

NUMERICAL CALCULATIONS OF ADDED MASS AND DAMPING COEFFICIENTS FOR TWIN HULL VESSEL

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Problem formulation and method of solution

The 2 – d problem for the estimation of added mass and damping for one cylinder was formulated by F.John [1] for incompressible and irrotational flow. The numerical solution with the application of boundary integral equation method was developed by W.Frank [2]. The 2-d problem (in vertical plane) for added mass and damping coefficients for vertical motions was formulated by Potash [3], who found the solution without providing numerical results for semisubmerged twin cylinders, rigidly connected (Fig. 1) above the free surface. De Jong [4] has found a numerical solution for the same problem, applying conformal mapping and multiple expansion for added mass and damping coefficients of heaving twin cylinders in a free surface, using Frank scheme. In this paper the numerical calculations of hydrodynamic coefficients in vertical plane – heave, sway and roll oscillations are presented and numerical and model experiments are discussed.

In Fig.2 the 2- d boundary value problems for swaying, heaving and rolling motions are presented.

With the assumption of small oscillation, the velocity potential can be written as:

$$(1) \quad \Phi(x, y, t) = \operatorname{Re}\{\Phi(x, y)e^{-j\sigma t}\} = \Phi_c \cos \sigma t + \Phi_s \sin \sigma t$$

where $\Phi(x, y) = \Phi_c + j\Phi_s$.

The motion of any point of the surface for harmonic oscillations is:

$$(2) \quad x_k(t) = x_k^a \sin \sigma t$$

where

$k = 2$ - sway motion

$k = 3$ - heave motion

$k = 4$ - roll motion

It is supposed that the fluid disturbance about the Y -axis is symmetrical. The solution for velocity potential $\Phi(x, y)$ is presented as follows [6]:

$$(3) \quad \Phi(p) = \int_{C_0} Q(s) G_r(p; s) ds$$

where $p = (x, y)$ is the field point

$Q = Q_c + jQ_s$ is a complex density of pulsated source
 $G_r = G_{rc} + G_{rs}$ is source-Green function
 C_0 is immersed contour $y = 0$.

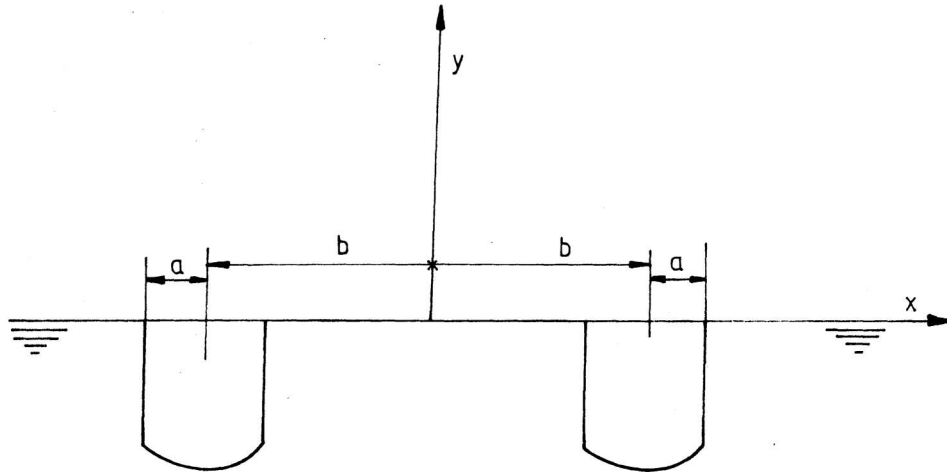


Fig. 1. Coordinate System

The Green function is expressed in the form of:

$$(4) \quad \begin{aligned} G(z, \zeta) &= G_r(x, y; \xi, \eta) + jG_i(x, y; \xi, \eta) = \frac{1}{2\pi} \{ \log(z - \zeta) - \log(z - \bar{\zeta}) + \} \\ &+ 2 \int_{C_0}^{\infty} \frac{e^{-jk(z-\bar{\zeta})}}{k - \beta} d\beta - j2\pi e^{-jk(z-\bar{\zeta})} \end{aligned}$$

where $\zeta = \xi - j\eta$.

