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An experimental investigation of the finite amplitude wave in the nearfield

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ABSTRACT

An experimental investigation of the pressure field distribution produced by a plane circular piston in water were carried out applying two receivers of different size. A transducer of 46-mm-diam and 1,0-MHz center frequency was used as a transmitter. The PVdF needle hydrophone of 1 mm diameter was the first receiver, whereas the second one had a diameter equal to that of the source. All experiments were performed using a high precision computer-controlled tank facility.

INTRODUCTION

Recently there has been a steady growth of interest in the nonlinear problem of finite aperture sound beams in a few disciplines such as acoustic microscopy [10], ultrasound therapy and diagnostics [6, 9], parametric acoustic arrays [8], and the measurements of the nonlinear parameter B/A with finite amplitude effects of sound waves [11, 14].

In many applications the most important are phenomena occurring in the nearfield area. It is caused by such a measurement set up arrangement and the choice of the parameters of used transducers that the measured or diagnosed object are situated there.

Many papers have been published which consider a problem of the nonlinear distortion of the finite amplitude wave in the nearfield of the source. The fine structure of the nearfield brings difficulties to both the theoretical and the experimental investigations. One of the first papers devoted to the theoretical description of the nearfield of the finite amplitude source was published in 1971 by Ingenito and Williams Jr. [12]. The second harmonic field of a piston transducer was calculated by means of the perturbation method. The significant step was made by Norwegian scientist, who solved the KZK equation numerically, using the finite difference scheme [1], which is known as the Bergen code. It accounts for the nonlinearity, absorption and diffraction. The solution is widely used in comparisons with the measurement results [3, 17] and modified according to the measurements conditions, for instance for focused circular sources [4], for rectangular sources [5, 16].

The paper presents the results of the experimental investigations of the finite amplitude wave radiated by the circular piston. The investigations were carried out in the nearfield of the transducer using the high precision device which controlled the movement of the receiver.

EXPERIMENTAL METHODS

The experimental measurements were made with a plane transducer (46-mm-diam) mounted at the one end of the water tank 1,4 m long by 1,2 m wide and 1.2 m deep. The transducer was driven at its center frequency of 1,0-MHz corresponding to ka=96 (k is a wavenumber, a is the transmitter radius). It was driven with a tone pulse, approximately 50 cycles long and a pulse repetition was of about 8 msec. This gave a quasi-continuous wave in the measuring area field without standing waves. Reflections were eliminated by using a time gate on the receiver pulse.

The pressure generated by the transducer was measured using a 1-mm-diam PVdF needle hydrophone. The hydrophone was mounted on a three-dimensional translation stage that allowed to position the hydrophone anywhere in a plane perpendicular to the acoustic axis of the transducer or along this axis. The movement resolution is theoretically equal to 0,0125 mm. The output from the hydrophone was fed directly into on a digital storage oscilloscope (HP 54503A). The oscilloscope was used to capture a part of the time waveform from the middle of the tone burst. The time waveform was then transferred to the controlling computer and five (or two) cycles were Fourier analyzed to extract the harmonic amplitudes. The measured waveforms were averaged before analyzing.

The second receiver used in measurements was of equal area as the transmitter, but it was sufficiently broadband to receive the harmonics generated by nonlinear propagation in water. The measuring method of nonlinear distortion in which two coaxial transducers of equal area are used was described by Cobb [7].

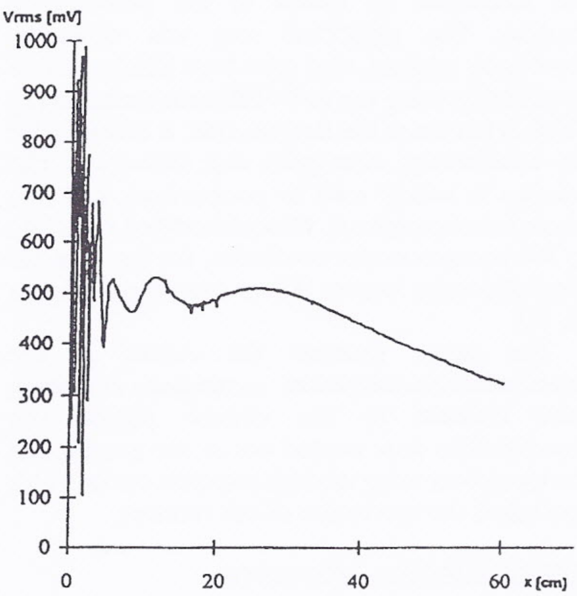

Fig. 1. Results of measurement an axis pressure distribution

EXPERIMENTAL RESULTS

Results of the experiments allow to make a thorough study of the nonlinear distortion growth

