the average transverse velocity was zero. Both the transverse velocity and velocity fluctuations were smaller than the longitudinal time-averaged velocity and velocity fluctuations in the shear flow, and were quantitatively comparable to those in the free-surface region, revealing different turbulent structures in the lower and upper roller regions. The approximate of Reynolds stresses was discussed together with the limitation of the method. The present work also provided some guidelines for the use of phase-detection probe array and correlation signal processing techniques in complex turbulent two-phase flows.

Keywords: hydraulic jump; three-dimensional flow; phase-detection probe array; transverse velocity; turbulence intensity.

1 Introduction

A rapidly-varied open channel flow in a prismatic flume is commonly treated as a two-dimensional flow, although three-dimensional flow patterns are often observed associated with the development of large-scale turbulent structures and secondary flow at the rapid flow transition (Henderson 1966, Novak et al. 2010). A canonical case is a hydraulic jump. Figures 1A and 1B show respectively a hydraulic jump in a natural stream and an artificial jump in a horizontal rectangular channel. While the former exhibits a three-dimensional flow pattern with a curved impingement perimeter, the latter is considered to have a zero average flow motion in the horizontal transverse direction perpendicular to the channel centreline.

Experimental characterisation of three-dimensional flow field becomes extremely difficult with the occurrence of air entrainment and intense interactions between the entrained air bubbles and turbulent structures (Jones & Delhaye 1976). Most classic velocity measurement techniques such as laser Doppler velocimetry (LDV), acoustic Doppler velocimetry (ADV) and particle image velocimetry (PIV) are adversely affected by the presence of air-water interfaces (Boyer 2002), thus their applications in hydraulic jumps were restricted in weak jumps at low Reynolds numbers with very-low air content levels (Svendsen et al. 2000, Liu et al. 2004, Lennon & Hill 2006, Misra et al. 2008, Mignot & Cienfuegos 2010). For highly-aerated flows, the largest number of and most successful air-water flow measurements in the past decades were conducted with intrusive phase-detection probes (Cartellier 2001, Chanson 2016). The phase-detection probe is a local point-measurement technique. In addition to local void fraction and bubble characteristics, time-averaged