Hydrodynamic pressure of a ship

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ABSTRACT

The paper presents a method of description of hydrodynamic pressure distribution generated by a moving ship. The solutions consider the basic geometric parameters of a hull. Both the numerical and experimental investigations of hydrodynamic pressure have been carried out for different speeds of a hull in reference to the surrounding water medium. The results have been presented for two measurement depths. The numerical results were compared with the data obtained while the "in situ" measurements. The similarity between the time waveforms of pressure was analyzed and the correction coefficients were introduced.

INTRODUCTION

The majority of the experimental results describing the changes in pressure caused by a moving ship lack the data of very low frequencies. The lowest frequency for most of the measurements is 10 Hz. This paper presents the results of measured changes in pressure in a frequency band of 0-10 Hz.

The knowledge about changes in pressure in this frequency band is practically useful. The disturbances generated by a hull are directly connected with the ship and take place very close. The hydrodynamic field of a ship depends on the velocity of the ship, the distance from the hull and also the hull's size and shape. The paper will consider the influence of the ship's motion parameters on its hydrodynamic field. There will be presented the results of both the experimental investigations and the computations of the pressure field generated by a hull, for which the curve of frames cross-sections areas corresponds to the changes of cross-section areas of two paraboloids of revolution [5](one for the bow, the other for the stern). The calculations were carried out applying the corrected formulas obtained basing on the sources and sinks theory and the linear, asymmetric in relation to the hull's center [2],[3],[5] distribution of sources.

THE METHOD OF DETERMINATION OF THE HYDRODYNAMIC FIELD DISTRIBUTION CREATED BY A SHIP

Taking into account the methods of determination of the ship's hydrodynamic field distribution it can be stated that the method of sources and sinks is more advantageous than

the method based on direct solution of the Laplace formula. The method of sources and sinks depending on the complexity of the hull's shape can be used to determine the hydrodynamic field basing on surface [1], [4] or linear distributions of sources. The first ones are placed on the hull's surface whereas the second ones in the axis of body of revolution built basing on the curve of frames cross-sections areas of the hull. Moreover this method allows to consider the influence of the seabed, effects connected with the propagation of a surface wave which is caused by the ship's movement and also the influence of the ship propeller's work.

Although this method will allow to determine the pressure distribution precisely, its programming will be very complicated and the calculations time consuming. While determining the field distribution for some sources (i.e. the axial-symmetric hulls), probably it will not be necessary to apply such a laborious method.

The work [3] describe the method of determining the pressure distribution, which will give good results for axial-symmetric hulls. This method was worked out applying the theory of sources and sinks, where the sources are distributed linearly and asymmetrically referring to the hull's center. The following formulas describe the disturbance of pressure at the seabed created by a hull, for which the curve of frames cross-sections areas corresponds to the changes of cross-section areas of two paraboloids of revolution (one for the bow, the other for the stern)

- from sources:

$$\Delta p_z(x,y,h) = \frac{\rho v_o^2 S_m}{\Pi a_z} \sum_{n=1}^{\infty} \left[-\frac{1}{R_{2z}} + \frac{1}{R_{1z}} \right] \quad (1)$$

- from sinks:

$$\Delta p_u(x,y,h) = \frac{\rho v_o^2 S_m}{\Pi a_u} \sum_{n=1}^{\infty} \left[-\frac{1}{R_{1u}} + \frac{1}{R_{2u}} \right] \quad (2)$$

where:

$$R_{1z} = \sqrt{(x+E_z)^2 + y^2 + (2n-1)^2 * h^2}$$

$$R_{2z} = \sqrt{(x+c_z)^2 + y^2 + (2n-1)^2 * h^2}$$

$$R_{1u} = \sqrt{(x-c_u)^2 + y^2 + (2n-1)^2 * h^2}$$

$$R_{2u} = \sqrt{(x-E_u)^2 + y^2 + (2n-1)^2 * h^2}$$

S_m - the maximal frames cross-section surface (to the water-line)
a_z - the length of a bow
a_u - the length of a stern
$c_z + c_u$ - the length of the cylinder insertion of a hull
$L_{oo} = E_z + E_u$ - the length of a ship (at the water-line)
ρ - the density of water
V_o - the velocity of a ship