The same as for single cylinder, however in this case the following boundary condition has to be satisfied:

$$(5) \quad G_{rx}(0, y; \xi, \eta) = 0$$

Adding the new function $G(z; -\zeta)$

$$F(z; \zeta) = G(z; \zeta) + G(z; -\zeta)$$

$$R_{\infty i} \left\{ \frac{d}{dz} F(0 + iy; \zeta) \right\} = 0.$$

Then $G(z; \zeta) = G_r(x, y; \xi, \eta) + iG_i = G_{rc} + jG_{rs} + j(G_{ic} + jG_{is}) =$

$$(6) \quad = \frac{1}{2\pi} \left\{ \log \frac{(z - \zeta)(z + \bar{\zeta})}{(z - \zeta)(z + \zeta)} + 2 \int_0^\infty \frac{e^{-jk(z - \bar{\zeta})} + e^{-jk(z + \zeta)}}{\beta - k} d\beta + \right. \\ \left. + j2\pi(e^{-jk(z - \bar{\zeta})} + e^{-jk(z + \zeta)}) \right\}$$

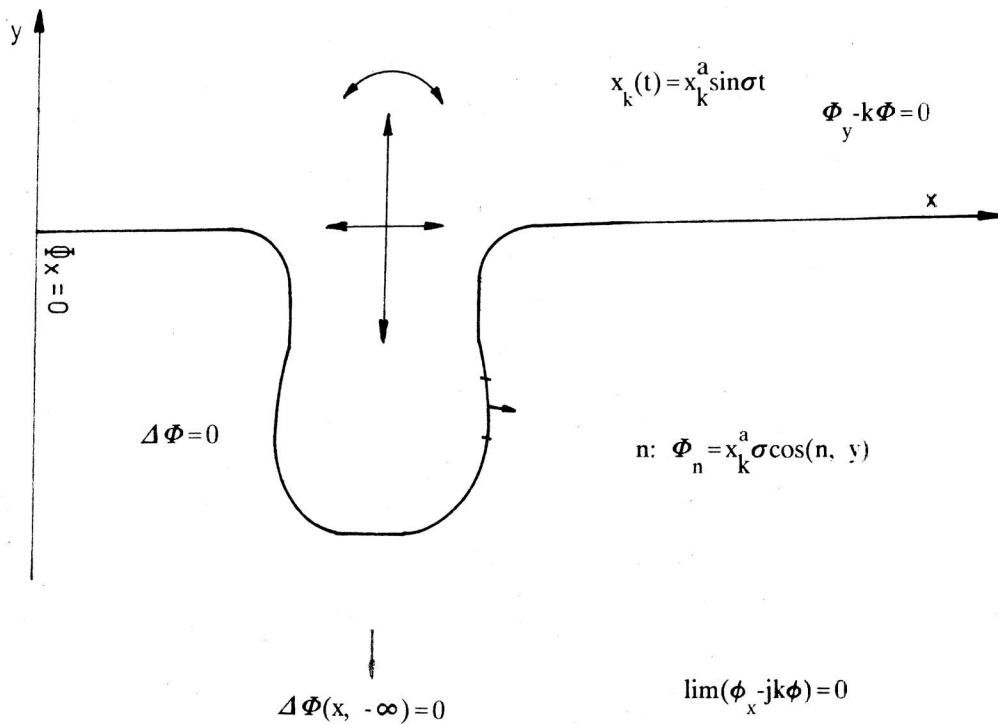


Fig. 2. Description of the boundary value problem for velocity potential $\Phi(x, y)$

Now G_r satisfies the same boundary conditions as Φ , except for the kinematic boundary condition on the cylinder. From that equation source strength $Q(s)$ is obtained. For the numerical calculations the contour is approximated by N segments (Fig. 3) and following (3) is expressed the velocity potential:

$$\begin{aligned}\Phi(p) &= \sum_{j=1}^N \int_{c_j} Q(s) G_r(p; s) ds = \sum_{j=1}^N Q_j \int_{c_j} G_r(p; s) ds = \\ &= \sum_{j=1}^N Q_j (n \nabla) \int_{c_j} G_r(p; s) ds = x_k^a \sigma \cos \alpha.\end{aligned}$$

