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A Simplified Boundary Integral Method for the Two-Dimensional Floating Body Problem

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The two-dimensional finite depth floating body problem is formulated as a boundary integral equation by using the elementary fundamental solution of the Laplace equation

$$\gamma(p,q)=\frac{1}{\pi}\left[\log\frac{|q|}{|p-q|}+\log\frac{|q_1|}{|p-q_1|}\right]$$

where $p=(x_p,y_p)$, $q=(x_q,y_q)$, and $q_1=(x_q,-2h-y_q)$ denote the points in the plane, and h denotes the finite depth of the fluid. It is easy to see that this fundamental solution satisfies the boundary condition on the fluid bottom but not on the free surface. As a result, the domain of the resulting integral equation now consists of the wetted portion of the ship hull as well as the whole free surface. However, it will show that this fundamental solution is much simpler than the standard Green's function of Fritz John not only in form but also from the computational point of view. A simple computation shows that the boundary value problem considered here can be reduced to the integral equation

$$\alpha(p)\phi(p)+\int_{c_0}\phi(q)\frac{\partial\gamma(p,q)}{\partial n_q}ds_q+\int_{c_f}\phi(q)\left[\frac{\partial\gamma(p,q)}{\partial n_q}+k\gamma(p,q)\right]ds_q$$

$$=\int_{c_0}V(q)\gamma(p,q)\,ds_q$$

It is one of main purposes to develop a numerical scheme for constructing the solution of the integral equation and computing relevant physical quantities such as added-mass and damping coefficients.

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The essence of our scheme is to approximate appropriately the integral equation over a finite distance away from the ship hull. By using a collocation method together with asymptotic behavior of the potential function at infinity, we may replace the integral equation by a system of finite algebraic equations. Numerical experiments will be included for various boundary conditions. In particular, we will consider the heave motion. Our results are in excellent agreement with those results obtained by Yeung and Bai from other schemes.

Discussion

Ron Yeung: You were looking for a Green function as simple as possible. But you seem to compromise and use a more complicated Green function than that used in Bai & Yeung (1974). The idea of using an image source below the bottom for the case of flat bottom was actually implemented as well as mentioned in the Bai-Yeung paper. What you propose is to apply a weighting function on the source and bottom image combination. This weighting function favors information near the origin; therefore it introduces an approximation when you truncate the domain. The choice of weighting function is not unique.

Tuck: The error in added mass and damping seems to appear in the second figure. How many segments did you use?

Liu: I used a mesh size of 100.

X.J. Wu: You used the coefficient value 3/2 for the corner point. It is well known that there is no solution for the sharp corner point. Therefore in numerical evaluation we can simply avoid such points or smooth the corner to obtain a solution.

Liu: The value of gamma is ill-defined at segment intersections, so we avoid putting collocation points at corners. Then there is no ambiguity in the definition of the normal derivative at the collocation point.

Mei: It seems that lots of people design new numerical methods for the linear radiation - diffraction problem This is worthwhile if numerical efficiency is improved. Have you compared your efficiency with other methods?

Liu: I used a mesh size of 100. This required about 3 seconds of CPU time.

Yeung: CPU-times for certain special cases were presented in the Bai-Yeung paper. Keep in mind however they were for a vintage computer.

C. Lee: Have you investigated an oscillating wedge, especially at the point of body/free surface intersection? With your method, you may assign the value of ϕ at the contact point, and calculate the free surface elevation on the wedge.

Liu: No, I have not applied the method to a body section which does not intersect the free surface perpendicularly.

Hearn: We have tried sections with non-perpendicular intersections and proved that a constant of twice alpha is appropriate. The choice of alpha is critical, however. An incorrect choice leads to large discrepancies in the in-phase and out-of-phase components of the pressure distribution on the body.