ON THE ESTIMATION OF WASH EFFECT OF SHIP WAVES SYSTEM

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Introduction

Development of fast speed waterborne transportation forced to carry out numerous investigations dedicated to shore erosion due the waves generated by high speed ships. The results of such investigations are the recommendations on fast speed ship design and on limitations on the ship speed in order to minimize wash effect. In Russia formerly this problem was not so crucial because during very long time the majority of high speed ships were hydrofoils with undersurface foils which do not generate strong waves. But presently a number of other types of fast ships and yachts are under development. So, the problems of shore wash, as well as of waves impact on small yachts moored near the shore “marine” have arise. Brief analysis of experimental work on wash led to conclusion that vast shallow water area in European part of Russia, especially on the rivers, on Caspian, Baltic and northern seas are rather unfavorable for development of the ship waves.

It is clear, that for development of recommendation and rules on waves limitation and it is necessary to obtain at least approximate data on the development of ship waves in the shallow water with various bottom profiles.

Some information on waves development may be obtained by model experiment. But allowance of bottom profile and wave pattern and great distance from the ship for all variety of environmental conditions and ship types may be obtained only by computer simulation and development of proper software is urgent task. It is natural to use as the basis for development of such software well done programs for computer simulation of ship wave pattern applied for perfection of ship hull lines in deep water. Present paper describes the first step of such work.

Problem set up

Shore erosion usually is provoked by waves generated by fast speed ships even of small displacement when they are going with fast speed or by big ships at medium speed heading near the seaside or on internal water ways. Character of wave pattern in both these case suggest on simulation by non-linear methods. The problem is unsteady due to irregularity of bottom bathymetry and shape of shore line. Practical tasks of hull line perfection due to design restrictions as a rule should be solved only by local modification of the hull. So, simulation methods should be sensitive to local change of hull lines.

Presently for solution of the tasks on development of the waves in shallow water successfully applied the methods based on Boussinesq’s equations. These methods make it possible to obtain the non – linear unsteady solution far away from the ship hull. [1]. Simultaneously for vicinity of the hull a number of simplified methods are applied for example the theory of slender ship. Simplified methods can not take into account local particularity of the hull.

KSRI had developed and applied in hull perfection routine software ShipWave based on non- linear panel method for solution of wave problem [2]. Experience of calculations by this software demonstrated acceptable sensitivity to local hull modification and now such method is applied both for monohulls and polimarans. As disadvantages of the method for solution of the wash-waves problem it may be mention that method solves the steady problem and it requires great computer resources for investigation of wave development at big distance from the ship. That's why in present work both methods are to be combined.

At the first stage it was considered the question on applicability of non – linear panel method for simulation of the steady motion of the ship in the channel.

Description of a method

The flow around a ship is considered as initially uniform, non-viscous and incompressible and the flow is non -rotational. Within such assumptions the full task is reduced to a potential problem described by Laplace equation:

$$\Delta \Phi = 0$$

Calculation domain is bounded by hull, seabed and free surface. The boundary conditions are to be imposed on all domain boundaries. On the wetted part of the hull and seabed the conventional Neumann boundary conditions are set:

$$\vec{n} \cdot \nabla \Phi = 0$$

Combined condition on free surface includes both a kinematics and a dynamic ones:

$$\frac{1}{2g} \nabla \Phi \cdot \underline{\nabla} \left(\nabla \Phi \cdot \nabla \Phi \right) + \frac{\partial \Phi}{\partial x^3} = 0$$

At far distance ahead the ship the flow is assumed as undisturbed.

Let's define the velocity potential Φ and the wave elevation η as a sum of values obtained from the previous iteration (ϕ, H) and perturbations (φ', η'). Substituting it in governing equations and neglecting the terms included square or higher order of perturbations, we obtain free surface conditions as follows:

$$- \frac{Fn^2}{2} \nabla \phi \cdot \underline{\nabla} \left(\nabla \phi^2 + 2\nabla \phi \cdot \nabla \varphi' \right) + \nabla \varphi' \cdot \underline{\nabla} H - \frac{\partial \phi}{\partial x^3} - \frac{\partial \varphi'}{\partial x^3} = 0$$

The governing equations outlined above are solved by a boundary element method. For that the hull, seabed and free surface are replaced by quadrilateral elements with Rankin sources distribution. On the hull and seabed surface the quadrilateral elements and Rankin sources distribution is distributed according to the classical Hess and Smith method. Some differences are defined by nonlinear feature of the problem. The boundary condition is to be imposed on the actual wetted part of the hull and seabed and actual wave surface, which were updated on each iteration.