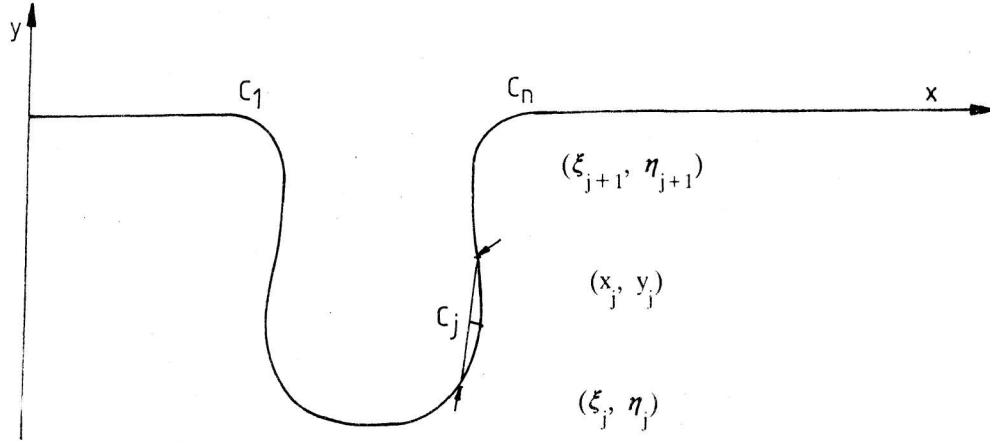


Fig. 3 Contour segmentation scheme

Thus the unknown coefficients Q_{cj} and Q_{sj} of velocity potentials components Φ_c and Φ_s are calculated.

$$\begin{aligned}\sum_{j=1}^N Q_{cj} I_{ij} - \sum_{j=1}^N Q_{sj} J_{ij} &= x_k^a \sigma \cos \alpha_i \\ (8) \quad \sum_{j=1}^N Q_{cj} J_{ij} + \sum_{j=1}^N Q_{sj} I_{ij} &= 0, \quad i, j = 1, 2, \dots, N\end{aligned}$$

The hydrodynamic pressure in the point (x_0, y_0) of the cylinder, is presented using linearized Bernoulli equation as:

$$\begin{aligned}(9) \quad P(x_0, y_0, t) &= -\rho \Phi_t(x_0, y_0, t) = \\ &= -\rho \sigma (\Phi_s \cos \sigma t - \Phi_c \sin \sigma t)\end{aligned}$$

The hydrodynamic force acting on twin cylinders can be obtained

$$\begin{aligned}
 10) \quad F &= -2 \int_{co} P \cos \alpha ds = \\
 &= 2\rho\sigma(\cos \sigma t \int_{co} \Phi_s \cos \alpha ds - \sin \sigma t \int_{co} \Phi_s \cos \alpha ds)
 \end{aligned}$$

The added mass and damping coefficients presentation is:

$$11) \quad F = -A\ddot{y}(t) - B\dot{y}(t) = x_k^a \sigma^2 A \sin \sigma t - x_k^a \sigma A \cos \sigma t$$

The added mass is:

$$12) \quad A = -\frac{2\rho}{x_k^a \sigma} \int_{co} \Phi \cos \alpha ds = -\frac{2\rho}{x_k^a \sigma} \sum_{j,k=1}^N (Q_{cj} A_{ik} - Q_{sj} B_{ik}) \cos \alpha_k / \Delta S_k /$$

The damping is:

$$13) \quad B = -\frac{2\rho}{x_k^a} \int_{co} \Phi \cos \alpha ds = -\frac{2\rho}{x_k^a} \sum_{j,k=1}^N (Q_{cj} B_{ik} + Q_{sj} A_{ik}) \cos \alpha_k / \Delta S_k /$$

where

$$/\Delta S_k/ = /S_{k+1} - S_k/ = [(\xi_{k+1} - \xi_k)^2 + (\eta_{k+1} - \eta_k)^2]^{1/2}$$

$$A_{jk} = \int_{cj} G_{rc}(x_k, y_k, s) ds$$

$$B_{jk} = \int_{cj} G_{rs}(x_k, y_k, s) ds$$

The numerical calculations are based on the calculation of the potential integrals. In the derivation of Green's function $G(z, \zeta)$, which can be interpreted as a wave source near a vertical wall, besides the logarithmic and exponential functions the principle value is encountered. These integrals are reduced to the exponential integral which is expanded on to the finite series.

