UNDERWATER OBJECT CLASSIFICATION BY MEANS OF AN ACOUSTIC METHOD

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The paper deal with the basic problem connected with the free vibration of finite cylindrical steel shell immersed in water. At the first there is described the theoretical model of this problem by means of the Helmholtz equation with the von Neumann boundary condition on the radiated surface. Next the results of a numerical investigation are presented. The final results are the acoustic characteristics obtained in the sea. These ones were compared to the numerical results..

INTRODUCTION

Underwater object detection, identification and classification immersed or buried by means of an acoustic method has been of great interest for a few decades by acousticians marines and archaeologists. There are often used the objects e.g. mines, amphoras in a finite cylindrical shape or similar.

The method of active locations (echolocations) is very popular in detection of the immersed or buried objects. In the shape of reflected sounding pulse one can observe the rigded part of sounding pulse and so-called tail. In this tail we can find a substantial feature of the object, that scattered the sound pulse.

This paper described the basic method that allows to determine the shape, volume of the cylindrical steel shell immersed or buried in the sea.

1. PROBLEM FORMULATION

For describing the pressure distribution in a far field we used the Helmholtz equation in the following form:

$$\Delta\Phi(\vec{R}) + k^2\Phi(\vec{R}) = -f(\vec{r}_0) \quad (1)$$

where:

$$\Delta = \frac{1}{q}\frac{\partial}{\partial q}(q\frac{\partial}{\partial q}) + \frac{1}{q^2}\frac{\partial^2}{\partial \varphi^2} + \frac{\partial}{\partial x^2},$$
$$q = \sqrt{z^2 + y^2}, \quad R = \sqrt{q^2 + x^2}$$

The solution of this equation is as follow:

$$\Phi(\vec{R}) = \int_{S_0} \frac{\partial \Phi(\vec{r}_0)}{\partial \vec{N}_0} G(R, r_0) dS_0 \tag{2}$$

where:

S_0 is a radiated surface and

$G(R, r_0)$ is a Green function.

On the source surface for $r_0 = a$ should be satisfied the boundary condition so-called von Neumann condition in this form:

$$-\frac{\partial \Phi(\vec{r}_0)}{\partial \vec{N}_0}\Bigg|_{r_0 = a} = \dot{w}(\vec{r}_0) \tag{3}$$

where:

$\dot{w}(r_0)$ is normal velocity of the shell vibration.

The pressure distribution is described by the following formulae:

$$p_{mn} = \frac{ac\rho}{4R}\dot{W}_{mn} e^{-i\pi/2(n+1)} e^{-i(\omega t - kR)} [J_n(ka\sin\Theta) + iE_n(ka\sin\Theta)]\psi \tag{4}$$

where:

$$\psi = \frac{\sin(kL/2\cos\Theta)}{\cos\Theta}[1 + \frac{(kL\cos\Theta)^2}{(2m\pi)^2 - (kL\cos\Theta)^2}]$$

c - speed of sound;

ρ - medium density;

$J_n(\cdot), E_n(\cdot)$ - Bessel and Weber-Lommel functions order *n* respectively.

Geometric configuration of radiating cylinder is presented on figure 1.

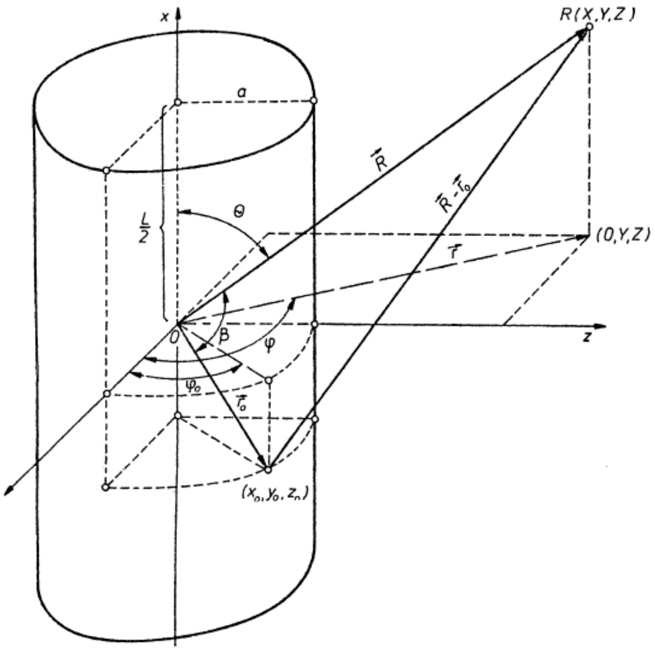

Fig. 1. Geometric configuration of radiating cylinder

We assume that cylindrical surface is covered by continuous distribution of single sources given by:

