Verification of 3-D Stereoscopic PIV Operation and Procedures

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Abstract— **Particle image velocimetry (PIV) is a non-intrusive, whole-field velocity measurement technique that has been used since the mid-1980s. The accuracy, flexibility and versatility offered by PIV systems have made them extremely valuable tools for flow studies. 3-D stereoscopic PIV is the package capable of measuring 3-dimensional velocity components. It involves a very sophisticated routine during setup, calibration, measurement and data processing phases. This paper aims to verify the procedures of operation used for 3-D stereoscopic PIV measurements. This is important to ensure that the best data representation with low associated uncertainty is obtained. A free-diffuser inlet of rectangular cross-section, 14.2 cm x 6.2 cm, with known local air velocities (i.e. measured using pitot-static probe), is presently considered. The flow is assumed to be fully developed turbulent since sufficient hydrodynamic entry length, $4.4D_hRe^{1/6} < L_{h,turb} < 50D_h$ and Reynolds Number, Re>10000 are introduced. Images that are captured by CCD cameras are interpreted using Dantec Dynamic software providing 3-dimensional velocity vectors. The velocities obtained from PIV and pitot-static probe are compared in order to justify the quality of PIV measurement. The range of velocity obtained using probe is 2.31 – 2.58 m/s, whereas using PIV is 2.31 – 2.91 m/s. It thus gives the average discrepancy of 0.8%. Besides, there is also a close agreement between the air velocities measured by PIV and theories with average discrepancy of 1.2%. This discrepancy is mainly due to some uncertainties in the experiments such as imperfect matching of coordinate between probe and laser sheet, unsteadiness of flow, variation in density and less precision in calibration. The operating procedures of 3-D stereoscopic PIV have successfully been verified thus are justified to be used for future PIV measurement, provided minor discrepancies are recorded.**

Index Term— **3-D stereoscopic particle image velocimetry (PIV), uncertainty analysis (UA).**

I. Introduction

Particle image velocimetry (PIV) is a non-intrusive whole-field velocity measurement technique that has been used since the mid-1980s [1]. In contrast to other conventional methods such as hot wire anemometry and pitot-static probe, PIV allows flows to be instantaneously interpreted both qualitatively and quantitatively.

The application of PIV in research and industry is widespread, on account of its ease of use and accurate data representation. 3-D stereoscopic is the recent PIV application introduced, capable to measure the third velocity component by means of correlating the 2-D PIV data. Involving a very sophisticated routine during setup, calibration, measurement and data processing, 3-D PIV demands proper judgements towards each procedure taken [2].

This study is a part of the work to investigate pressure recovery and flow uniformity in 3-D turning diffuser [3]. The main aim is to verify every procedure taken in running 3-D stereoscopic PIV measurements. Thus, the best data representation with low associated uncertainties could be obtained. All the uncertainties due to measurement will be specified, and further enhancement to the experimental setup will be made accordingly.

A. Scope and limitation of study

A free-diffuser inlet of rectangular cross-section, 14.2 cm x 6.2 cm, with known five-point local air velocities is considered. The flow is expected to be fully developed turbulent as sufficient Re>10000 and $4.4D_hRe^{1/6}<L_{h,turb}<50D_h$ are introduced. The flow interpreted using 3-D PIV is compared with the flow calculated theoretically and the flow measured using pitot-static probe. Well-run experimental practice shall produce good results with low associated uncertainties.

III. Literature Review

A. PIV Measurement Principles

Fig. 1 shows the basic principles of PIV measurement. In PIV, the velocity vectors, $\bar{V}$ are derived from sub-sections (i.e. interrogation area, IA) of the target area of the particle-seeded flow by measuring the particles displacement, Δx between two light pulses, Δt. The principle of PIV measurement on flow velocity, $\bar{V}$ is in detail described as following [2], [4]:

$$\bar{V} = M\left(\frac{\Delta X}{\Delta t}\right) + \delta U \quad (1)$$

where,

$\bar{V}$ = flow velocity (m/s)

M = magnification factor

Δx= particles displacement (m)

Δt=time between pulses/ time between two successive frame images (s)

δU= consolidation of uncertainty factors

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