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THE INVESTIGATION ON PREDICTION AND CALIBRATION OF LOW-FREQUENCY SOUND FIELD CHARACTERISTICS IN LARGE-SCALE NON-ANECHOIC POOL

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In order to predict the sound field of the underwater sound source in non-anechoic pool, a numerical calculation method based on Actran is proposed in this paper. The non-anechoic pool is being as a widely used experimental apparatus, mastering the sound field characteristics is very important for acoustical testing. The boundary conditions of non-anechoic pool cannot be treated as rigid boundary conditions because of high absorption at the walls. For non-anechoic pool of concrete structures, using impedance boundary to describe the sound field boundary is more appropriate. The numerical method is based on finite element theory, in which the acoustics finite element software Actran is used for computing. By carrying out principle verification tests, the impedance values at different frequencies are obtained. Based on the established numerical method, the relationship between sound field of non-anechoic pool and free field was studied. By using the results of numerical calculation, the correction of sound field between free field and non-anechoic pool is obtained. Using this correction quantity, the sound source's sound field in free field can be obtained by measuring the sound field in non-anechoic pool. Comparisons of the results of the proposed method with verification tests show good agreement.

Keywords: low frequency, sound field prediction, impedance boundary, sound field calibration

1. Introduction

With the increase in the regulation of anthropogenic ocean noise pollution, measuring the level of underwater acoustic noise sources will become increasingly important in the future. There are two principal ways to measure the noise level of underwater sources. The most direct way is measuring the noise level of underwater sources in open sea or lakes [1]. However this method is expensive in time and is easily affected by the environment. Another way is measuring the noise level of underwater sources in non-anechoic pools[2-3]. Compared with the measurement in open sea or lakes, measuring noise level of underwater sources in non-anechoic pools has significant advantages such as lower cost, short test time and lower background noise.

The non-anechoic pool is being as a widely used experimental apparatus, mastering the sound field characteristics is very important for acoustical testing and exploring advanced measurement methods. Compared to the reverberation chamber , the water-filled tank, that we call it the non-anechoic tank cannot be treated as ideal reverberant because of higher absorption at the walls[4]. Therefore, it is inappropriate to use the ideal boundary to describe the boundary of the sound field. For non-anechoic pool of concrete structures, using impedance boundary to describe the sound field boundary is more appropriate.

The acoustic characteristic of a chamber is determined by the boundary conditions, accurately describing the boundary of the sound field is a prerequisite for accurate prediction of the sound field.

Literatures about reverberation chamber have focused on the problems of the influences by different boundary conditions. Maa [5] established a transcendental equation for an arbitrary impedances rectangular room from the case of uniform impedances. Bistafa [6] developed two numerical procedures for finding the acoustic eigenvalues in the rectangular room with arbitrary wall impedances, one numerical procedure applies Newton's method and another procedure poses the eigenvalue problem as one of homotopic continuation from a non-physical reference configuration in which all eigenvalues are known and obvious.

Du [7] proposed a Fourier series method to analysis a rectangular cavity with arbitrary wall impedances.

This paper proposed a numerical method to predict the sound field of non-anechoic pools. The numerical method is based on finite element theory, in which the acoustics finite element software Actran is used for computing. The impedance values at different frequencies are obtained by numerical method and used to describe the boundary of the sound field for numerical calculation.

2. Method

In order to use impedance boundary to describe the boundary of the sound field, the impedance values at different frequencies must be obtained. In this paper, a virtual Kundt's tube is established in software Actran to obtain the impedance values of non-anechoic pools' walls at different frequencies. In the noise control and architectural acoustics engineering, a large number of acoustic materials and acoustic structures are used, the acoustic performance of the test is an important part of acoustic measurements.

The Kundt's tube is a common measuring device to measure acoustic parameters of acoustic materials. The sound absorption coefficient and acoustic impedance of the acoustic material can be measured by using standing wave ratio method and transfer-function method in Kundt's tube, these methods have been Become the standard test method and the international standards for these measurement methods have also been established [8-9].

As shown in the Figure 1, the Kundt's tube consists of a finite length pipe, the source is placed at one end of the pipe and the material to be tested is placed at another end, the pipe wall can be considered as rigid boundary when placed in air. If the frequency of the source in the tube is lower than the cut-off frequency of the pipe, only the plane wave is propagated. The cut-off frequency of the pipe is

$$f_0 = \frac{1.84}{\pi} \cdot \frac{c_0}{D} \tag{1}$$

where D is diameter of the pipe, c_0 is sound speed.