$$\dot{w}_{mn}(\vec{r}_0) = \frac{\dot{W}_{mn}}{2}[1-\cos\frac{m\pi}{L}(2x_0+L)]\cos n\varphi_0 \tag{5}$$

where:

m, n are modal and nodal number respectively,

$\dot{W}_{mn}$ is amplitude of normal velocity.

Another relation is obtained when we take into account the pressure wave radiation by a part of an infinite cylinder. It is given by these formulae:

$$p_{mn} = \frac{i\rho\omega_{mn}}{\sqrt{2\pi}} e^{in\varphi} \int_{-\infty}^{\infty} \frac{A_n(\xi,\varphi_0)H_n(\tau R)e^{ix\xi}}{\tau H_n'(\tau a)} d\xi \tag{6}$$

where:

ξ is a wave number in x direction.

After simplification we obtain:

$$p_{mn} = \frac{c\rho\varepsilon(n)}{4\pi kR}\dot{W}_{mn} e^{-i\pi/2n} e^{-i(\omega_{mn}t-kR)} \frac{\psi}{(\sin\Theta)H_n'(ka\sin\Theta)} \tag{7}$$

where:

$\varepsilon(n) = 1 \quad for \quad n = 0$

$\varepsilon(n) = 2 \quad for \quad n \geq 1$

Distribution of sound pressure can be find by means of the relation (4) or (7) for the cases when we know ω_{mn} and connected with them $\dot{W}_{mn}$. On the figure 2 the chart of $|p_{mn}|_1$ and $|p_{mn}|_2$ as function of kasin Θ was presented.

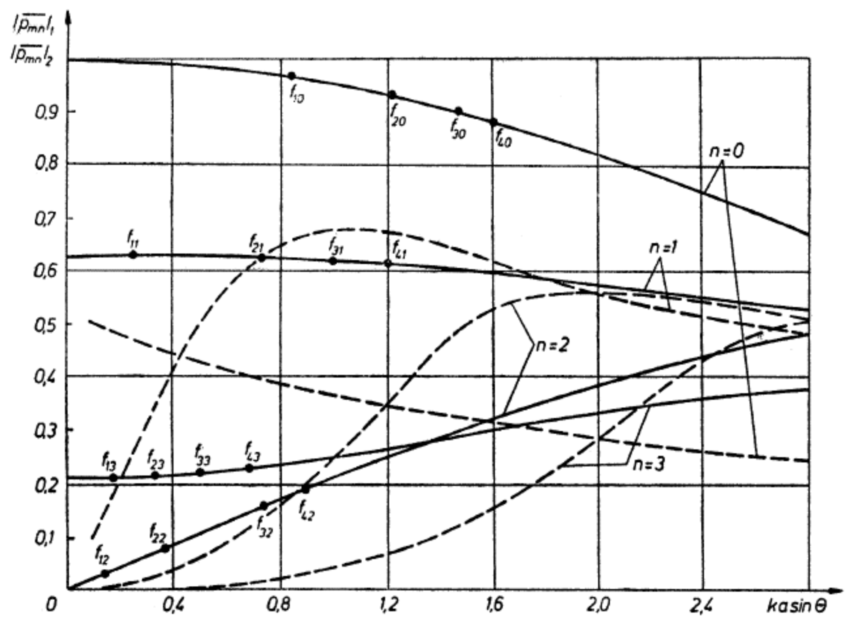

Fig. 2. The chart of $\left|p_{mn}\right|_1$ and $\left|p_{mn}\right|_2$ as function of kasin Θ

To normalized these function we divided it by factor:

$$\frac{ac\rho}{4R}\dot{W}_{mn}\varphi . \tag{8}$$

2. EXPERIMANTAL INVESTIGATION

As a first step we are carried out examinations of the normal velocity distribution on the cylindrical steel shell. The cylindrical shell was immersed in water in an anechoic basin. On its surface was mounted velocity transducer as is shown in figure 3.