Results

Fig.1 demonstrate calculated wave system generated by motor yacht in the channel with trapezium section. Main dimensions of the yacht L=40 m: L/B=9.2, B/T=2.9 (L- length, B – breadth, T - draught). Maximal depth of the channel was taken H=10 m, cross section is shown in Fig.2.

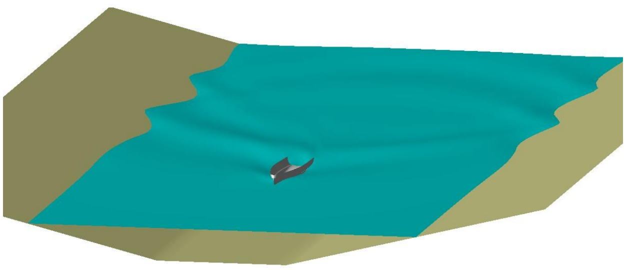

Fig.1 Wave pattern of the ship in the channel.

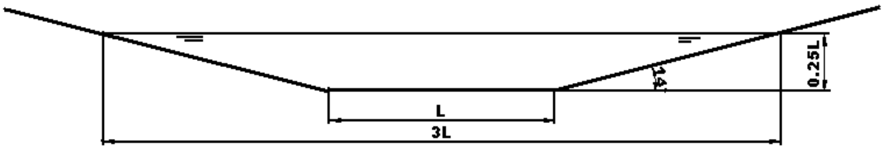

Fig.2 Cross section of the channel.

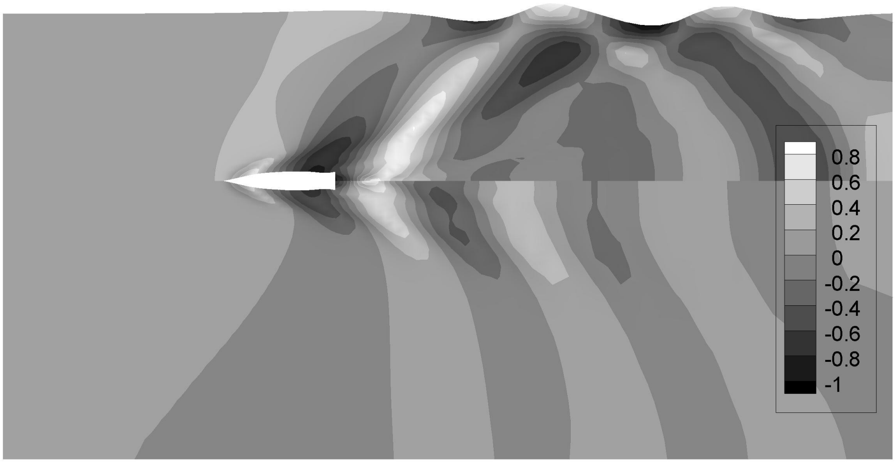

Fig.3 Wave pattern in channel (up) and in deep water (low)

It was considered the most dangerous from point of wave generation speed mode at full speed corresponded to $Fn = \frac{V}{\sqrt{gL}} = 0.45$ and $Fn = \frac{V}{\sqrt{gH}} = 0.9$ (V – ship speed). Fig.3 demonstrated the comparison of wave pattern in deep water and in the channel. The results qualitatively correlated with general ideas on wave particularity in shallow water. If consider the quantitative characteristics, one can find that for sea side the most dangerous is stern wave. Maximal breadth of shore area covered by wave (in regards of calm water line) is equal 3.9 m, maximal breadth of the area opened by wave - 4.2 m. Lift of wave surface at the line of undisturbed calm water is equal to 0.75 m.

Wave elevations corresponded to Fn=0.3 at various conditions are shown in Fig.4.

Direction of future investigation

Present results demonstrated that developed panel method made it possible to obtain at least qualitative characteristics of wave pattern for the ship of different type in the channel.