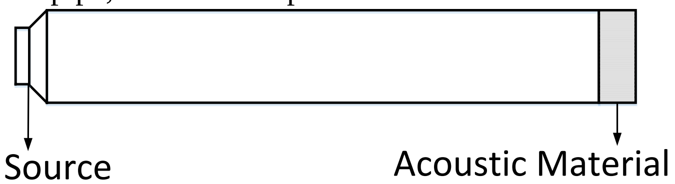


Figure 1: Schematic of Kundt's tube.

For impedance boundaries, the ratio of sound pressure to particle velocity at the interface of the two media is determined by the nature of the two media. If Z is used to describe the impedance value, the expression of Z is

$$Z = \frac{p}{v} \tag{2}$$

where p is the complex sound pressure on the boundary, v is the complex particle velocity on the boundary. As long as the impedance values at the interface of the two media are obtained, the boundary of the sound field can be described by the impedance boundary in the simulation calculation.

The impedance values can be obtained by establishing a virtual Kundt's tube in software Actran. Unlike the actual measurement, the virtual Kundt's tube in Actran can calculate the sound pressure and velocity at the interface. Therefore the impedance of the material can be obtained by placing a field point at the interface.

3. Numerical Calculation and Verification

Actran is a finite element programs for modeling sound propagation, transmission and absorption in an acoustic, vibro-acoustic or aero-acoustic condition. Since the Kundt's tube is axisymmetric model, in order to save the calculation time, the 2D model is used to calculate. The modal of the virtual Kundt's tube in Actran is shown in Figure 2, the fluid mesh and test material mesh are established and a microphone is placed at the interface of two medium. Rigid boundary added at the boundary of the tube and velocity boundary is added as the source. After the numerical calculation, the sound pressure and the velocity at the microphone are extracted by the post-processing part of Actran. The impedance can be calculated by (2). The advantage of describing the boundary of the sound field with the impedance boundary is that the structure of the pool wall is not taken into account in modeling. Therefore, only the model of the fluid in the pool need to be established when calculating the sound field.

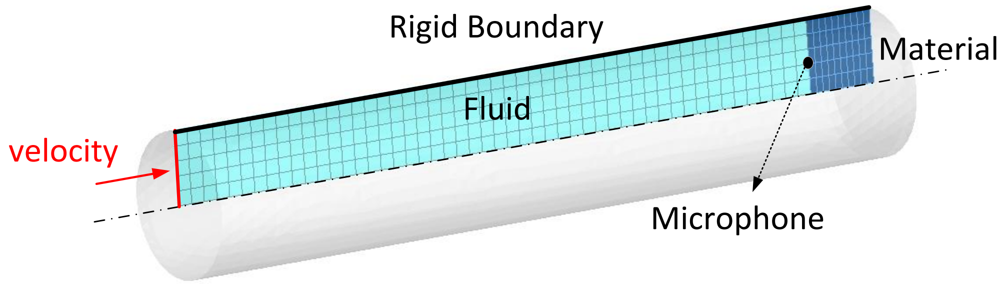


Figure 2: Schematic of virtual Kundt's tube in Actran.

In order to verify the feasibility of the proposed method, the sound field of a glass tank with 1.474m internal length, 0.9m internal wide, 0.013m thickness and 0.6m water depth was calculated by using this method and the experimental measurements were made. The modal of the virtual Kundt's tube in Actran included water, glass and air, a microphone was placed at the interface of water and glass. The value of the impedance is calculated by using the post-processing part of Actran and shown in Figure 3.

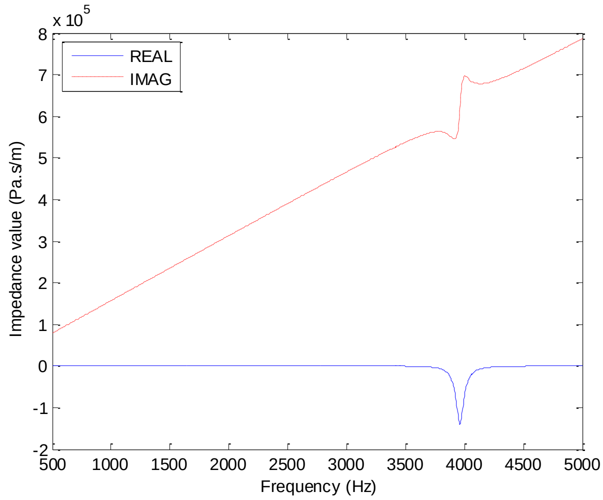


Figure 3: The impedance value.

