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EXPERIMENTAL INVESTIGATION OF ACOUSTIC FIELD ENERGY STRUCTURE IN AN INTERFEROMETER IN THE PRESENCE OF AN ABSORBER,[1]

BAHVALOV, G. A.,[2] IVANNIKOV, A. N.[3], Moscow, SLABEYCIUS, J.[4], Žilina

The results of an experimental investigation of field structure in the acoustic interferometer in the presence of an absorber are presented. The five fields quantities (i.e. sound pressure p, particle velocity v, phase mismatch φ_{pv} between p and v active and reactive components of the energy flow density vector) were measured. Especial attention is paid to the methodical aspect of the question – a comparative analysis of different approaches to determine the reflection coefficient of the absorber R.

I. INTRODUCTION

The purpose of this article is to investigate the field structure in the acoustic interferometer in the presence of an absorber. Especial attention is paid to the methodical aspect of the question – comparative analysis of different approaches to determine the reflection coefficient of the absorber R.

II. METHOD

The geometry of the problem and a block-scheme of the experimental setup are presented in Fig. 1.

The interferometer was a long metallic tube with a diameter of $D \cong 0.3\,\mathrm{m}$, closed by a steel flange on one side. Inside this tube was the wide band absorber (Fig. 1), whose internal diameter changes step by step with $\Delta D = 0.04\,\mathrm{m}$. In the present experiment the absorber was made of glass filament with a density of $\rho_o = 15\,\mathrm{kg/m^3}$.

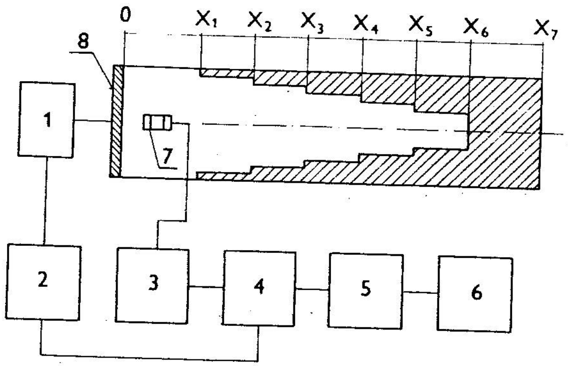

Fig. 1. The block-scheme of the experimental system. 1 – vibrator Brüel & Kjaer Type 4812; 2 – power amplifier Brüel & Kjaer Type 2707; 3 – sound intensity meter Brüel & Kjaer Type 4433; 4 – two canal signal analyser Brüel & Kjaer type 2034; 5 – computer *Hewlett Packard* 216; 6 – Plotter, type 7550A N/R; 7 – sound intensity probe Brüel & Kjaer Type 3519; 8 – rigid piston. Coordinates of the absorber's layer: $X_1 = 0.52\,\mathrm{m}$; $X_2 = 0.77\,\mathrm{m}$; $X_3 = 1.01\,\mathrm{m}$; $X_4 = 1.33\,\mathrm{m}$; $X_5 = 1.66\,\mathrm{m}$; $X_6 = 2.00\,\mathrm{m}$; $X_7 = 2.50\,\mathrm{m}$.

The experiment was carried out according to the following scheme: the signal from the internal generator of the two-channel analyser (4) through the power amplifier (2) was applied to the vibrator (1) that excited the rigid metallic piston (8). The parameters of the acoustic field inside the interferometer were measured by the intensitymeter's probe (7): the signal from the probe was connected with the intensitymeter. The outputs from the intensitymeter corresponding to the sound pressure and the particle velocity were connected with the two-channel analyser (4).

Operating with the measuring system, the data and their application were accomplished by means of a personal computer of the type *Hewlett Packard* (5). All the results have been presented by the graphic plotter.

To determine the spatial distribution of the field's characteristics in which we were interested, the intensitymeter's probe was moved along the axis of the interferometer with a step of 50 mm, "including" the region of the absorber. At each point the quantities characterizing the sound field (pressure p, particle velocity v, phase mismatch between p and v, energy flow density vector's component I_a) were measured.

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[2] Automobile plant named after Likhachev. Dolgoprudnaya st., 5/55., 127411 Moscow, Russia

[3] Department of Accoustics. Faculty of Physics. Moscow State University, 119899 Moscow, Russia

[4] Technical university of transport and communications, Moyzesova 20, 010 26 Žilina, CSFR

III. RESULTS

The measured results are presented as figures.

