CHARACTERISATION OF MATERIALS FOR UNDERWATER ACOUSTICS APPLICATIONS USING TEST PANEL MEASUREMENTS

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1. INTRODUCTION

Many passive materials are used in SONAR systems. Futhermore they are used in acoustical coating in order to improve the acoustical furtivity of operational submarines.
To design such devices properly it is necessary to know the acoustical characteristics of the materials. The latter can be either homogeneous (according to the acoustic wave length) or heterogeneous (network of tubes or inclusions). An homogeneous material is completely characterized if the density (ρ), the complex longitudinal (C_L) and transerve (C_T) velocities are known. These parameters are frequency, hydrostatic pressure and temperature dependant.
As far as the heterogeneous materials are concerned, the characterisation is more complex.
In order to deal with the different types of materials we propose to use the measurements of transmission coefficient and reflection coefficient using test panel.
First these measurements can be used in order to work out the velocities of the waves which are propagated into the materials. Second these measurements can be used in order to calculate specific coefficients to define the optimal application for the measured materials. In this paper the experimental aspects of the measurement are discussed. Then we describe the exploitation of the measurements in order to obtain acoustical characteristics.

2. ANALYSIS OF THE MEASUREMENT OF REFLECTION AND TRANSMISSION COEFFICIENT USING TEST PANEL

The measurement of the reflection and transmission coefficients in normal incidence are illustrated on figure 1. The measurements are disrupted by the scattering waves due to the edge. In our laboratory we use a surface hydrophone for normal incidence measurement. This sensor reduces the perturbation. The size of the hydrophone has been obtained using a theoretical model based on Helmhotz equation [1]. For example, for a 0.9 x 0.9 m^2 panel the optimal size is 0.3 x 0.3 m^2.
This model also defines a low frequency limit for this type of measurement : the size of the panel should be larger than the acoustic wave length of the incident acoustic wave which is propagated in the water.
The incident wave is also important. Some researchers use directive projectors in order to reduce the effects of the edges.

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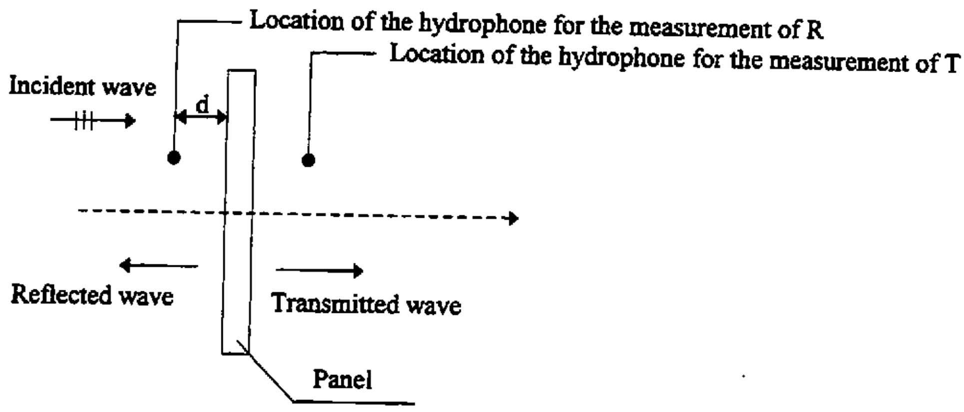

Figure 1 - Measurement of the reflection and transmission coefficient using test panel

For some situations when the reflection and transmission coefficients change drastically according to the incident angle of the incidence wave this type of projector leads to measurement errors. As a matter of fact this emission wave can be assumed to be a superposition of many waves at different incidence angles. Hence, the measured coefficients are a combination of the coefficients of the different incident waves. These measured coefficients are different from the normal incident ones because of the evolution of these coefficients according to the incident angle.
These results were at the origin of the method which has been developed in our laboratory for the measurements of the reflection and transmission coefficients according to the incident angle. The principle is the following:
The panel is excited by an arbitrary wave. The incident, reflected and transmitted acoustic pressures fields are sampled using a receiving array.
Then using Discrete Fourier Transform (2 dimensional in space domain) the measured data are converted in the wave numbers domain. The informations obtained at each wave number which corresponds to a specific incidence angle are used to calculate the reflection and transmission coefficients according to the incident angle.
The accuracy of the measurement is better for transmission coefficient. For reflection measurement, it is necessary to locate the receiving array close to the panel (less than 2 cm).
Using the theoretical model based on the Helmholz equation we have shown that incident acoustical field should respect some conditions [2] :

- the acoustical field should not be larger than the receiving array size.
- the level of waves to be measured should be more important than the noise.

An experimental set-up has been developed : A column of projectors is moved in order to synthetize a cylindrical array. At the reception, weightings are applied depending on the location of the column. The weightings are calculated in order to obtain in a given volume (measured volume) the generation of the desired waves. This is an extrapolation of the concept of the Trott array [3]. On figure 2, we present the measurement of transmission coefficient of a viscoelastic panel at 5 kHz up to the incident angle equal to 50° using this technique.