The complete disturbance of pressure at the seabed is a sum:

$$\Delta p = \Delta p_z + \Delta p_u \quad (3)$$

Comparing the theoretical curves, determined using the dependence (3), with the measurement curves [2] it can be stated that their shapes are similar. However, the differences in absolute values of pressure can be noticed. These values are greater for the measurement curves. It can be supposed that the above differences are the result of introducing several assumptions and simplifications at the analytical formulation of the problem, especially:
- neglecting the influence of the ship propeller's work
- assuming the slender and narrow shape of the hull
- approximation of the real curve of frames

174

cross-sections areas with the simplified one
- assuming the stiffened free water surface
- considering the seawater as the ideal liquid

Experimental investigations, both real and model ones indicate that the following assumptions may have a great influence, depending on the circumstances, on the size and the distribution of the hydrodynamic field of a ship.

The work of a ship propeller makes water suck in. As the result the longitudinal characteristics of pressure field is changed. On the other hand making the free water surface stiff eliminates the pressure field generated by surface waves created by the ship's motion. These changes can be seen in a characteristic wave arrangement behind the ship. The last assumption that the seawater is the ideal liquid may make the results of calculations inaccurate in points placed very close to the hull's surface.

The assumptions mentioned above can be eliminated (more or less depending on the needs). This can be done applying a calculation scheme for more precise determination of pressure field connected with water flow about a hull. The scheme which was described in [4] gives more precise results but at the same time is more labor and time consuming. Because of these disadvantages the way of eliminating the differences between the theoretical and measurement curves by considering corrections was introduced:

$$\Delta p_{zm} = A_p(1 + L_F)\Delta p \qquad (4)$$
$$t = A_t t$$

where:

A_p - a correction of pressure value
A_t - a correction of pressure duration
$t = x/V_o$
L_F - the Froude number described by the following formula:

$$L_F = \frac{V_o}{\sqrt{g \cdot L_\infty}}$$

g - the acceleration of gravity

INVESTIGATION RESULTS

One ship was chosen to compare the computation and experimental results of investigations of the hydrodynamic pressure field. The measurements were carried out in the Gulf of Puck region for different speeds of the ship. The measurement sensors were placed at the seabed, at different depths.

The dependence (4) was used to calculate the distribution of the ship's hydrodynamic field for different speeds and distances from the hull. The hull's parameters which are occurring in the formulas were derived from the approximation with paraboloids of revolution. These parameters' values were chosen for which the differences of shapes between the curves of frames cross-sections areas and the approximating ones were minimal.

The sample results of measurement and corresponding calculation results have been shown in the Fig. 1, 2, 3 and 4. The presented results of investigations of the hydrodynamic field were obtained for one ship, different depths and ship's speeds.

CONCLUSIONS

Basing on comparison of the obtained theoretical and experimental curves it can be stated that their shape is generally similar. The differences in the pressure values are small too. The method presented in the paper was used to determine the ship's hydrodynamic field for different speeds and distances from the hull. It gives good results for hulls of axial symmetry. However, it does not consider the effects connected with the propellers' work and generation of surface waves caused by the motion of the ship. The method was worked out applying the theory of sources and sinks. The sources were assumed to be distributed linearly and asymmetrically in reference to the hull's center.

