

ACOUSTICS FLOW FIELD VISUALIZATION USING SOUND INTENSITY AND LASER ANEMOMETRY METHODS

Stefan WEYNA

*West Pomeranian University of Technology, Faculty of Marint Technology and Transport
Szczecin Poland, e-mail: weyna@zut.edu.pl*

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Although acoustics consists in the propagation of an oscillatory disturbance of local pressure, particle velocity, density and temperature, sound measurement is often assimilated to pressure measurement. This is because for decades only pressure fluctuations were accessible and because their relation with the other oscillatory quantities is well known under linear acoustic approximation and in simple configurations. Such a correct description of the origins of sound has long been known from the theory of sound, but there is a bad habit of acousticians to use the descriptions of sound as acoustic pressure only. Meanwhile, a sound wave is a form of energy transport in the field and has the vectors features. Sound intensity (SI) as a vector variable inseparably couples the acoustic particle velocity (called also *acoustic velocity*), and acoustic pressure ($I_a = p \mathbf{v}$) and represents a stream of acoustic energy flowing in the field. This vector parameter of acoustic wave can be measured with special sound intensity probe and can be easily shown in a graphical form.

Acoustic intensity as a very useful energetic quantity gives information about the propagation paths and the amount of energy radiated. The SI technique was in our team used for many years to examine the stream of acoustic energy flows in real acoustics fields. Our experiments confirm that flow acoustic imaginations in real-live conditions are very complex, even for extremely simple models facility. Various measurements with sound intensity technique were made to get a full picture of the dynamics of acoustic flow (see Fig. 1).

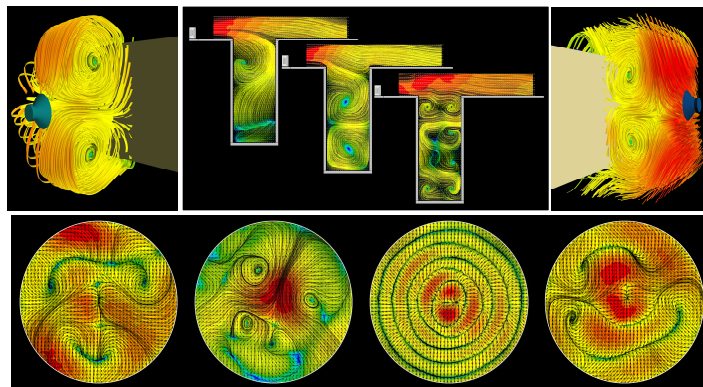


Figure 1. Some examples of vector distributions in the real-life acoustic fields recorded by Sound Intensity methods

These investigations allowed physical understanding of acoustic wave flow phenomena in real condition showing both qualitative and quantitative effects of the wave movement. Applying the method of SI, we can see that this method has one disadvantage: lead can not be measured very close to the sound source (eg at a distance of roughly <1 mm). In this region

so cold *hydrodynamic acoustics near field* (very, very small *near acoustic field*) the sound is born and radiated to the environment. Since SI is the size of vector, to describe the stream intensity we need to know value of *particle acoustic velocity* \mathbf{v} . Measurements of this magnitude can be made using modern methods of measurement using non-invasive laser techniques PIV-Particle Image Velocimetry and LDA- Laser Doppler Anemometry adapted for acoustic research as a A-PIV and A-LDA. Our conviction as to the validity of the assumptions of the proposed technique of the acoustic laser anemometry is based on our experience which we acquired through investigations of flow acoustic method using SI techniques.

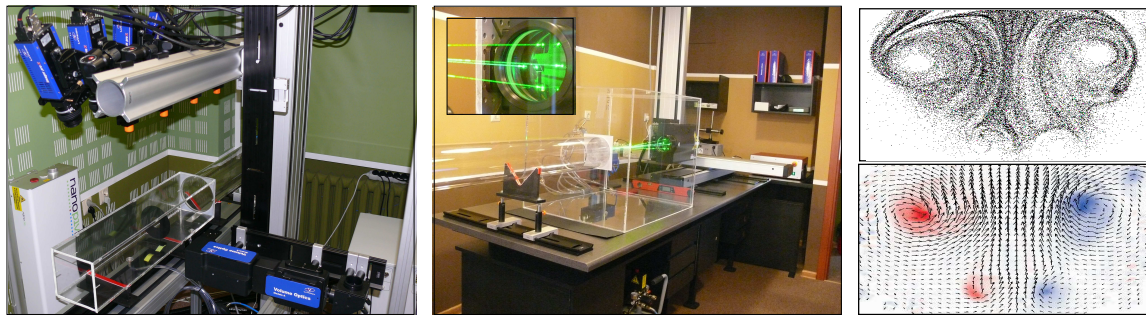


Figure 2. Set-up of laser PIV and LDA laboratory and example of measurement result

PIV is nowadays used in very different areas from aerodynamics to biology, from fundamental turbulence research to applications in the turbo-machinery design, from combustion to two phase flows and very intensively in micro devices and systems. Due to the variety of different applications of PIV and the large number of different possibilities to illuminate, to record and to evaluate, many different technical modifications of the PIV technique have been developed. Moreover, most publications describe the problems from a specific point of view (eg. in fluent mechanics). We therefore felt that it was time to compile the PIV knowledge and practice to the implementation in theoretical and applied acoustics.

The technique of Laser Doppler Anemometry (or Velocimetry), is a technique of using the laser light and Doppler effect for velocity measurements. In most applications, LDA measurements are considered as measurements of local flow velocities in points, for instance of the flow distribution in the near-wall region (eg., in the turbulent boundary layers).

Today, the laser anemometric techniques are applied to an investigation of the spatial and temporal development of coherent structures in a turbulent flat-plate boundary layer flow in the vicinity of the trailing edge and in acoustics boundary layer. Expected that known from studies of fluid mechanics measurement techniques, laser PIV and LDV should be also successfully adapted to experimental studies of acoustic flows in those areas to provide an instantaneous flow and acoustic particle velocity and sound intensity mapping with the minimum disturbance of the sound field. Acoustic flow velocity measurements by means of PIV/LDA methods are based on random sampling of velocity events occurring when the seeded particles pass through the measurement volume.

For the development of adaptation methods for PIV and LDV techniques for acoustics testing, we have adequate testing concept and fully equipped laboratories in modern measuring equipment. Our proposed investigations in acoustic field will be carried out in newly launched *Acoustic Laboratory for Laser Anemometry* equipped with the latest 3D PIV tomography system (Tomo-PIV) made by LaVision GmbH company and 2D LDV 200 TR system Artium Technologies Inc. supplied by U.S. company. Recent developments in terms of our capacity to both numerically and experimentally analyze the physics of turbulent shear flows have opened up new possibilities to improve our knowledge of Vortex Sound Theory about the noise generation and sound propagation mechanism.