

## Application of Stereo-PIV to determination of turbulent kinetic energy balance in free jet

A.V. Bilsky<sup>1</sup>, V.M. Dulin<sup>2</sup>, D.M. Markovich<sup>3</sup>, M.P. Tokarev<sup>4</sup>

1: Institute of Thermophysics of SB RAS, Russia, bilsky@itp.nsc.ru

2: Institute of Thermophysics of SB RAS, Russia, vmd@itp.nsc.ru

3: Institute of Thermophysics of SB RAS, Russia, dmark@itp.nsc.ru

4: Institute of Thermophysics of SB RAS, Russia, mtokarev@itp.nsc.ru

**Keywords:** Stereo PIV, PIV processing, PIV spatial resolution, free jet.

Interest in free turbulent jets study is caused by wide spreading of such flows in nature and industry. Moreover turbulent round free jet is a classical inhomogeneous flow representing a simple model for more complex flows. Non-intrusive PIV methods for flow field diagnostics can provide spatial distributions of instant flow velocity, spatial velocity derivatives and statistical correlations of these quantities, which are appropriate for development and validation of complex CFD codes. At the same time, for correct determination of quantities mentioned above it is necessary to elaborate a number of complex pre- and post-processing PIV algorithms.

In present work the axisymmetric turbulent submerged free water jet was experimentally studied using PIV and Stereo PIV techniques. Reynolds number was 25000, measurements were performed in a self-similar region of the jet (at distance of 16-18 nozzle diameters) Software package "ActualFlow", exhibited by IOT team at last two PIV Challenges (2003, 2005) was used for raw data processing.

Cross-correlation algorithm with image deformation is considered to have the best performance in terms of accuracy and spatial resolution. Both cross-correlation algorithms with and without image deformation were used for 2C velocity calculation and their performances were compared.

After instant velocity fields were calculated, it is necessary to apply validation methods and remove spurious vectors. Before derivatives computation or stereo reconstruction, obviously, holes must be filled with interpolated values. Widespread moving average filter is not optimal one for usage in interpolation (Nogueira et al, 1997), hence more effective interpolation procedures were elaborated. For derivatives calculation appropriate derivative filter was implemented in order to properly minimize the truncation error together with noise error (Foucaut and Stanislas, 2002).

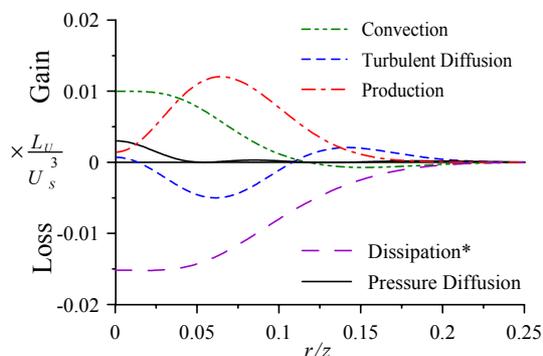
Realization of stereo PIV algorithm directly influences the measurement accuracy, whether implemented thresholding or correlation marker localization, image or vector dewarping technique. Also the kind of image model: pin hole camera model or polynomial scheme, affects the error. Multiple plane calibration procedure was applied to calculate imaging model (Soloff et al, 1997). It consists of calibration dynamic image thresholding marker localization and model fitting. Two mapping models were used and their performances were compared: projective transform and 3<sup>rd</sup> order polynomial function. The calculation of the displacements is done by resampling 2D velocity projections from both directions. The final reconstruction of 2C data to 3C vector fields is performed by a least-squares fitting.

Additionally the light-sheet misalignment correction algorithm with modification of an imaging model was applied to diminish processing error.

Application of statistical validation algorithm (Heinz et al, 2004) to 3C velocity fields allowed acceptable accuracy during high order (up to the 4th order) statistical moments calculation.

Recent works (Piiro et al, 2003) showed that estimated statistical characteristics of turbulence essentially depend on PIV spatial resolution. Thus, a special set of 2C PIV measurements was fulfilled assuming consecutive reducing of whole measurement area size (vector spacing up to several Kolmogorov lengthscales). The influence of PIV finite spatial resolution on measured dissipation and statistical velocity moments was analyzed.

Complete set of mean momentum and turbulent kinetic energy budget equations' terms was obtained for self-similar region of jet flow. In Figure the normalized TKE budget equation terms are presented, where dissipation was directly calculated from instant velocity fields and pressure diffusion was found as a residual term.



Foucaut JM, Stanislas M (2002) Some consideration on the accuracy and frequency response of some derivative filters applied to particle image velocimetry vector fields. *Meas Sci Technol* 13: 1058-1071

Heinz O, Ilyushin B, Markovich D (2004) Application of a PDF method for statistical processing of experimental data. *J. of Heat and Fluid Flow*. 25: 864-874

Nogueira J, Lecuona A, Rodriguez PA (1997) Data validation, false vectors correction and derived magnitudes calculation on PIV data. *Meas Sci Technol* 8: 1493-1501

Piiro M, Saarenrinne P, Eloranta H, Karvinen R (2003) Measuring turbulence energy with PIV in a backward-facing step flow. *Exp Fluids* 35: 219-236

Soloff SM, Adrian RJ, Liu Z-C (1997) Distortion compensation for generalized stereoscopic particle image velocimetry. *Meas Sci Technol* 8: 1441-1454