Further investigation will be directed to improvement of the method for estimation of far field waves. Another task is the solution of unsteady problem for near field waves. We hope that for last task it will be of enough quasi – steady solution. Important component of investigation of general problem should be validation. For that it is necessary to obtain the correct experimental data. Also, it is necessary to obtain systematic computation data for wave pattern characteristics generated by various ships in various shallow water conditions.

References

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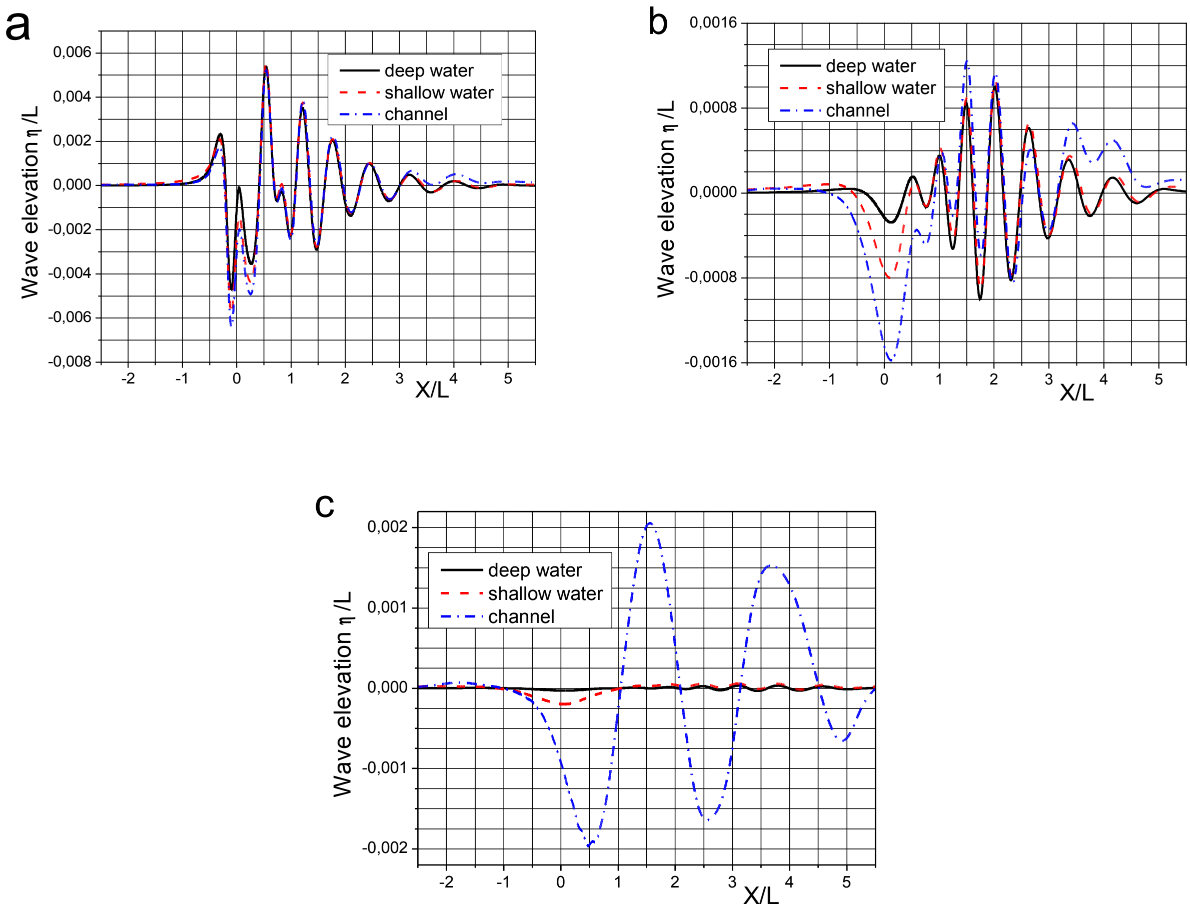

Fig.4 Free surface elevations in deep water, shallow water without bank (H=10 m) and in channel at various distance from ship centre line: a- y=0.15L, b- y=0.7L, c- 1.4L. Fn=0.3. Bow X/L=-0.5, stern X/L=0.5.