EXPERIMENTAL 3D VISUALIZATION OF POWER FLOW AROUND OBSTACLES IN REAL ACOUSTIC FIELD

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Abstract

The article presents the application of sound intensity technique to graphic presentation of spatial distribution the acoustic power flow over various geometrical shapes of structures located in a three-dimensional half space. As the results of research, the visualization analysis of the sound intensity flux in 3D space is show as a distribution of acoustic flow field. The visualization of acoustic power flow in real-life acoustic fields can be explain many particulars energetic effects (scattering, vortex flow, shielding area, etc.), concerning the areas in which it is difficult to make numerical analysis. Visualisation in this research results are shown in the form of a vector map, intensity streamlines in space, as a shape of wave front or a isosurface in three-dimensional space. Numerous methods of visialisation illustrate the application of the SI measurement for practical problems at the acoustical diagnostic and noise abatement.

THE STUDY OF WAVE FIELDS

Sound being scattered and reflected from several limiting surfaces together with the direct sound from source built up a sound field with such complicated patterns that even the simplest care is practically impossible to describe completely. Such a problem is encountered mainly as a acoustics pressure distribution fields in rooms or bounded spatial systems and can be solved theoretical and experimentally in several ways [1]. These study include the wave theoretical model, the geometrical acoustics model, the use of statistical methods, the psycho-acoustic approach or the physical modelling.

MORSE and INGARD have theoretically calculated diffraction and scattering from various geometrical shapes structures [2]. Based on the theory, also numerical method can be used [1,10]. The main numerical models are concerned with the geometrical presentation of the spherical sound propagation, that is to say that phase and wave spherically are ignored. In general, analytic models assume an omnidirectional source, reverberation absorption coefficients, specularly reflecting flat surfaces, and air absorption quantified by air absorption exponent. Each of these approaches provides useful information about pressure acoustics pressure fields, but none currently offers a full vectors mapping of the acoustic energy flow (vectors effect) in front and back of any scattering systems working in real environmental conditions. Interference, diffraction and scattering of waves made the real field very complex and is difficult to the theoretical modelling even the acoustical far fields.

Commonly known theoretical modelling methods have one weak point - the shadow and reflecting area is mainly described as a pressure (potential) field and description of mechanism of the acoustic power flow transported over the obstacles is practically omitted. In normal conditions, the real features of barriers and interactions with the environment cause their shielding efficiencies often drastically differ to the comparison of the result of modelling with the theoretical prediction. The analysis of sound propagation is done today, usually by application of many commercial computer programs, but theoretical calculations and predicted results are not so often compared with experimental measurements for checking accuracy of the programs (see [2,3] with comparison results of theoretical modelling with “SYSNOISE” v.5.3A and investigations of real-field measurement with SI method). Reflection of waves having a wavelength similar or smaller as the obstacle dimension scattered in all directions and the paths of transported energy theoretical are not easy to predict. The degree of discrepancy between modelling results and a real structure of the field formed over obstacles grows proportionally to the degree to which simplifying calculating assumptions differ from the conditions encountered in reality. The differences mainly result from the fact that theoretical forecasting uses far too big simplifications or that it is impossible to obtain proper data on real physical features of the tested area.

This is one of the reasons why the experimental investigation fields using Sound Intensity technique (SI) are a useful tool for the analysis of vector acoustic flow field distribution around the barriers. A properly used sound intensity method ensures the chance of display the acoustic energy flow distribution in any place of a restricted space, even within a near field.

Main advantages of the research carried out with the application of a sound intensity technique consist in the fact that the measurements taken refer to energy dependencies of the field described by intensity streaming flow and that they can be carried out in unrestricted environment even in acoustic near field. As it has been pointed out, the presented advantages of a sound intensity technique may be used in acoustic metrology much more effectively than classical methods e.g. to verify the theoretical methods of vectors field modelling with check-up measurements taken in real-live conditions.

THE VECTOR ACOUSTIC FIELD

In order to modelling of an acoustic field by means of computational methods, one of the methods known from literature and based on wave, geometrical or statistical models can be used [9]. Each of the methods has different ranges of usability and, while using them practically, they assume quite serious simplifications. It is even possible to formulate a hypothesis that no contemporary theoretical method used for modelling acoustic fields in acoustically near field with description of the energy distribution inside.