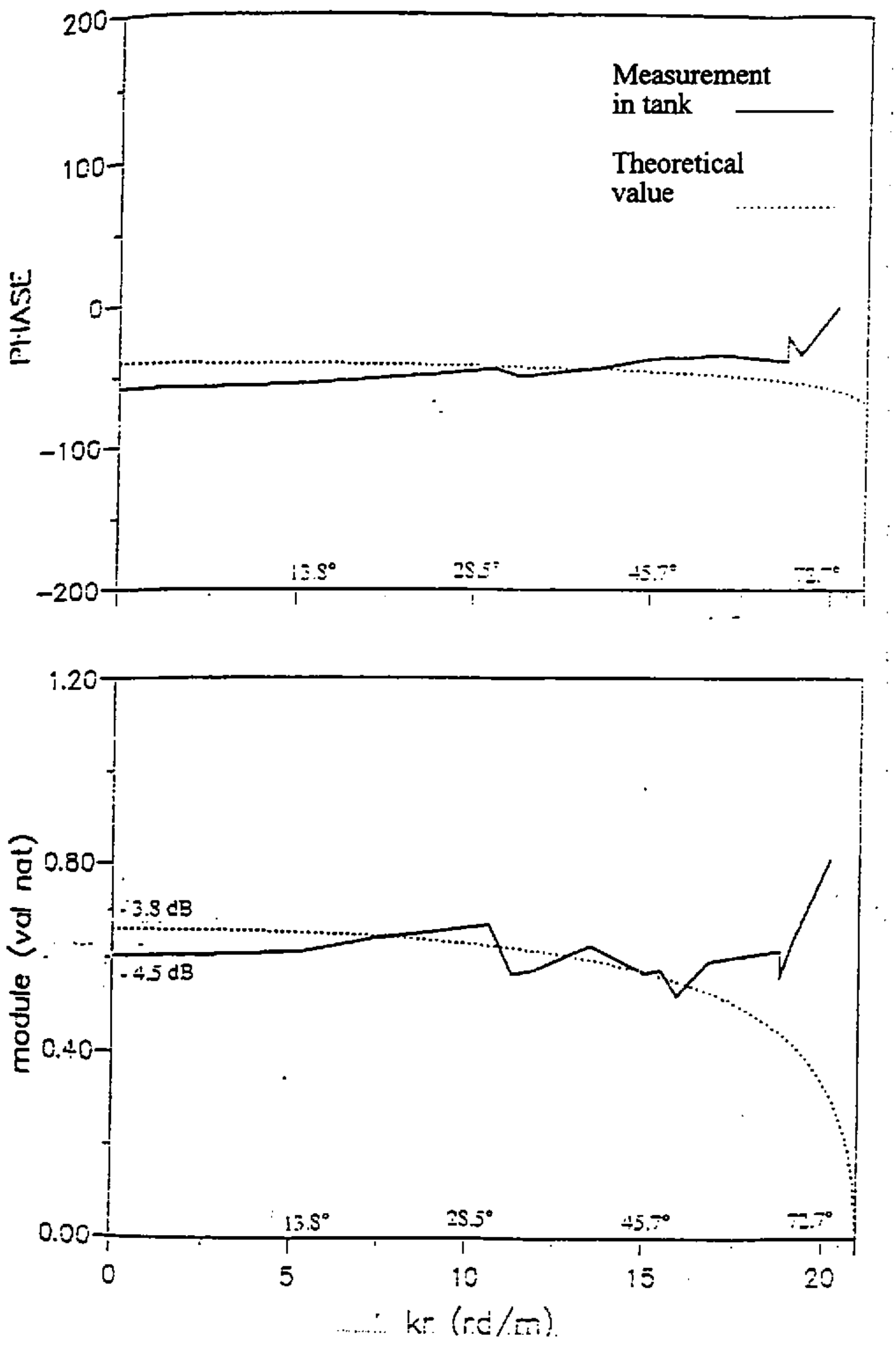

Figure 2 - Measurement of the transmission coefficient according to the incident angle of a viscoelastic panel at 5 kHz

3. DETERMINATION OF THE COMPLEX VELOCITIES OF THE LONGITUDINAL AND TRANSVERSE WAVES.

3.1. Complex longitudinal wave velocity

The measurement of R and T in normal incidence can be used to obtain the complex longitudinal wave velocity. In our laboratory we have developed two methods [4] :

- The first one consists of the resolution of an inverse problem in the complex plane using the theoretical expression of the transmission coefficient. This method is adequate if the velocity is drastically frequency dependant.
- The second one consists of the minimization of the function which uses the measurements and the theoretical expressions of R and T in a frequency band. This method is more convenient when the measurements are made according to the hydrostatic pressure. In this case, the density and the thickness of the material cannot accurately be known and are obtained using this method if we consider these data as imputs of the process of optimization.

These methods have been applied successfully to a polyurethan foam with air inclusion (see figure 3). These methods are not adequate in low frequencies for high acoustical impedance materials because in this case, R and T are not dependant on the complex longitudinal wave.

