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ACOUSTIC VELOCITY WITH MEAN FLOW MEASUREMENTS IN THE AIR BY MEANS OF LASER DOPPLER VELOCIMETRY

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Flow distribution images in acoustic fields, connected with the graphical presentation of the acoustic waves gives new possibilities of interpretation of dynamic phenomena occurring in real fields. Introduction of these possibilities has greatly changed the approach to examining many acoustic phenomena. It also facilitated ways to visualize the flow of acoustic energy. One of the new insight into the nature of acoustic field formation in real conditions of working sources is the sound intensity technique but laser Doppler velocimetry (LDV) can be also very useful in applications of acoustic.

It is a frequent occurrence that the sound velocity measurements in real conditions may show great disparity between the theoretical assumptions of the acoustic field distribution. The disparity mainly comes from simplifications accompanying the analytical and numerical methods due to the lack of complete data concerning physical properties of an investigated object.

Laser Doppler Velocimetry is a non-intrusive technique to measure particle velocity widely used in fluid experimental mechanics for years (Albrecht H-E et al., 2003). The technique has an established position when concerning mean flow measurements or even high-level acoustic flows (Zhang Zh., 2010). From the signal processing point of view, the measurement system is a non-uniform time-resolved measurement data acquisition system, so when high data rates comparing to the frequency of signal changes are obtained during measurements, the uniform time-resolved resampling can be applied to the acquired data and classic signal analysis can follow. An application of Laser Doppler Velocimetry to visualise the acoustic flows and mixed flows at low velocities and quite high acoustic frequencies requires some other methods of signal processing and data analysis. Many sophisticated methods have been developed for last 10 years to deal with acoustic flow visualization. The main aim of present research is to evaluate the usefulness of selected methods applied to visualize the mixed flow (mean and acoustic) and to propose some modifications allowing better results resolution and presentation.

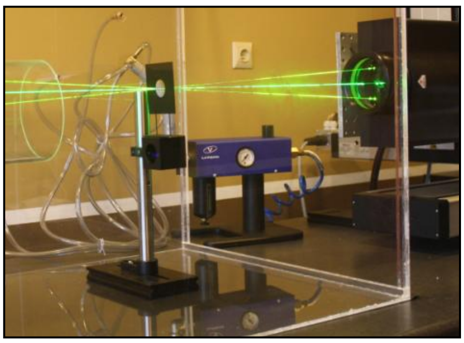

Fig. 1. LDV experimental setup

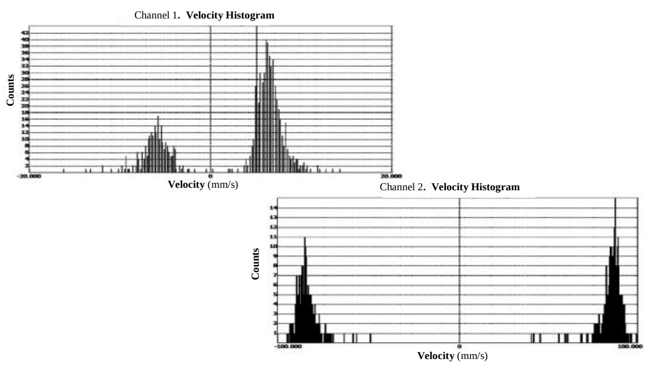

Fig. 2. Sample histogram of pulsating part of the flow

The main problem with the acquisition of acoustic signal with standard LDV hardware processor is the assumption, that the observed particle traverses the probe volume with constant velocity and direction. For acoustic particles velocity measurement this assumption is not always valid. It is because the acoustic particle movement trajectory has got at ordinary sound levels (below 120 dB SPL) and frequencies of hundreds Hz, the size of the same or lower range than probe volume. So the Doppler shift frequency in LDV signal originating from one particle varies during the single burst. Standard LDV hardware and software recognise such bursts as corrupted by noise and do not accept them as valid measurement data. We try to change this unacceptable situation e.g. in two ways: processing the acquired acoustic data (sampled burst values) in more time-frequency resolved way and/or observe mixed flows (with higher data rate) then evaluate acoustical parameters of the flow using statistical analysis. These two approaches will be presented in the paper.

In presented experiments the ARTIUM Technologies Inc. stereo-LDV system model TR-200 is used (Fig.1). It uses green (532 nm) and yellow (561 nm) lasers with 505 mm focal length transceiver optics. The interference fringe spacing is 4.53 and 4.84 μm respectively. The LDV transceiver was coupled with 3D positioning system. This allowed scanning the interesting volume around the investigated model.

The AIMS software originally provided with the ARTIUM LDV system provide basic tools to proceed the experiment (calibrations, positioning system control and synchronization), to collect the data and visualize them in the form of histograms (Fig.2). These abilities are convenient and sufficient for precise evaluation of the mass flow. To apply some advanced signal processing techniques for acoustic component evaluation, the demodulated burst signals were acquired with the auxiliary system based on Agilent MSO 3014 digital oscilloscope. The data were then processed in Matlab environment. We checked usefulness of the previously mentioned methods (Valiere J. C. et al., 2000): Cross-Wigner-Ville detector (CWV) and time-frequency synchronous detector (TFSD) according to classic wavelet decomposition and short time Fourier transform (STFT). The robustness of methods mentioned above has been evaluated and discussed.

It has been demonstrated in the paper that LDV measurement technique can be useful to obtain detailed insights into the complex mechanisms within aeroacoustic sound field (Acoustic-LDV). The observation of the mean flow (as in previous papers of other authors, e.g. (Paal G. et al., 2006) showed the large complexness of the flow dynamics which is very different from that obtained by simplified models. The advanced signal processing methods allows obtaining not only the mean part of the flow velocity, but also the pulsating part connected with other energy flow. The evaluated methods have different robustness, but it is still difficult to judge experimentally, which method will always perform in the best way. It shall be also the goal of further research.

References

Paal G., Angster J., Garen W., Miklos A. (2006) – A combined LDA and flow-visualisation study on flue organ pipes. Experiments in Fluids, 40, 825-835.

Valiere J. C., Herzog P., Valeau V., Tournois G. (2000) – Acoustic velocity measurements in the air by means of laser Doppler velocimetry: dynamic and frequency range limitations and signal processing improvements. Journal of Sound and Vibration, 229(3), 607-626.

Albrecht H.-E., Borys M., Damaschke N., Tropea C. – *Laser Doppler and Phase Doppler Measurement Technique.* Springer-Verlag London 2003.

Zhang Zh.– *LDA Application Methods. Laser Doppler Anemometry for Fluid Dynamics.* Springer-Verlag London 2010.