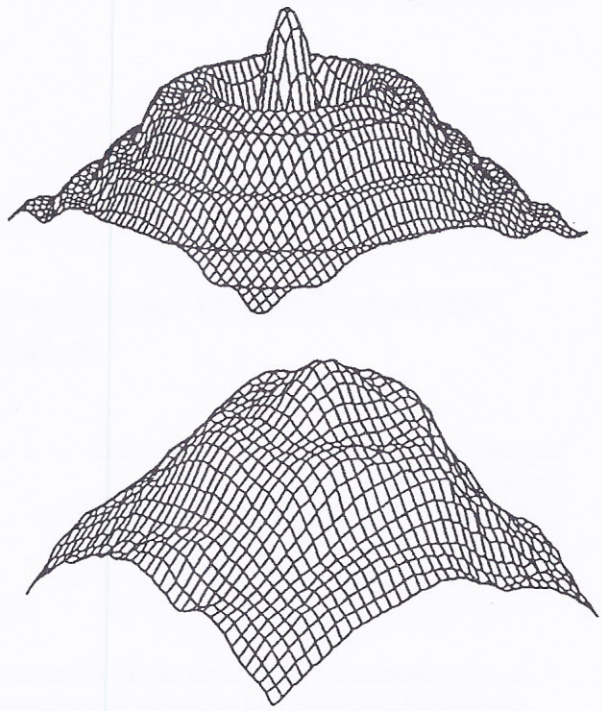

Fig. 2. The distribution of the pressure in the plane perpendicular to the transmitter axis placed at 12,7 cm from the transmitter;
a - the theoretical prediction,
b - results of measurements

in the area close to the transmitter. Figure 1 shows the measured relative rms value of the pressure along the axis. The distance at which the last axial maximum occurred (about 30 cm) is approximately equal to the one predicted basing the linear nearfield theory [2].

The distribution of the pressure (rms) in a plane perpendicular to the transmitter's axis placed at the distance of 12,7 cm from the transmitter is shown in Fig. 2. The fine structure of pressure well visible in theoretical prediction (Fig. 2a) is confirmed by the results of the measurements (Fig. 2b). The differences between the predicted and the measured distributions are caused by a large distance between the points of the measurement net and the large diameter of the hydrophone. Both values are large in comparison with the wavelength (1,5-mm).

The growth of the nonlinear distortion can be noticed by observing the rising in the amplitude of the second harmonic with the distance from the source. Fig. 3 shows the relative amplitude of the second harmonic pressure in planes placed at the distance of 120 mm, 270 mm and 370 mm from the transmitter. In the last of these planes (370 mm from the source) the distortion is quite great. In the Fig. 4 are shown the four first harmonics measured in this plane.