The literature seldom contains publications in which the results of analytical model calculations are verified by experimental tests. At its best, such an analysis concerns only a distribution of pressure levels i.e. a scalar parameter of an acoustic field. However, in a real acoustic field, there is a close connection between scalar and vector effects represented by the acoustic pressure and particle velocity that fully explains the physical meaning of wave phenomena, and makes it possible to consider the mechanisms of propagation, radiation, diffraction or scattering. A good form of illustration of scalar-vector phenomena occurring in real conditions is the application of the sound intensity technique in tests in which the product of the pressure and particle velocity of the acoustic wave is measured by means of a proper measurement intensity probe.

Traditionally sound intensity is measured by the use of two closely spaced microphone (*p-p* probe) or pressure-velocity probe (*NE-216 Norwegian Electronics*) however the direct measurement of particle velocity in one place is today possible with The Microflown Ultimate Sound Probe - USP.

The Microflown USP (made by *Microflown Technologies B.V.*) is a quite new construction as a combination of three Microflown particle velocity sensors and pressure microphone [5] The 3D particle velocity and pressure sensor is based on the new particle velocity sensor. It measures the relative change in electrical resistance of two tiny platinium strips heated to about 300 ^{o}C. When particle velocity is present, it asymmetrically alters the temperature distribution around the resistors and relative change his resistance, which quantifies the particle velocity. From measurement of the particle velocity of the three mutually perpendicular directions and simultaneously measured the pressure of acoustic wave in this same place, the time averaged active sound intensity vector can be calculated [6]. With use of this kind of miniature size of the 3D intensity probe (the measured head about 5 mm x 5 mm x 5 mm), the times consuming of vector distribution measurement in space is three time shorter. We can also use this probe in the field region very close to the acoustic source in his hydrodynamic near field. That is new possibility in the acoustical metrology.

POWER FLOW VISUALISATION

Many of the techniques used in computer graphics flow visualisation have been adapted from the traditional methods practised in wind and water tunnels. Scientific visualisation is the use of computer graphics to create visual images which aid the understanding of these often immense data set. Visualisation system, by serving a dual role as a provider of exploration and exposition capabilities, have became indispensable to the analysis of *computational fluid dynamics* (CFD) results [7].

Up until the last decade the study of sound flow visualisation are rather seldom in the acoustical practice. To day, power flow motion as the acoustic particle velocity may be measured experimentally using intensity probes, which can be used to collect the vectors data to visualisation all the wave phenomena occurring in real physical space [8, 9]. Having the technical possibilities of measuring a sound intensity vector in three-dimensional space, it was necessary to work out a proper form for the graphical presentation of the acoustic vector field distribution. The problem involved a way of demonstrating, on a two-dimensional or three-dimensional form vector field.

A simultaneous measurement of the three components of intensity vectors for the frequency intervals makes it possible to imagine the spatial placement of the vector at a given measurement point. Additionally, a graphical analysis of the field may include a picture of streamlines of the sound intensity flux. This is a form of qualitative analysis for stationary fields which consists in a complex evaluation of the paths along which the acoustic energy of a radiating source is transported.