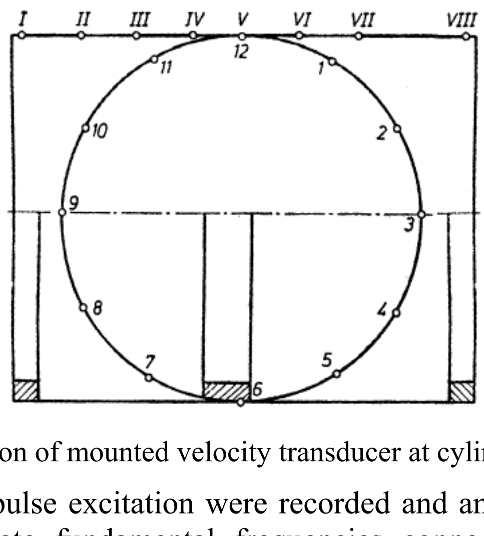

Fig. 3. Position of mounted velocity transducer at cylindrical shell

These signals after a pulse excitation were recorded and analysed. On the base of this examination we can estimate fundamental frequencies connected with free oscillations frequencies. Figure below shown an example of velocity signal observed at point VIII.

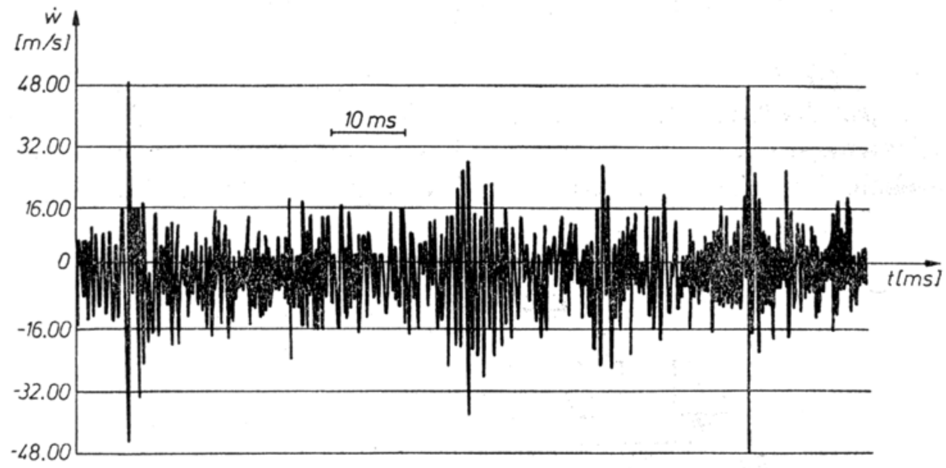

Fig. 4. Signals observed at point VIII

On the figure 5 are shown the form of function for different free vibrations frequences. The velocity distribution along the x - axis and φ - angle.