The effects described above can be considered (more or less depending on the circumstances). This can be done applying a calculation scheme for more precise
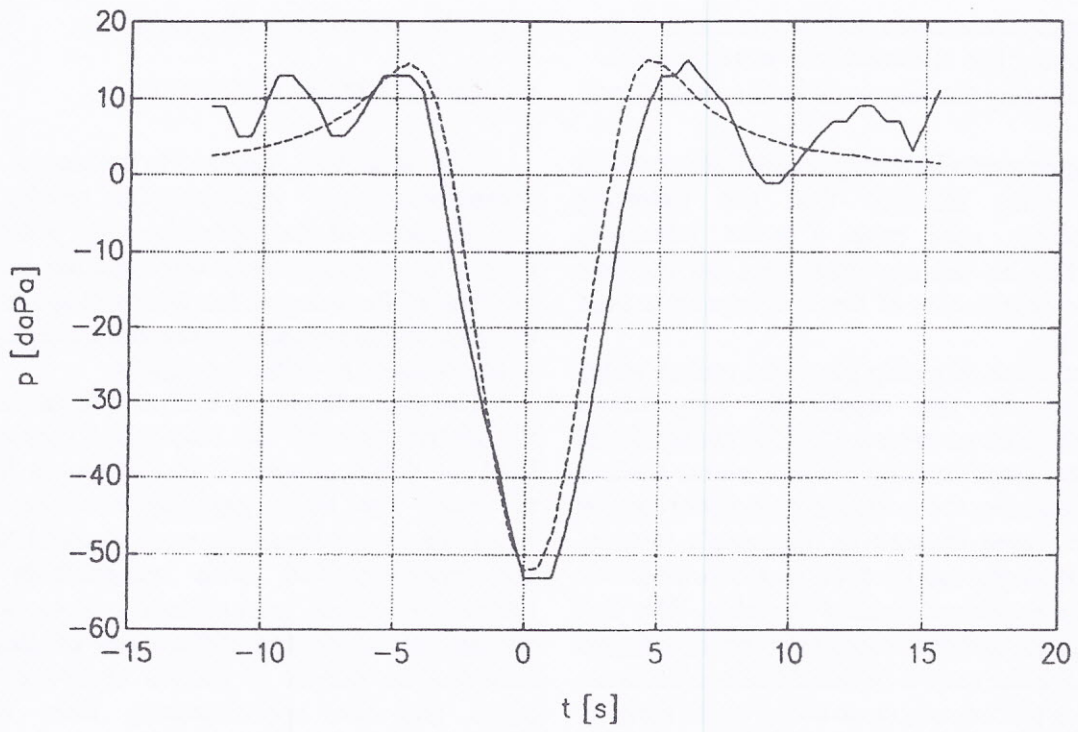
175

Fig.1. Curves of the hydrodynamic field of a ship for h=10.7 m, V$_o$=7.5 (kn) and y=0m
measurement _____ , theoretical - - - - -
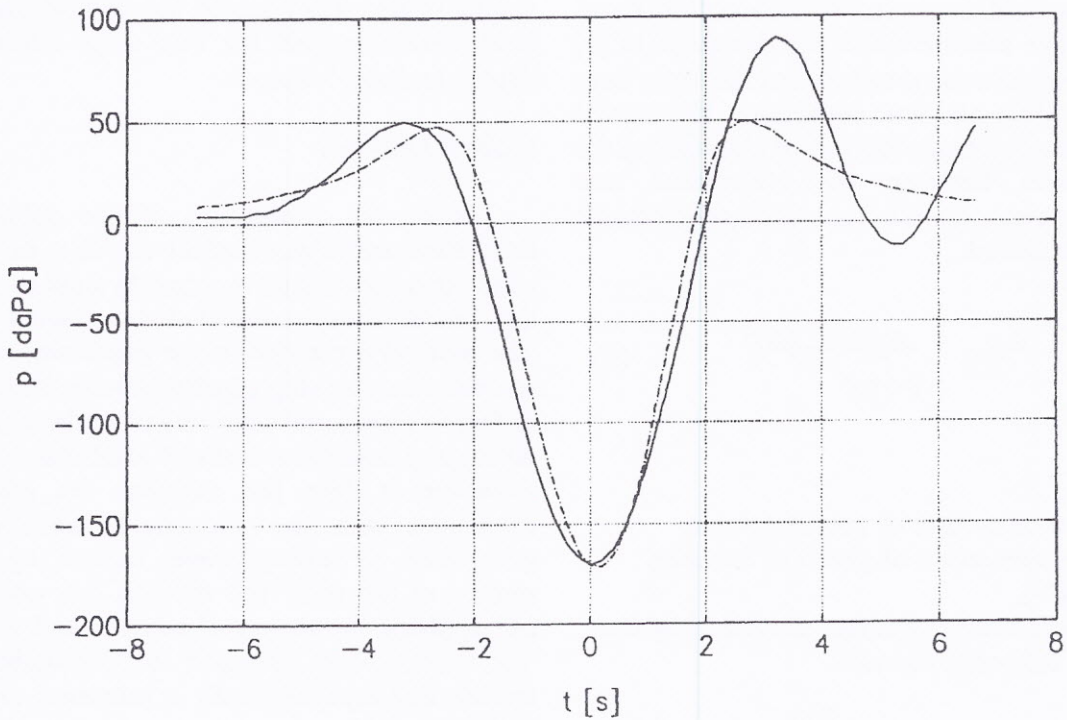