The modal of the glass tank is shown in Figure 4, the walls of the pool are set as impedance boundaries and the water surface is set as an absolute soft boundary. In order to facilitate the description of the spatial position in the sound field, the length of the pool is defined as the x-axis, the width direction is defined as the y-axis and the depth direction is defined as the z-axis. A point source is placed at (1.3m, 0.75m, 0.3m) and 12 field point is placed along the length direction.

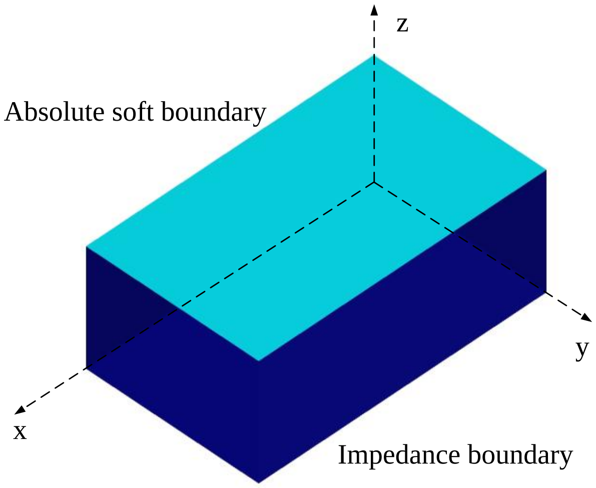


Figure 4: Schematic of glass tank modal in Actran.

The principle verification tests are carried out in the glass tank. The transmit signal was loaded to the transducer (EDO 6829) after amplified by power amplifier (Instruments, INC. L2). A hydrophones (B&K 8103) was used to measure the sound field of the glass tank, the outputs of the hydrophones were then fed to an analyzer (B&K PULSE3660D) and stored in a computer. The results of the experiments and numerical calculations are shown in Figure 5 and Figure 6, the experimental and numerical results are in good agreement and the feasibility of the proposed method is verified.

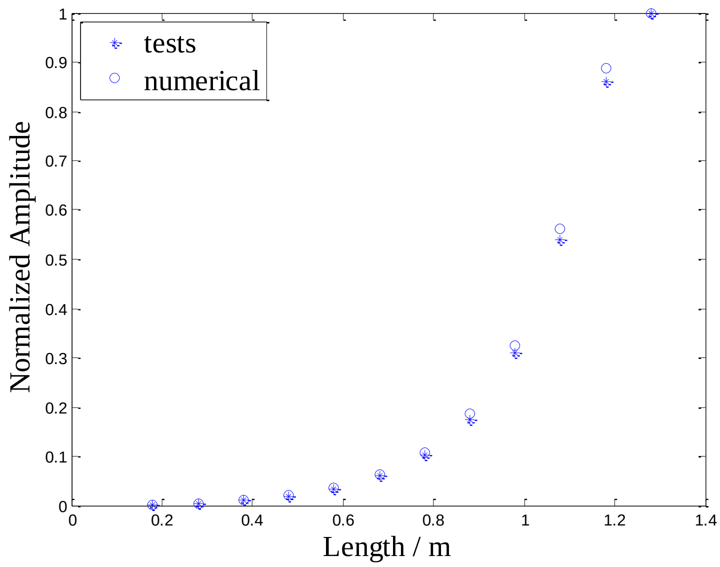


Figure 5: The comparison results along the length direction of the glass tank at 1300 Hz.