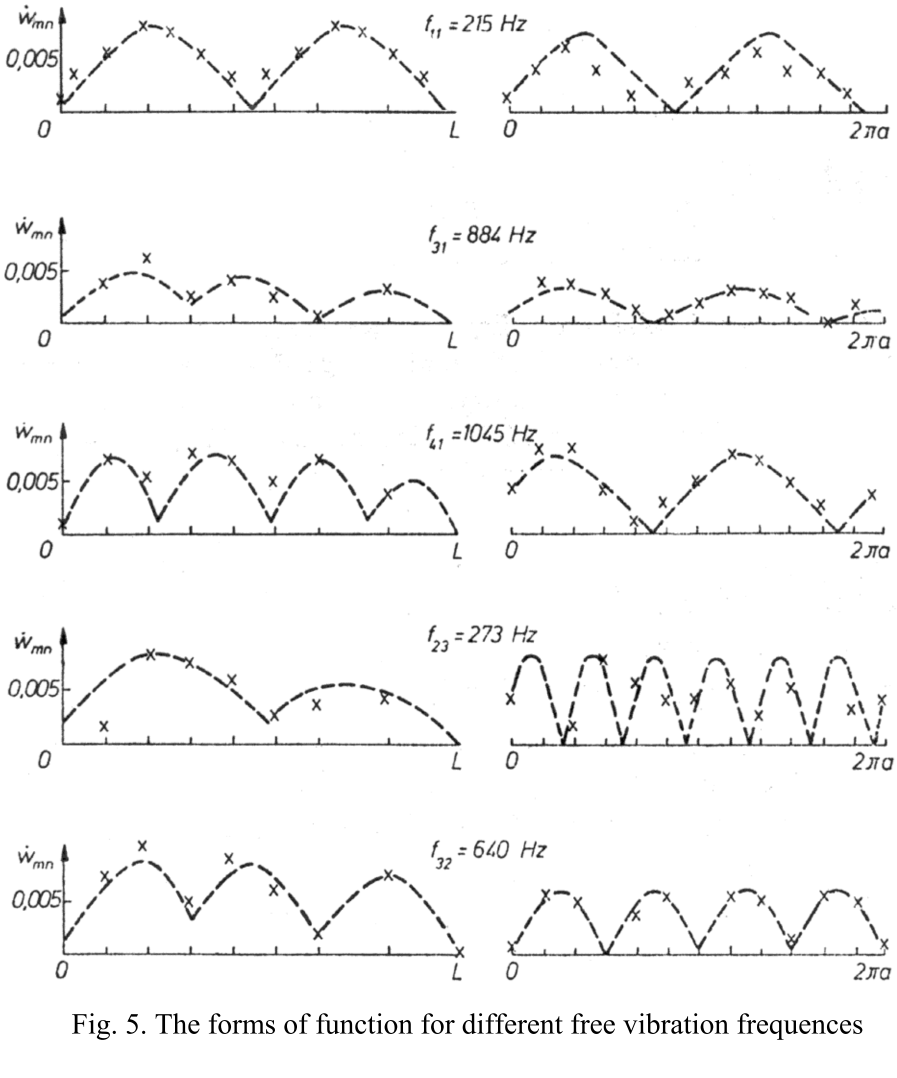

Fig. 5. The forms of function for different free vibration frequences

3. MEASUREMENTS CARRIED OUT IN THE SEA

The next step of these investigations were measurements of scattered sound pressure by a finite cylindrical steel shell exciting by sound pulse generated by the impulsive source. This kind of source allows to excite low free oscillations of the cylindrical shell for e.g. less than $f = 200\ Hz$.

In figure 6 are shown two curves as a results of comparison of two different relations between the values obtained by means of theoretical relation and measurement one. The better approximation gives the relation (7).

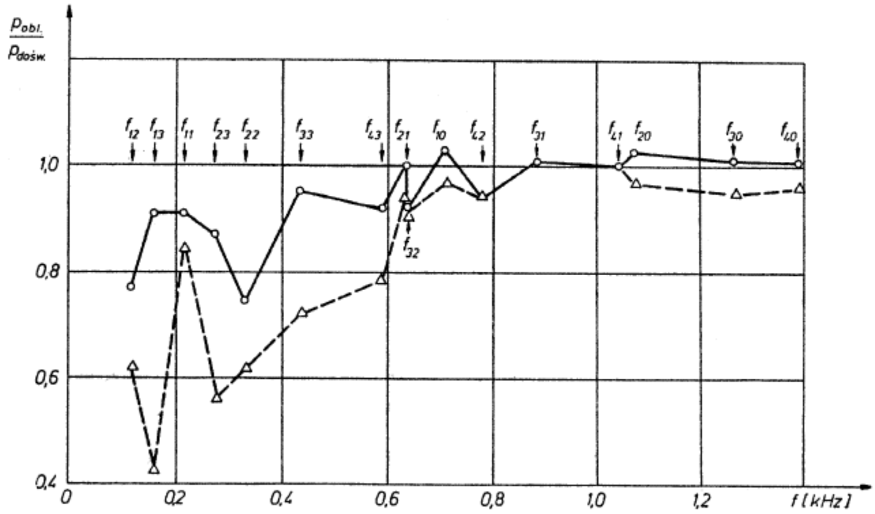

Fig. 6. Results of comparison of two different relations

4. CONCLUSIONS

Finding a free oscillation of a immersed finite cylindrical steel shell we can estimate its volume and shape and some times also inside content. These investigations are a first step to find a method for interpretations some relation between geometrical relation of the target and scattered sound field.

The next step of the investigation will be devoted to the proper signal processing allowing to extract the interesting information from scattered signal.

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