Fig.2. Curves of the hydrodynamic field of a ship for h=10.7 m, V$_o$=12.8 (kn) and y=0m
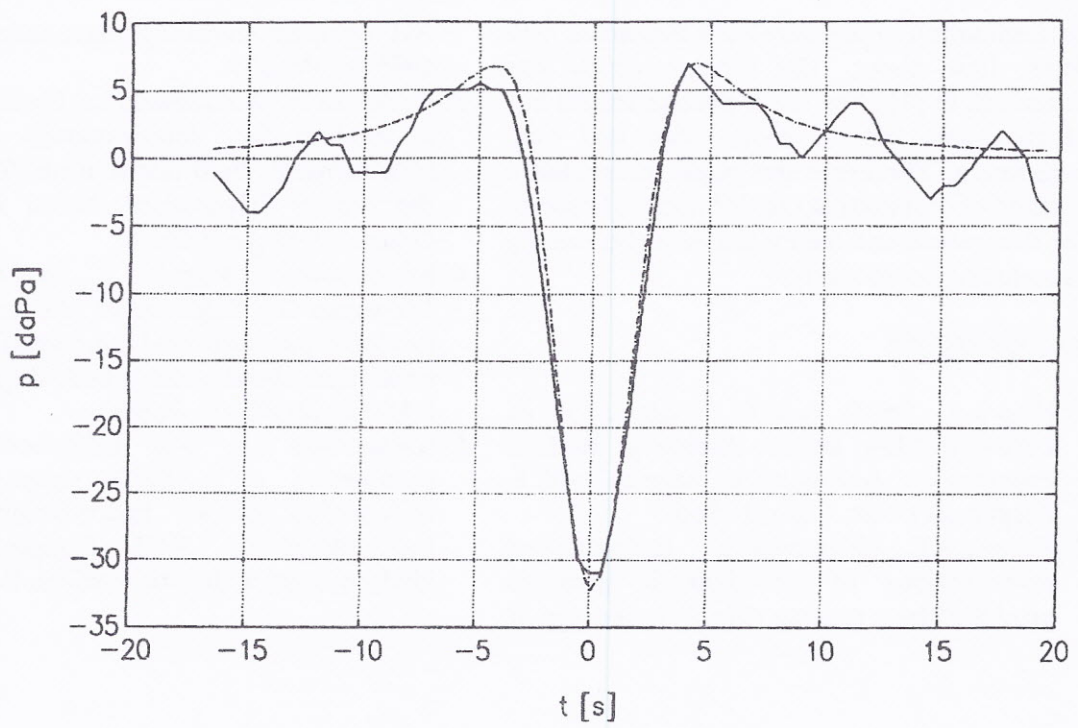measurement _____ , theoretical - - - - -