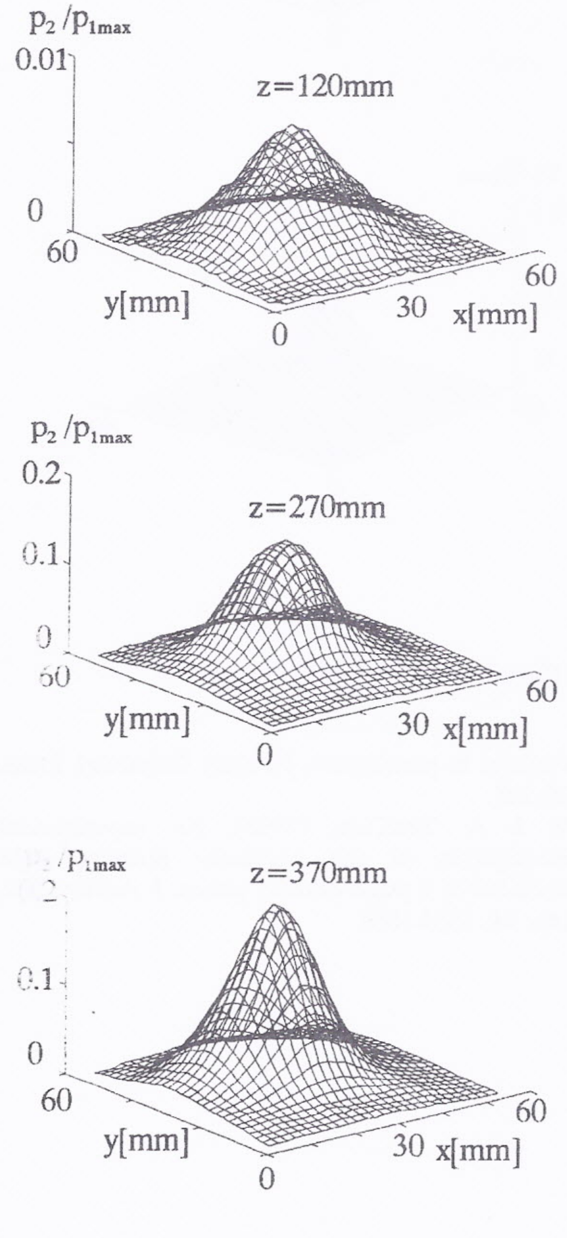

Fig. 3. Relative amplitude of the second harmonic pressure measured at different three distances from the source

CONCLUSIONS

The paper presented the method of the experimental investigations of the finite amplitude wave field distribution. The measurement results obtained using the high precision facility which controlled the movement of the receiver were presented as well. The results of measurements allow to make a thorough study of the nonlinear distortion growth in the nearfield. They confirm the usefulness of both the elaborated method and the measurement set up for the investigations of the finite amplitude wave source in its nearfield.

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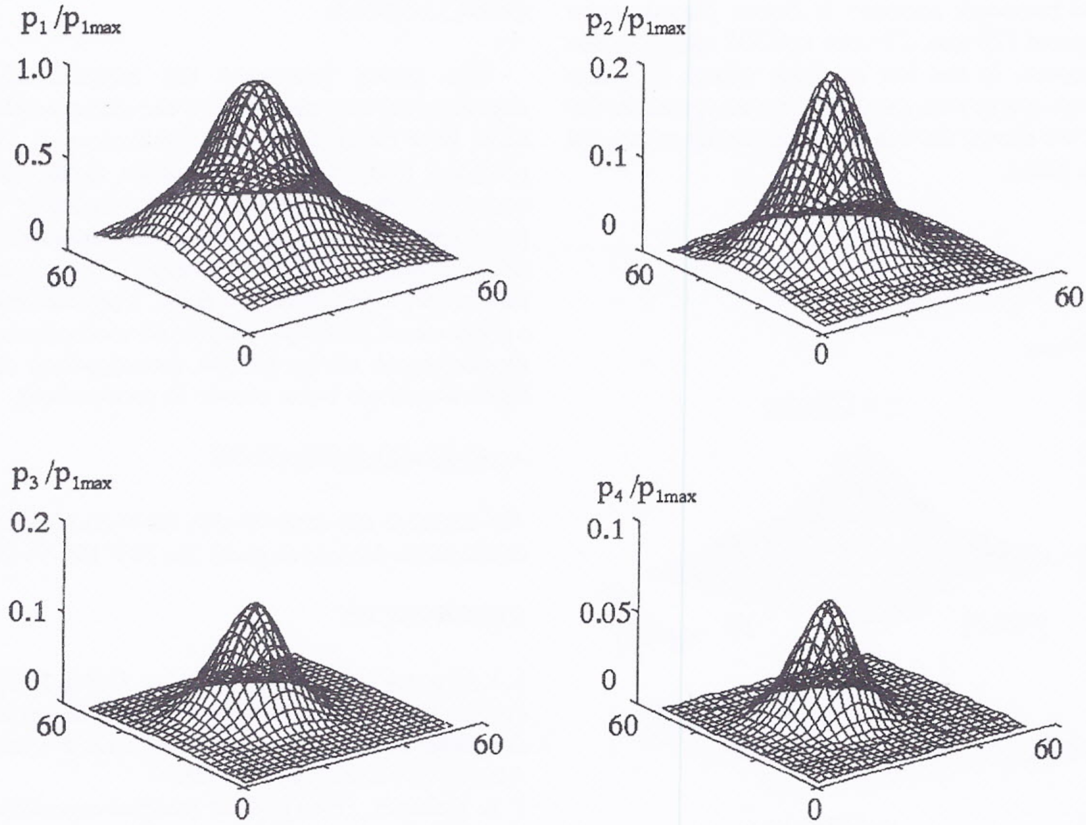

Fig. 4. The four first harmonics measured at the plane placed at 370 mm from the source

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