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PANEL MEASUREMENTS AT LOW FREQUENCIES (≤ 2000 Hz) IN WATER TANK

C. GIANGRECO and J.F. ROSSETTO*

*C.E.R.D.S.M., Chemin de la Gardiole, Le Brusq, F-83140 Six Fours les Plages, France***NEREIDES, rue du Docteur Calmette, ZI Toulon Est, BP. 125, F-83088 Toulon cedex, France***ABSTRACT:**

This paper deals with the panel measurements at low frequencies in underwater acoustic. A technique based on the cross correlation function is used in order to test different methods of determination of reflection and transmission coefficients of panels. The tests, conducted on three panel tests, show the feasibility of doing acoustical characterization using test panel measurements at low frequencies (500-2000 Hz).

INTRODUCTION

Many materials are studied to be acoustically efficient at low frequencies (below 2000 Hz) for underwater purposes. The acoustical characterization can be done by measuring the complex (modulus and phase) reflection and transmission coefficients with respect to the frequency using panel test. The size of the latter must be at least larger than the wave length of the acoustic wave which is submitted to the panel [1]. Furthermore, it is necessary to develop method which can retrieve the free field information using measurements made in confined environment. As a matter of fact, below 2000 Hz, the pulsed sound technique cannot be used any more in tank of reasonable sizes.

In this paper, a technique based on a processing of the cross correlation function between the input signal of the projector and the output signal of the hydrophone is used. Using this technique, different methods of determination of the reflection and transmission coefficients have been tested at low frequencies (Total Pressure Method TPM, Acoustical Impedance Method AIM, Wave Separation Method WSM). These tests are conducted on three types of materials: (Steel - P.Foam - Compliant tube gratings). They show the feasibility of doing acoustical characterization using test panel measurement at low frequencies (below 2000 Hz).

PROCESSING OF THE CROSS CORRELATION FUNCTION:

A window is applied on the cross correlation function between the output signal of the hydrophone and the input signal of the projector in order to remove the effect of the boundary echoes (this is possible if the peaks are narrow enough) [2]. Then the direct FOURIER transform is applied to obtain the free field cross spectrum. This technique is applied on test panel measurements and a specific experimental set-up has been used (see figure 1).

DESCRIPTION OF THE MEASUREMENT TECHNIQUE:**- Transmission coefficient:**

The transmission coefficient is evaluated using two measurements: one with the panel ($G^c(f)$) and the second without the panel ($G_0^c(f)$) without moving the transducers:

$$T_{dB} = 20 \log \left(\frac{G^c(f)}{G_0^c(f)} \right)$$

Where:

$| |$ is the modulus of the complex number.

$G^c(f)$ is the free field cross spectrum with the panel using the processing of the cross correlation function described in the previous section.

$G_0^c(f)$ is the free field cross spectrum without the panel using the same processing of the cross correlation function.

- Reflection coefficients:

Different methods of determination of reflection coefficient have been tested.

Total Pression Method (TPM):

Two measurements are necessary (one with the panel ($G^c(f)$) and a second without the panel ($G_0^c(f)$)) and the reflection coefficient is calculated as follows:

$$R_{dB}(f) = 20 \log \left(\left| \frac{G^c(f)}{G_0^c(f)} - 1 \right| e^{-2jkd} \right)$$

Where: k is the acoustic wave number
 d is the panel-hydrophone separation.

Wave Separation Method (WSM):

In this case, measurements at two locations of the receiver (by moving the hydrophone) are used. The reflection coefficient is then determined by using the CHUNG method [3].

$$R_{dB}(f) = 20 \log \left(\left| \frac{[G_{S2}^c(f) \times E_1 - G_{S1}^c(f)] [E_1 - E_2]}{[G_{S2}^c(f) \times E_2 - G_{S1}^c(f)] [E_2 - E_1]} e^{jk(d_1 - d_2)} \right| \right)$$

Where:

$$E_1 = e^{jk(d_1 - d_2)}$$

$$E_2 = e^{-jk(d_1 - d_2)}$$

$G_{S1}^c(f)$ is the free field cross spectrum with the hydrophone located at the distance (d_1) from the panel using the processing of the cross correlation function described in the section 2.

$G_{S2}^c(f)$ is the free field cross spectrum with the hydrophone located at the distance (d_2) from the panel using the same processing of the cross correlation function.

Acoustic Impedance Method (AIM):

The reflection coefficient is determined using the measurement of acoustic impedance at the surface of the panel which is obtained using two hydrophones:

$$R_{dB}(f) = 20 \log \left(\left| \frac{Z_N - 1}{Z_N + 1} e^{2jk(d_1 - \frac{d_1 - d_2}{2})} \right| \right)$$

Where Z_N is the acoustic impedance of the panel at the measured point normalized to the water acoustic impedance.

EXPERIMENTAL RESULTS:

Experimental investigation has been conducted on three test panels which are the following:

- Steel panel ($1.35 \times 1.35 \times 0.03 \text{ m}^3$)
- P. FOAM panel ($1.3 \times 1.3 \times 0.028 \text{ m}^3$)
- Two layers of Compliant tubes ($2.00 \times 1.80 \times 0.13 \text{ m}^3$)

Experimental Set-up
 Figure 1

- Steel panel results:

The steel has been chosen because the acoustical characteristics of this material are well known and the effect of the diffraction due to the edge of the panel is strong. The experimental results are compared to the infinite panel model [4] results. The measurements are only valid after 700 Hz as said in the introduction (the panel size must be at least larger than the wave length of the acoustic pressure). Different distances have been studied experimentally (projector-panel separation, hydrophone-panel separation). As far as the steel is concerned, it is better to use the total pressure method (see figures 2, 3, 4). The WSM and AIM methods lead to same results.

- P. Foam material results:

The acoustical characteristics of the P. Foam are not well known in the frequency, temperature and pressure ranges of interest. The measurements using the technique described in this paper are compared to measurements made in lake using pulsed sound technique which is very accurate when the contribution between the boundaries echos can be separated from the direct wave one. The transmission coefficients are plotted in figure 5. The results obtained in tank are very close to the measurements made in lake. The slight discrepancies are due to different temperature condition during the experiments.

- Compliant tube gratings:

The measurements of this panel is not easy even in lake using the pulsed sound technique due to the long duration of the transient part of the output response of the panel. For these reasons the measurements made in tank using the technique described in this paper are compared directly to the results obtained using a mathematical model of compliant tube (5).

The measurements are very close to the expected values for the transmission coefficients (figure 6) and for the reflection coefficients (figure 7). In the latter, only total pressure method results are plotted because the other techniques lead to similar values. The accuracy is improved by doing a complex averaging using the reflection coefficients obtained at two panel-hydrophone separations (60 mm and 70 mm - figure 7).

CONCLUSION:

The experimental results using a processing of the cross correlation function between the output signal of the hydrophone and the input signal of the projector show the feasibility of doing acoustical characterization at low frequencies using test panel measurements. Nevertheless, the transmission coefficient is obtained more accurately than the reflection coefficient.

STEEL - Transmission coefficient in dB
Figure 2

STEEL - Reflection coefficient in dB
Figure 3

STEEL - Reflection coefficient in dB
Figure 4

P.FOAM - Transmission coefficient in dB
Figure 5

COMPLIANTS TUBE GRATINGS
Transmission coefficient in dB
Figure 6

COMPLIANTS TUBE GRATINGS
Reflection coefficient in dB
Figure 7

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