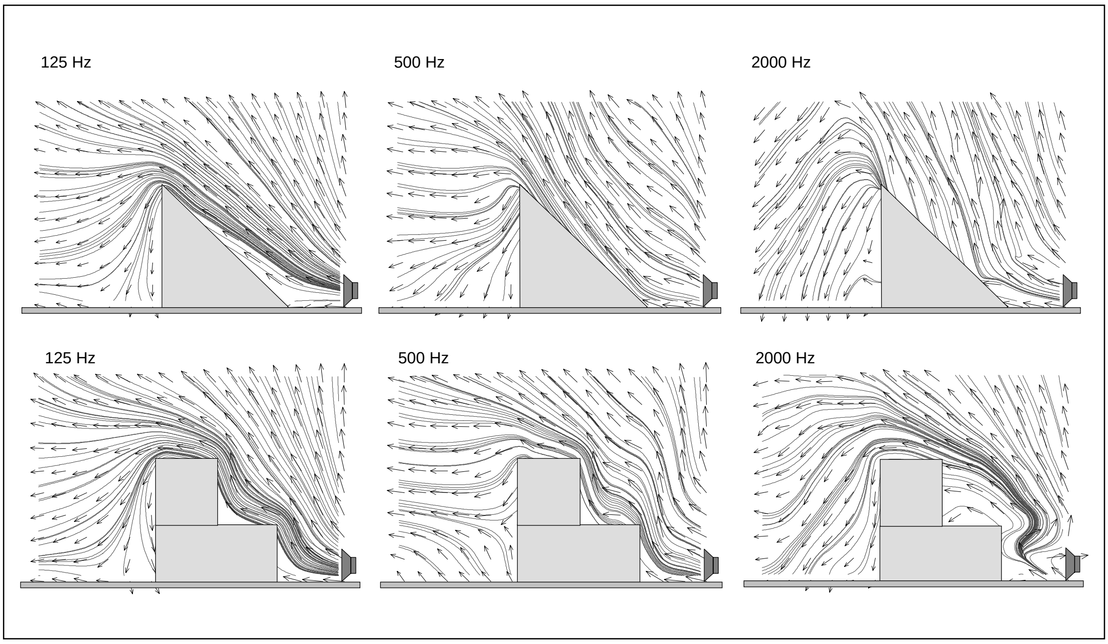

Fig.1. Distribution of vectors and intensity streamlines in the plane of symmetry axis of the investigated models

The article presents the application of sound intensity technique to graphic presentation of spatial distribution the acoustic power flow around the two models in shape as a “two steps of stairs” and “inclined plane”. As one of the results of research, the graphic analysis of the sound intensity flux in plane of the axis of symmetry of the models is show on the Fig.1. The tests concern the vector streamlines (2D form) in an axis of symmetry of the objects for acoustic excitation coming from broad-band five loudspeaker installed in line on the lower surface position before the investigated models. The source signal was a stationary broad band pink noise. The measurements are curry out in third-octave bands and flow map have been build in the frequency range between 25 Hz and 6300 Hz. On the figure 1 only the part of the results (for 125 Hz, 500 Hz and 2000 Hz) can be found.

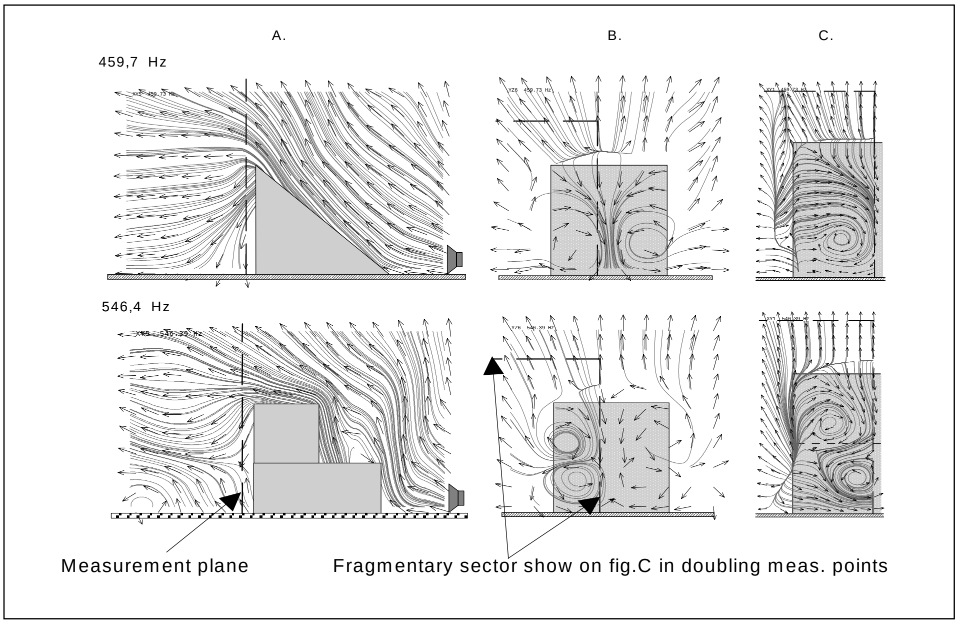

Fig.2. The shape of sound shadow in 2D space behind the models close to the rear side

On the Fig.2 a shape of sound shadows close behind the models are described. Notice how these streamlines form a circular pattern surrounding each primary vortex close the rear side of models. The shadow area represent focusing of sound energy. Such a phenomenon could not be observed by using pressure data to present the acoustic field.

Other examples from a graphic image of the flow acoustic wave generated into three-dimensional space are shown on Fig. 3. The image of an acoustic wave represents the shape of the front of wave flow around investigated models in various distance from the source.

On the next figures of visualisation of power flow in 3D space is show on the Fig.4. and 5. The images of vector field distribution illustrates in the shadow area of models focusing vortex streamlines as a typical anlinear effects in real flow field. This could constitute a major acoustical problem in many cases.

