PIV MEASUREMENTS IN WATER-PUMP INTAKES

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Vortex formation in and around the intake pipe and swirl in the intake channel are common problems that lead to poor pump performance and frequent maintenance. When the water in the channel falls below some critical level, vortices originate from the free-surface. These may be strong enough to entrain air, resulting in vibration, cavitation and general losses of efficiency of the pump. In addition, vortices that originate from the sump floor or walls may ingest, if strong enough, dissolved air from water.

Previous laboratory studies (e.g., Melville et al. 1984 and Rajendram and Patel 1998) have identified two main types of vortices: i) the free- surface vortices, which depend primarily on the submergence (pipe depth), and ii) the subsurface vortices, which depend strongly on the wall clearance and the local nonuniformity of the flow.

This study used an experimental technique based on PIV (Particle Image Velocimetry) measurements to analyse subsurface vortices for selected geometric conditions, in order to document the details of the flow structure including the number, shape and unsteadiness of the vortices. The selected water-pump intake geometry had been studied in previous numerical and experimental investigations [Li (2001) and Rajendran and Patel (1998)], thus enabling a comparison of the measurements and predictions performed in this work. The PIV measurements focused, first, the approach channel velocity profiles, in order to observe the flow uniformity and get some know-how of the PIV procedure, and, later, the near-wall sections close to the intake pipe, where the vortices were previously detected by flow visualization.

An experimental rig of a water-pump intake was constructed in *Instituto Superior Técnico*, Lisbon, Portugal, to study the flow behaviour inside the pump-bay. The adopted physical model corresponds to a 1:20 scale model of the circulating water-pump intake bay in Union Electric's Labadie plant on the Missouri River, USA. It includes the equipment of flow discharge control, optics, light source, water-tanks, electromagnetic flow meter, valve, pump, screens, honeycomb, optic system and laser. The boundary conditions of the set-up are the same as those described in Chapter 6 of Rajendran and Patel (1998). The intake pipe is positioned asymmetrical to enhance vortex generation. The flow discharge was kept at the constant value of 0.003 m^3/s. The Reynolds number, based on the intake pipe diameter and average speed in the pipe, was 45000, at which well-formed subsurface and free-surface vortices are present. 60-μm pollen particles were used as tracers. Particular emphasis was placed in determining the location of near-intake pipe vortices.

Components of the streamwise mean velocity were measured using PIV at sections $L^*/d = 10$ and $L^*/d = 5$, where L^* stands for the distance from the intake pipe axis to the upstream measuring location. The PIV measurement of velocity profiles at the approach channel was a challenge due to the 210 mm-height target view. The first attempt to measure the entire water depth was to place the CCD camera sufficiently far from the target area, in order to capture the entire water depth. This option was dropped due to the loss of spatial resolution and the inferior quality of the PIV digital images caused by the particle light dispersion decrease. In order to work around this problem, three independent 90mm-target areas were assembled. The three-independent target areas were overlapped into a 210 mm-target area in order to allow the measurement of the entire water depth velocity profile.

PIV was used to measure near-wall velocity fields wherein vortex formation was expected to occur. The PIV measurements of such complex flows embrace considerable trial and error to obtain good quality data. PIV is essentially a two-dimensional measurement technique and its application to a complex, three-dimensional, flow has limitations. The small size of the vortices and their movement posed challenges in the successful implementation of PIV. With the aid of conventional flow visualization and careful choice of the view field, it was possible to have PIV measurements in planes cutting across the vortices to determine their number and location.

In general, the PIV measurements done in this work are in good agreement with the previous studies by Rajendran and Patel (1998). The time analysis shows a periodicity in the floor vortex movement, suggesting that the vortices have a characteristic oscillation frequency.

The main difficulty during the PIV measurements was the *loss of pair's* error, especially on the floor vortex measurement due to the high-velocity field, mostly the normal velocity-component regarding the plan view. In order to work around the *loss of pair's* error, it was necessary to increase the thickness of the light plane and increase the frame rate.

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