The distribution of the sound pressure along the axis of the interferometer is shown in Fig. 2 in logarithmic scale reference level $P_o = 2 \times 10^{-5}$ Pa. From the mark X_1 the probe was situated inside the absorber. The distribution of the active intensity component I_a value is presented in Fig. 3 in logarithmic scale relative to 1×10^{-12} W/m². Fig. 4 shows the distribution of the reactive intensity component I_j in linear scale. The spatial distribution of the phase mismatch between sound pressure and the particle velocity φ_{pv} is presented in Fig. 5. In Fig. 6a the spatial distribution of the reflection coefficient values is shown. It was determined at a frequency of 500 Hz by several different methods:

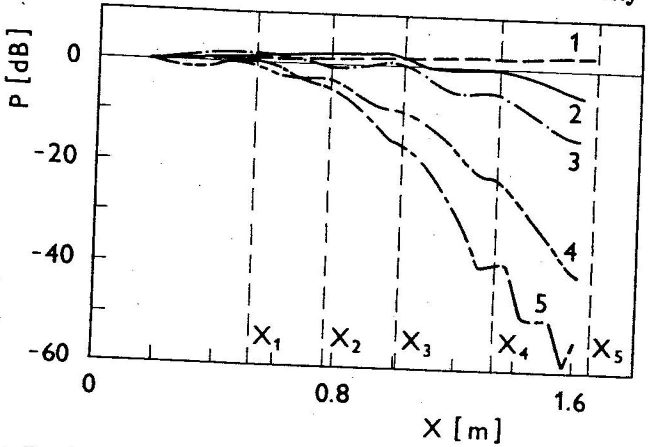

Fig. 2. Distribution of the sound pressure along the axis of the interferometer: 1 – 63 Hz; 2 – 125 Hz; 3 – 250 Hz; 4 – 500 Hz; 5 – 800 Hz.

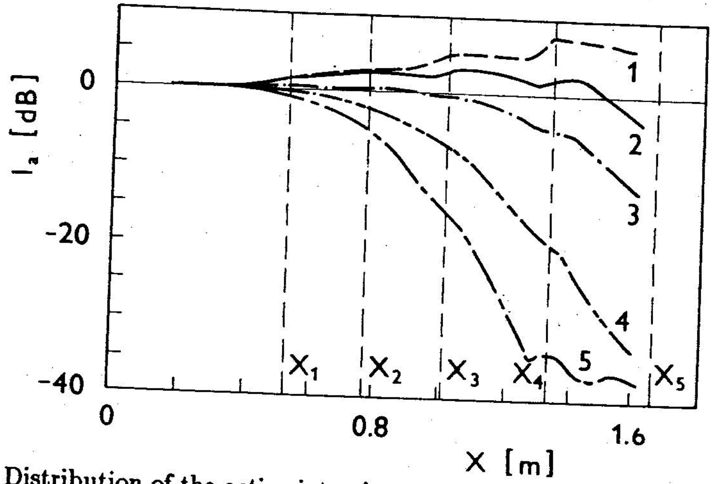

Fig. 3. Distribution of the active intensity value on the interferometer axis: 1 – 63 Hz; 2 – 125 Hz; 3 – 250 Hz; 4 – 500 Hz; 5 – 800 Hz.

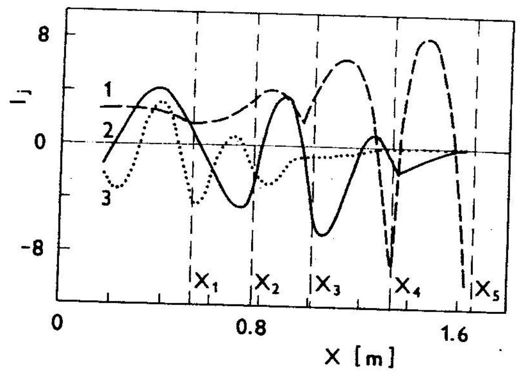

Fig. 4. Spatial distribution of reactive intensity (in $W/m^2 \times 10^{-3}$) in the interferometer: 1 – 125 Hz; 2 – 250 Hz; 3 – 500 Hz.

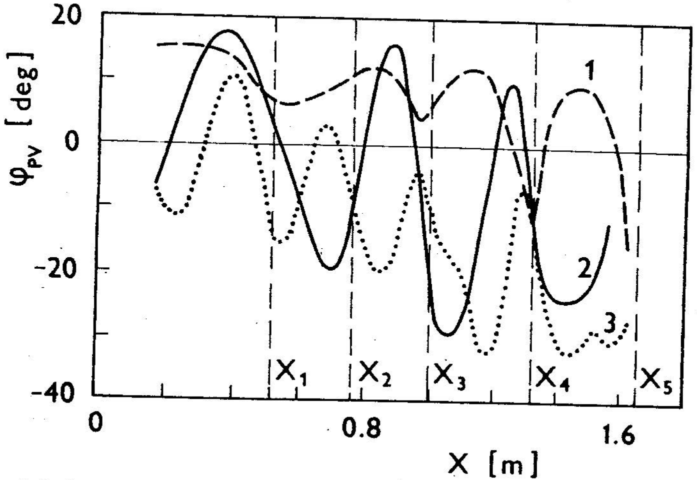

Fig. 5. Spatial change of the value of the phase mismatch φ_{pv} between the sound pressure and the normal component of the particle velocity of the sound wave: 1 – 64 Hz; 2 – 250 Hz; 3 – 500 Hz.