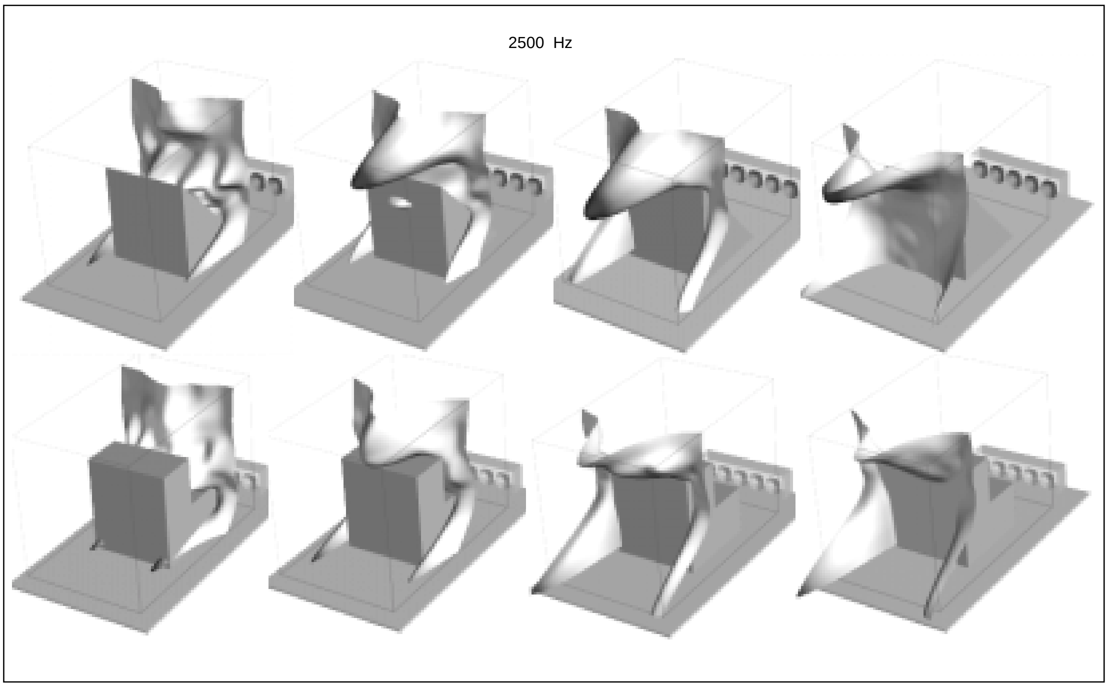

Fig.3. Visualisation of acoustic wave form measured in a surface in various distance from the source