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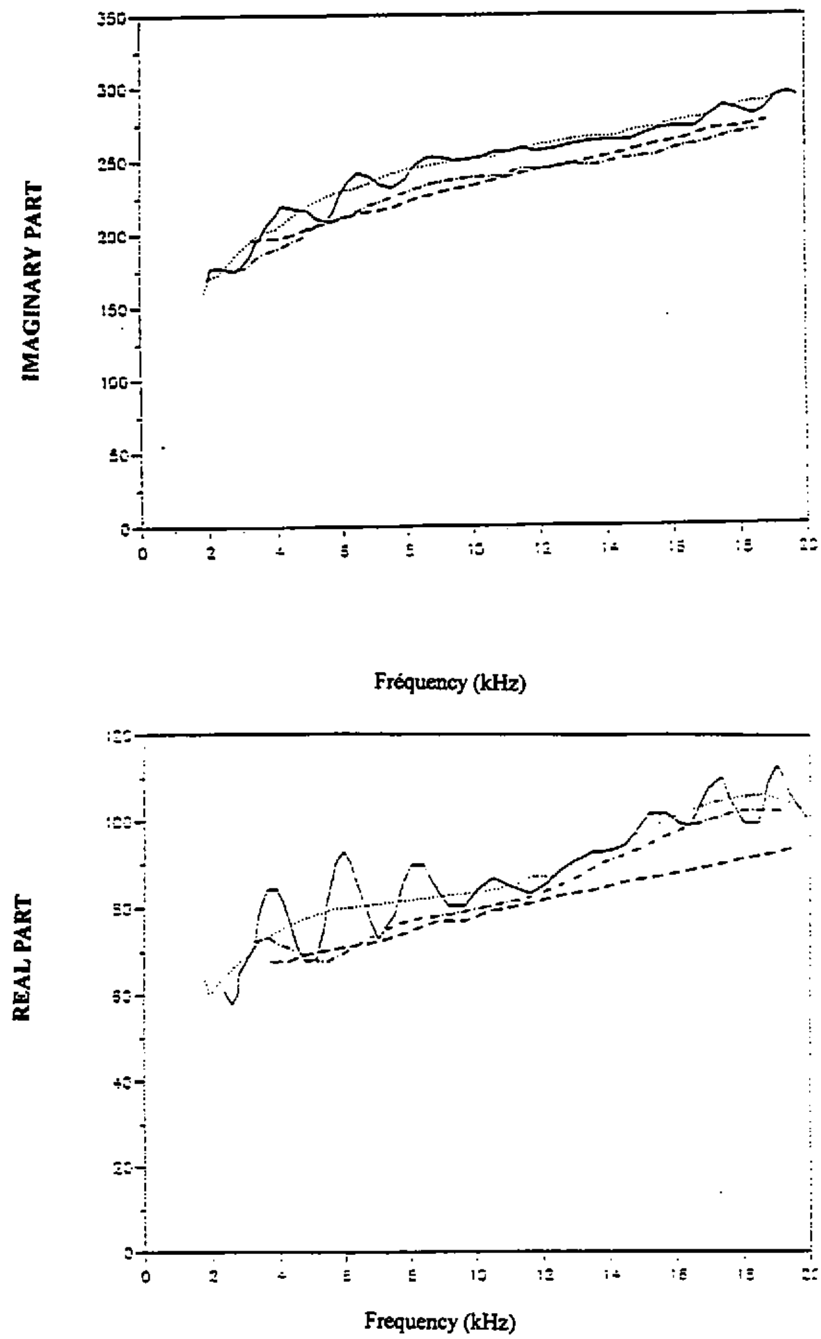

Figure 3 - Determinations of the longitudinal wave velocity of a polyurethan material using panel measurements

3.2. Complex transverse wave velocity

The complex transverse wave velocity can be obtained by measuring the complex shear modulus (G):

$$C_T = \sqrt{\frac{G}{\rho}} \qquad (1)$$

But we have studied the feasibility of obtaining C_T using transmission coefficient measured according to the incident angle. We have used only T measurements because the R measurements are not accurate enough. C_T is obtained by minimizing the following function F :

$$F = \frac{1}{N}\sum_{i=1}^{N}\left|T_m(\theta_i) - T(\theta_i)\right| \qquad (2)$$

Where N is the number of incident angles which are measured at the given frequency.

- $T_m(\theta_i)$ is the measured transmission coefficient at θ_i
- $T(\theta_i)$ is the theoretical value using infinite plan model.

A parametric study was undertaken. The main conclusion is :
This method is adequate except for materials whose transerve velocity is too low (< 170 m/s) or too high (> 2400 m) and for low or high acoustical impedance materials.

4. CONCLUSION

This paper has presented the acoustical characterization used in DCN Ingenierie. We mainly use panel measurements either at normal incidence using a surface hydrophone or at off normal incidence using a technique based on acoustical holography technique.
These data can be used to work out C_L and C_T. They can also be used to calculate specific coefficients to determine the optimal application for the measured materials [5].

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5. REFERENCES

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