1. By measurement of the parameters p, v, φ_{pv} [1];
2. By maximal values of the phase mismatch ($\varphi_{pv^{max}}$)
3. By correlation between active and reactive components of the energy flow density at the extreme points of the reactive intensity distribution [2,3].

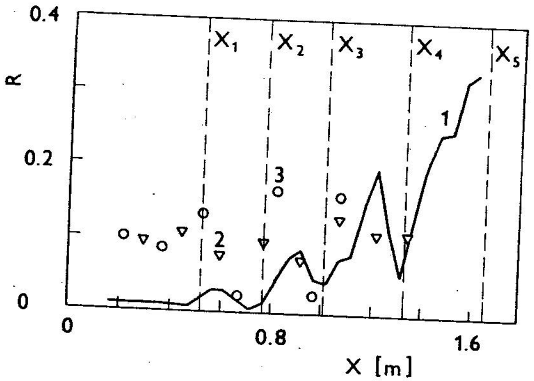

Fig. 6a. The value of the sound wave reflection coefficient, calculated by different methods in a few points of the interferometer's axis: 1 – by measurement of p, v and φ_{pv} in the same point; 2 – by measurement of $\varphi_{pv\,\max}$; 3 – by correlation of active and reactive components of energy flow density.

The mentioned methods are of interest because they yield the same results in determining the reflection coefficient as traditional methods. The value of the reflection coefficient in the neighbouring points can differ significantly since at these points the absorber forms its new step and just at these points the sound field is most nonhomogeneous. It can be seen clearly from Fig. 6b, where the spatial changing of the reflection coefficient for different frequencies is presented. We can see that at the points of the appearance of the absorber's new step the maxima of the reflection coefficient are observed (points X_3, X_4 and X_5).

Let us summarize the results represented by these dependences.

1. In the regions of each new step the change of the main field's characteristics occurs. As a rule the minima of the reactive intensity are situated in these zones.

2. In the first zones of the absorber, at frequencies of 63 and 125 Hz an increase of the intensity and sound pressure values is observed. Apparently it is connected with the effective geometrical factor's contribution – the decreasing of the internal diameter of the pipe.

3. Also it is possible to notice that the average value $\langle\varphi_{pv}\rangle$, while moving inside the absorber, decreases monotonically with increasing frequency, the inclination of the average line grows.

4. The gradual increase of the absorber's reflection coefficient, while moving towards the absorber's centre, occurs at all frequencies.

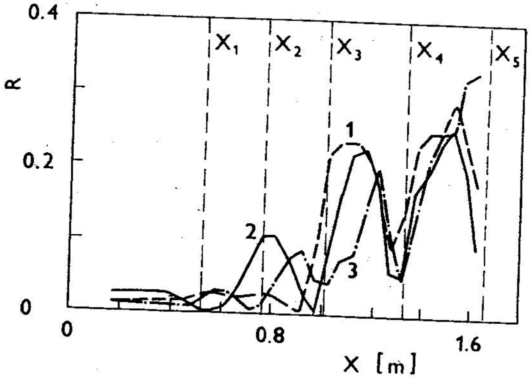

Fig. 6b. Spatial dependence of the reflection coefficient value for different frequencies: 1 – 125 Hz; 2 – 250 Hz; 3 – 500 Hz.

IV. CONCLUSIONS

From these preliminary results it is obvious that in the region of the sudden change of the interferometer diameter the behaviour of the quantities that characterize the field distribution differs greatly from the monotonic. Here two factors come into play: the absorber's diameter change (geometry) and the presence of the absorber in the regions, close to the interferometer's walls (absorption). The combined influence of these factors leads to the fact that the energy field characteristic distribution inside the interferometer possesses a quasi oscillating character. It is possible to calculate the reactive component of the energy flow density vector according to the formulae obtained in the approximation of plane waves [2,3]. The significant difference between the obtained dependence and the expected one implies that in the area considered the field is essentially unhomogeneous.

In a similar situation great care is required in using the traditional methods of measurements. Only an extensive investigation of all the parameters will explain the sound field structure's features.

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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ЭНЕРГЕТИЧЕСКОЙ СТРУКТУРЫ ЗВУКОВОГО ПОЛЯ В ИНТЕРФЕРОМЕТРЕ ПРИ НАЛИЧИИ ПОГЛОТИТЕЛЯ

В статье приведены результаты экспериментального исследования структуры поля в акустическом интерферометре при наличии поглотителя. Измерялось пять полевых величин: акустическое давление p, колебательная скорость v, сдвиг фаз φ_{pv} между p и v, активная и реактивная компонента вектора плотности тока энергии. Особое внимание уделялось методическому аспекту вопроса — сравнительному анализу различных подходов к определению коэффециента отражения от поглотителя R.