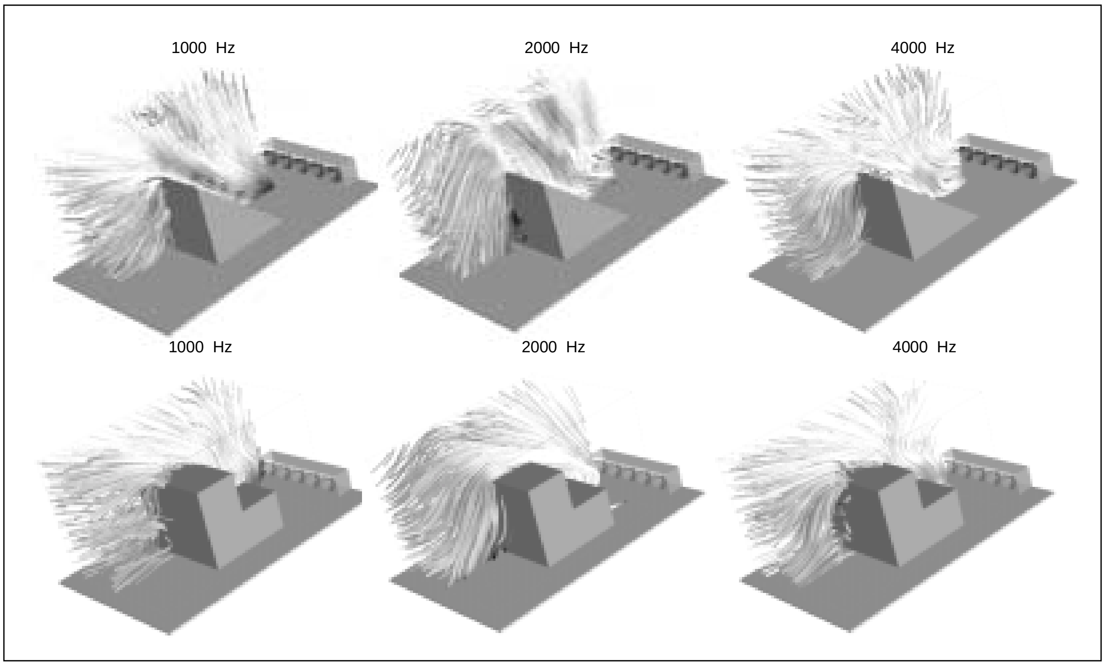

Fig. 4. Intensity streamlines in ribbon form around the models in 3D half space (only the one half of measured space is show)

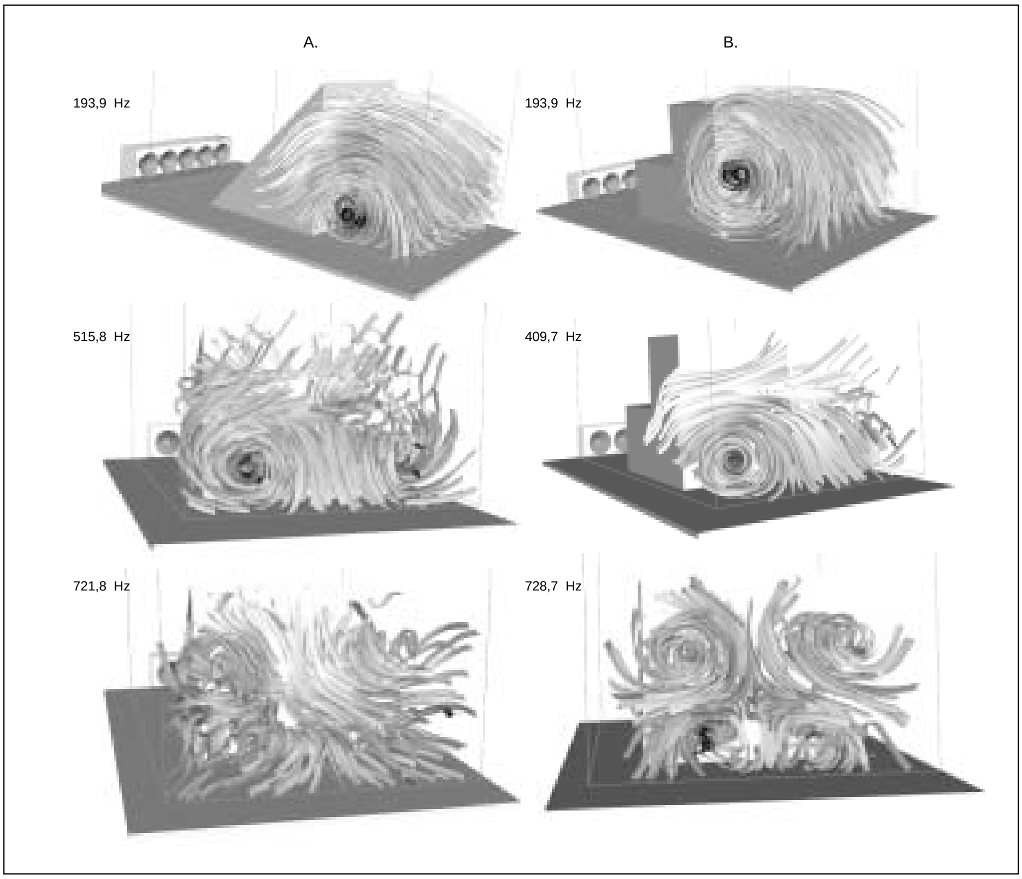

Fig.5. Intensity streamlines (vortex one selected) in shadow area of models

CONCLUSIONS

The tests of the acoustic power flow and presentation of the results in a graphic form shows, that the presentation of vector distributions in real acoustic fields can explain many particulars, concerning in the areas for which it is difficult to make theoretical analysis (3D direct and near field, effects of scattering, shielding area, etc.).

An important consideration for a flow acoustic wave visualization is the collection of visualization methods and the effectiveness of these methods in investigation of acoustic engineering. These techniques illustrate how the governing ideas can put to practice to explore a acoustic vector field in real conditions. Traditional visualisation method with acoustic pressure distributions are not well suited to analyse these phenomena of acoustic field.

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