Validation of the created numerical procedure is estimated as follows:

– Comparison with other numerical results.

These comparisons show that when the compared procedures are based on the similar methods, the results are the same. When the compared procedures are based on the different methods, the results correlate well.

– Comparisons with the experimental results.

The numerical and experimental results for sway added mass are presented in Fig.4. The experimental results are obtained by Lee and Curphey [6] for SWATH ship

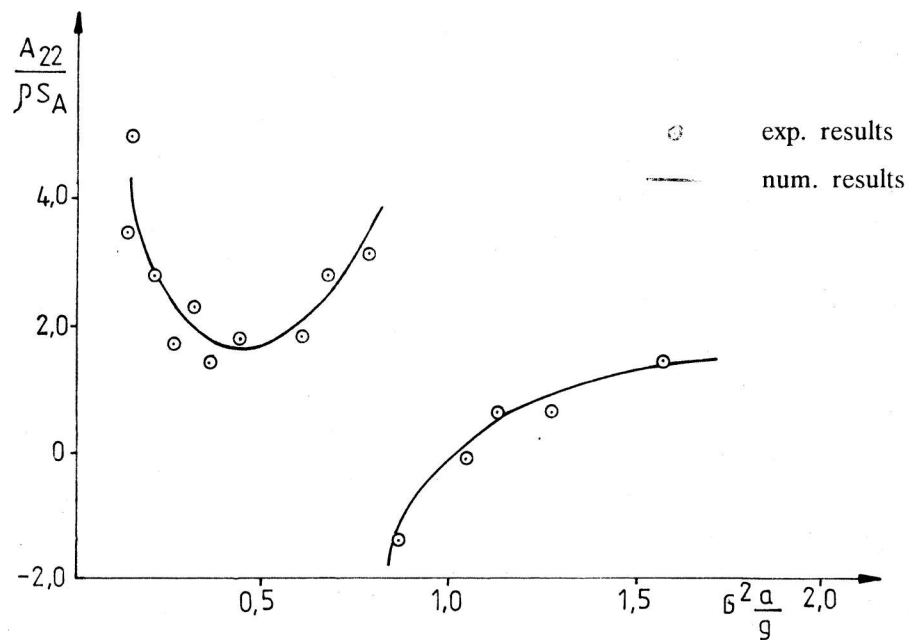


Fig.4 Sway added mass coefficient - numerical and experimental results

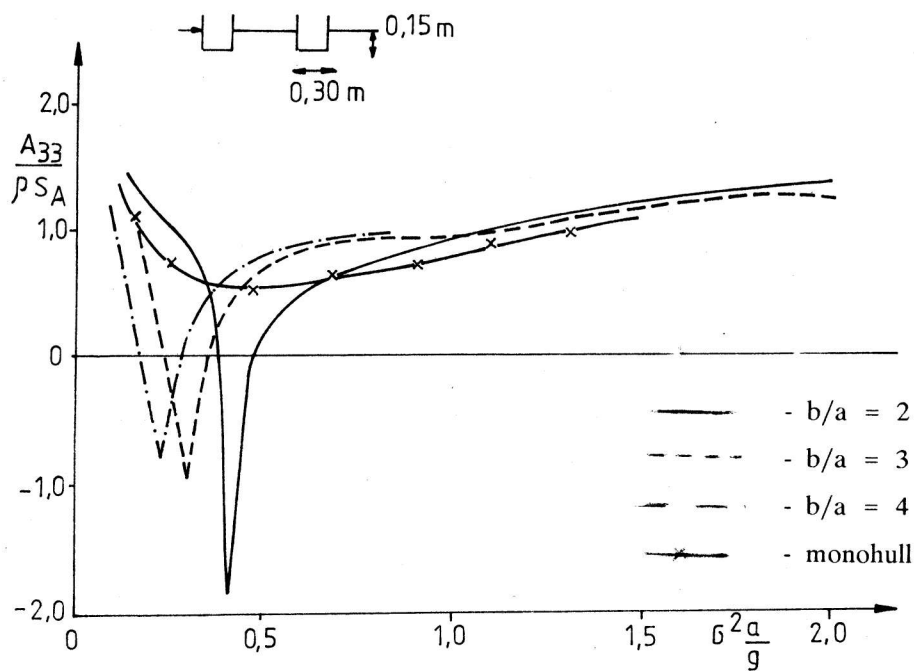


Fig.5. Influence of the clearance variation of the heave added mass coefficient

for small amplitude forced oscillations test. The agreement is good. The negative added mass is obtained by numerical calculations, as well as by experiments.

– Numerical experiments for the variation of the distance between cylinders.

Figs. 5 and 6 show heave added mass and damping coefficients for twin hull ship and monohull ship with one and the same contours. The results for the smallest distance $b/a = 2$ is nearest to the monohull added mass.

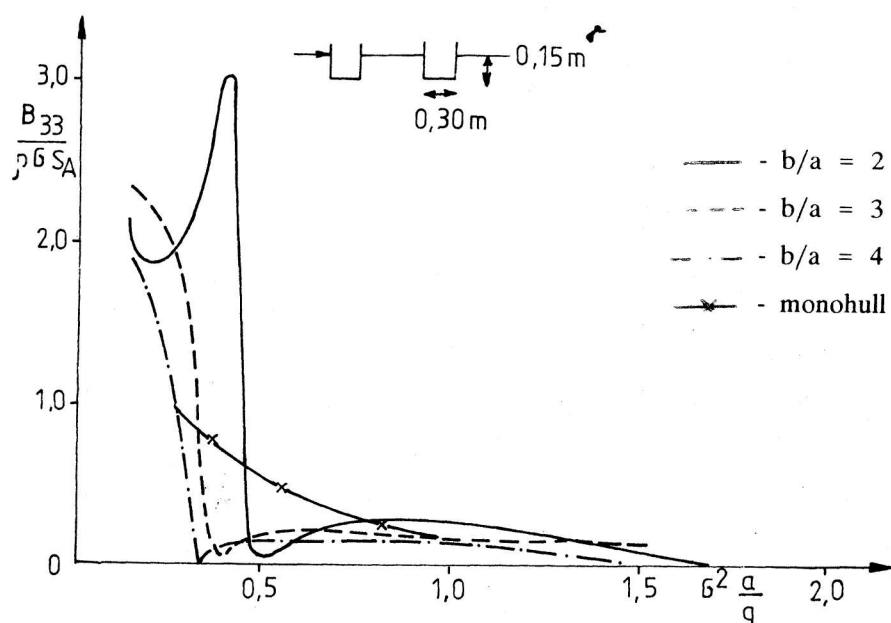


Fig.6 Influence of the clearance variation on the heave damping coefficient

The existence of negative added mass for twin cylinders strongly suggests the effect of hydrodynamic interaction between the two cylinders. The increasing of the wave length indicates negative added mass and corresponds to the increase of clearance between the hulls. The smaller is the distance of passing by each ship, the creation of specific forms of hulls of catamaran vessels becomes more important.

Conclusions

Computational numerical solution of the 2-d boundary value problem for estimation of sway, heave, roll and sway-roll added mass and damping coefficients is developed. Programme package for calculations of added mass and damping coefficients of twin hull vessels is created. The validity of the programme product is checked. The variation of the values for low frequencies (long waves) are greater than in the high frequency domain. Potential flow assumptions are valid for sway and heave twin hull

vessels motion. The numerical procedure for roll motion and nonsmooth forms should be extended to viscous damping coefficients.

Acknowledgments

The author would like to express his gratitude to the National Fund for Scientific Research, grant TN-248/92: "Investigation of dynamics of offshore structures in waves, current and wind action". This grant made possible the theoretical and experimental work done at the Bulgarian Ship Hydrodynamic Centre.

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Received on December 18, 1991