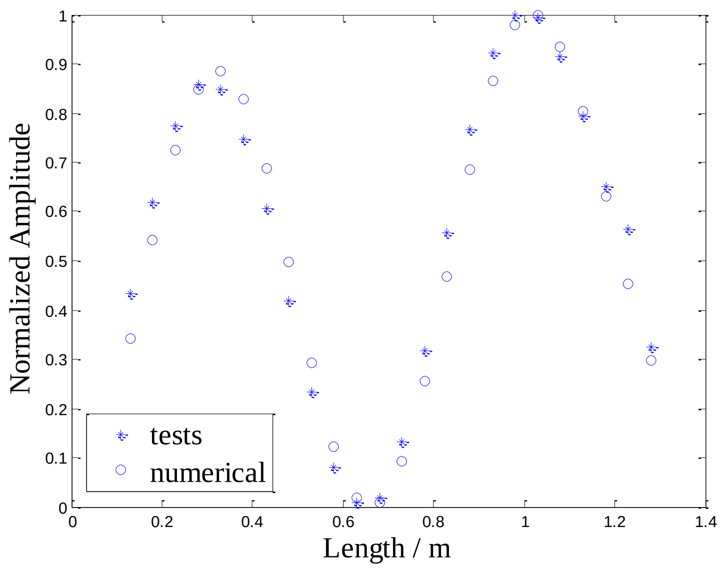
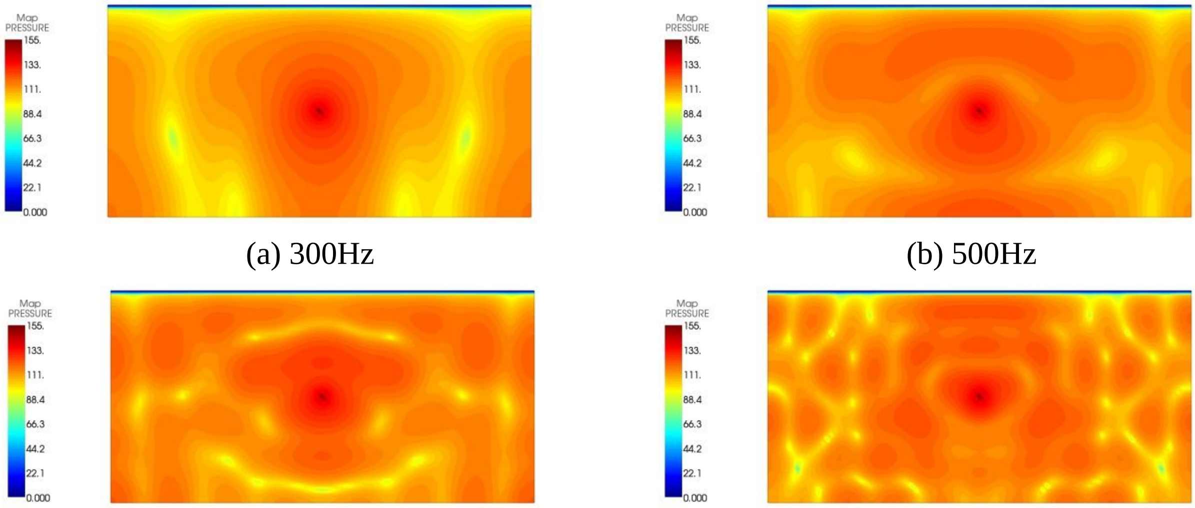


Figure 6: The comparison results along the length direction of the glass tank at 1800 Hz.

4. Numerical Calculation of Sound Field in Large-scale Non-anechoic Pool

For non-anechoic pool of concrete structures, using impedance boundary to describe the sound field boundary is more appropriate. The low frequency sound field of a non-anechoic pool of concrete structures, of which the internal length is 10m, the internal wide is 5m and the water depth 5m, is simulated by the method proposed in this paper. The numerical results at different frequencies are shown in Figure 7, a point source is placed at center of the pool and Figure 7 shows the a cutplane along the length direction of the pool.



(a) 300Hz (b) 500Hz

(c) 700Hz (d) 900Hz

Figure 7: The numerical results of sound fields at different frequencies.

5. Discussion

A numerical calculation method based on Actran using impedance boundary to describe the boundary is proposed in this paper. A virtual Kundt's tube is established in software Actran to obtain the impedance values of non-anechoic pools' walls at different frequencies. For sound fields that can not be described with ideal boundaries, the use of this method can quickly and accurately predict the sound field. The method proposed in this paper is applicable not only to non-anechoic pools, but also to calculation of sound field of rooms and cars.

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