Fig.3. Curves of the hydrodynamic field of a ship for h=20 m, V_o=10.8 (kn) and y=0m
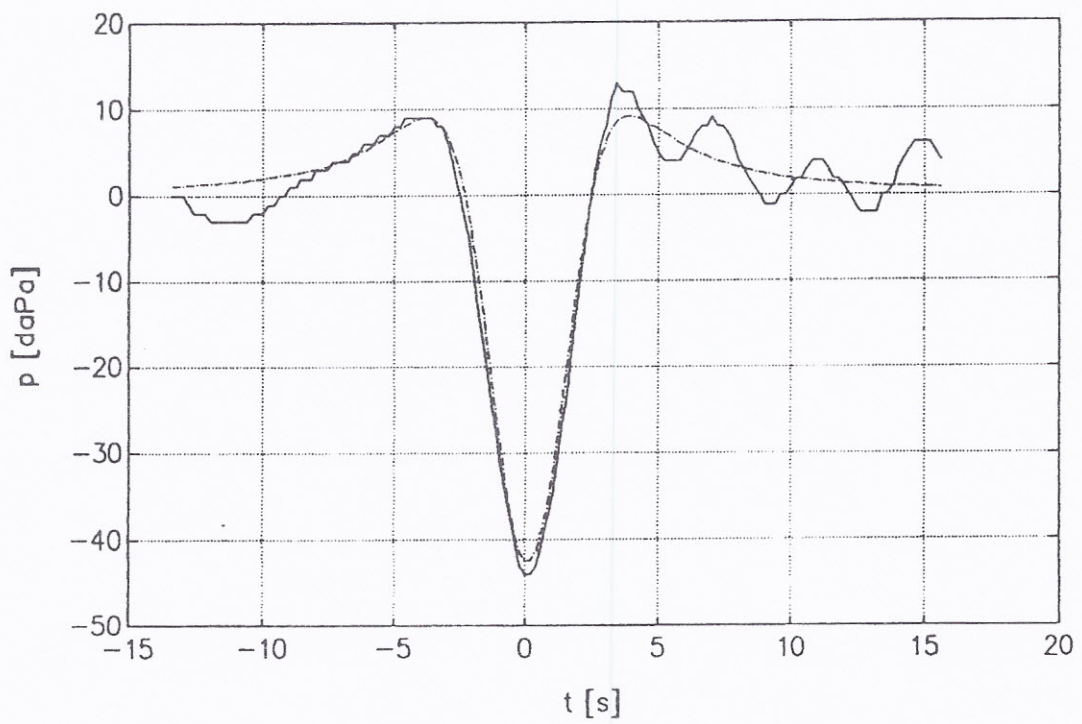measurement _____ , theoretical - - - - -

Fig.4. Curves of the hydrodynamic field of a ship for h=20 m, V_o=12.2 (kn) and y=0m
measurement _____ , theoretical - - - - -

determination of pressure field connected with water flow about. The scheme which was described in [4] gives more precise results but at the same time is more labor and time consuming. Therefore this paper presented a method of eliminating the differences between the theoretical and the measurement curves by introducing corrections.

REFERENCES

1. Hess J. L., Smith A.M.O. : Calculation of Potential Flow about Arbitrary Bodies. Progress in Aeronautical Science, vol. 8, Pergamon Press, Oxford 1966.
2. Kozaczka E., Milanowski L. : Experimental investigations of hydrodynamic pressure produced by a moving ship, Proceedings of XII Symposium on Hydroacoustics, Jurata 1995 (in Polish)
3. Kozaczka E., Milanowski L.: Elaboration of a method for determination of ships' hydrodynamic field distribution, Report on the project "Hydrodyn", Naval Academy, Gdynia 1995 (in Polish)
4. Koronowicz T., Bugalski T., Grabowska K., Waberska G.: Selection of the calculation model of pressure field connected with the water flow about a ship's hull, Report IMB PAS No 216/95 (in Polish)
5. Milanowski L. : The influence of the parameters of a hull's shape on the distribution of its hydrodynamic field, Proceedings of XIII Symposium on Hydroacoustics, Jurata 1996 (in Polish)