# A Panel Method for Ship Motions

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A Rankine source method (RSM) for solving the forward-speed diffraction problem, *Bertram (1990a)*, has been developed further to determine ship motions in waves using a fully 3-dimensional method linearized with respect to wave amplitude $h$, Bertram (1990b). The ship moves with mean speed $U$ in a harmonic wave of small amplitude. For $\tau = U\omega_e/g > 0.25$ diffracted and radiated waves can not propagate upstream. Only such cases are considered here. The diffraction and radiation problems then become similar to the steady wave resistance problem.

Discrete point sources are distributed above a finite section around the ship to fulfill the boundary condition at the free surface. On the hull, polygonal panels of constant strength are distributed. The involved integrals are evaluated by simple numerical integration. The stationary part of the flow is not set to uniform flow as usually, but is determined numerically as by *Jensen et al. (1989)*. Boundary conditions at the free surface and the ship's mean hull position are linearized around this correct stationary potential and its corresponding wave elevation. For the radiation problem second derivatives of the stationary potential are needed on the ship posing a considerable problem at present. These second derivatives are approximated by a simple slender-body theory. Radiation and open-boundary condition are enforced by shifting sources versus collocation points on the free surface. After solving diffraction and radiation problems separately – which involves one system of linear equations with 4 different right-hand sides in head sea and 2 such systems in oblique seas – motions are determined in the usual way by coupling forces and motion accelerations via a mass matrix.

Results are given for a Series 60 parent hull form with $C_B = 0.7$ in head sea at $F_N = 0.2$. RSM results are compared with experimental results of Gerritsma and Beukelman. In most other seakeeping methods, the stationary part of the potential is approximated by uniform flow. I investigated the effect of this simplification: Using the same discretization for ship and surface, the stationary part of the potential was set to uniform flow, the surface condition applied at $z = 0$ and the pressure integrated up to the still water line. The results of the simplified panel method are marked by crosses in the figures. For exciting forces, Fig.1, earlier results of *Bertram (1990c)* were confirmed. RSM shows good agreement with experiments especially for shorter waves. Substituting the correct stationary potential by uniform flow has little influence on the exciting forces. The influence of the simplified stationary potential becomes more obvious for motions, Fig.2. RSM predictions for motions agree satisfactorily with experiments. For $\lambda/L = 1.05$ to $\lambda/L = 1.35$ the model shipped green water in experiments introducing strong nonlinear effects. This is probably the main reason for differences in the pitch amplitudes in this region. The simplified panel method unacceptably overpredicts the maximal heave amplitude.

Computations used 342 collocation points on the body and 915 on the free surface. On a VAX 6310 one $\lambda$-$F_n$-combination needed 110 CPU minutes. Solving the systems of linear equations (SLE) using Gauss elimination required 85% of the CPU time.

BERTRAM, V. (1990a), A Rankine source approach to forward speed diffraction problems, 5th Int. WWWFB, Manchester

BERTRAM, V. (1990b), A Rankine Source Method for the Forward-Speed Diffraction Problem, IfS-Rep. 508, Dissertation, Univ. Hamburg

BERTRAM, V. (1990c), Ship motions by a Rankine Source Method, STR 37/4

JENSEN, G., BERTRAM, V., SÖDING, H. (1989), Ship wave-resistance computations, 5th Int. Conf. on Num. Ship Hydrodyn., Hiroshima

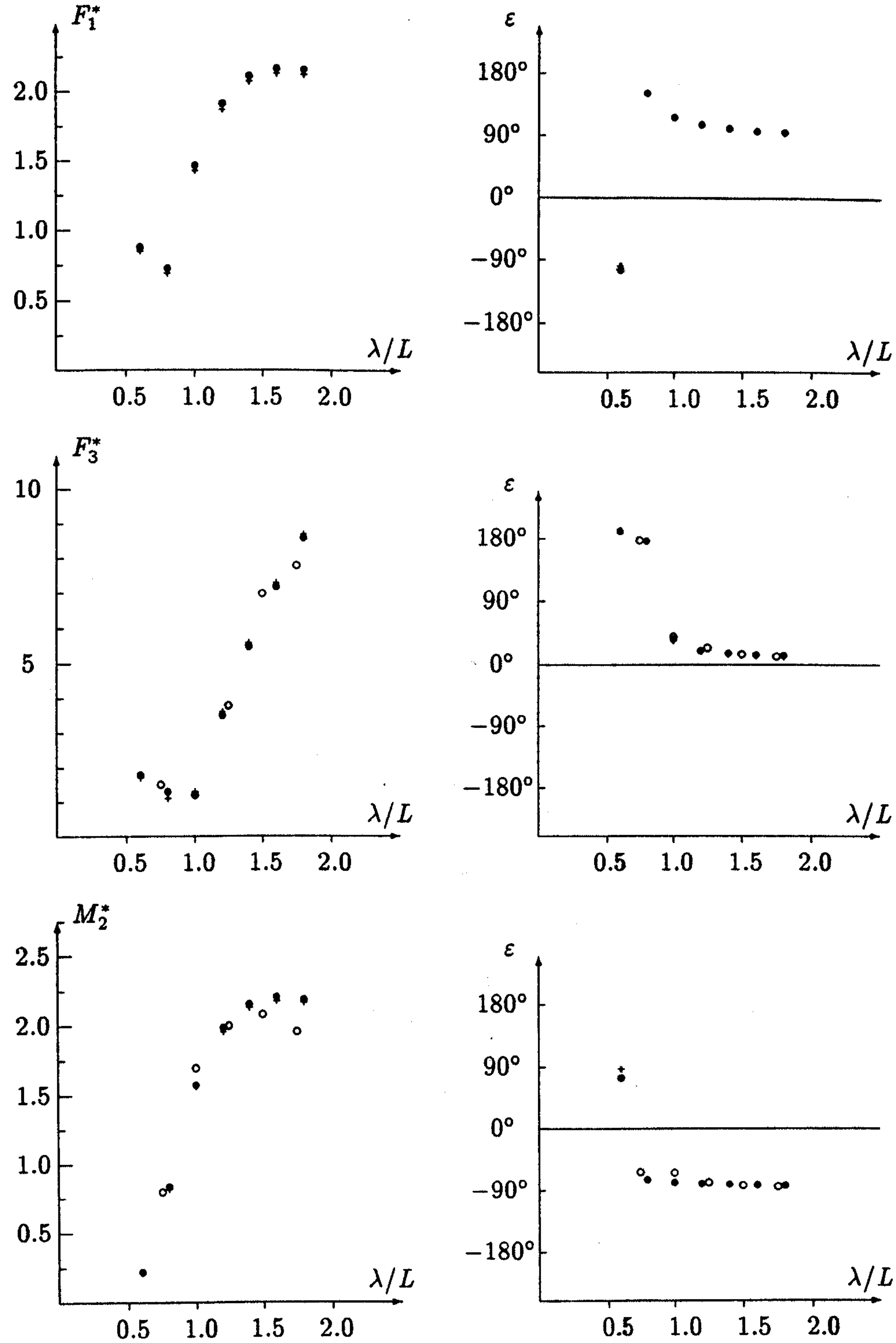



Fig.1: Exciting forces and moments for Series 60, head sea, $F_n = 0.2$
∘ experiment, • panel method, + simplified panel method
$F_1^* = |\hat{F}_1^e| L/\rho g h \nabla$, $F_3^* = |\hat{F}_3^e| L/\rho g h \nabla$, $M_2^* = |\hat{M}_2^e|/\rho g h \nabla$

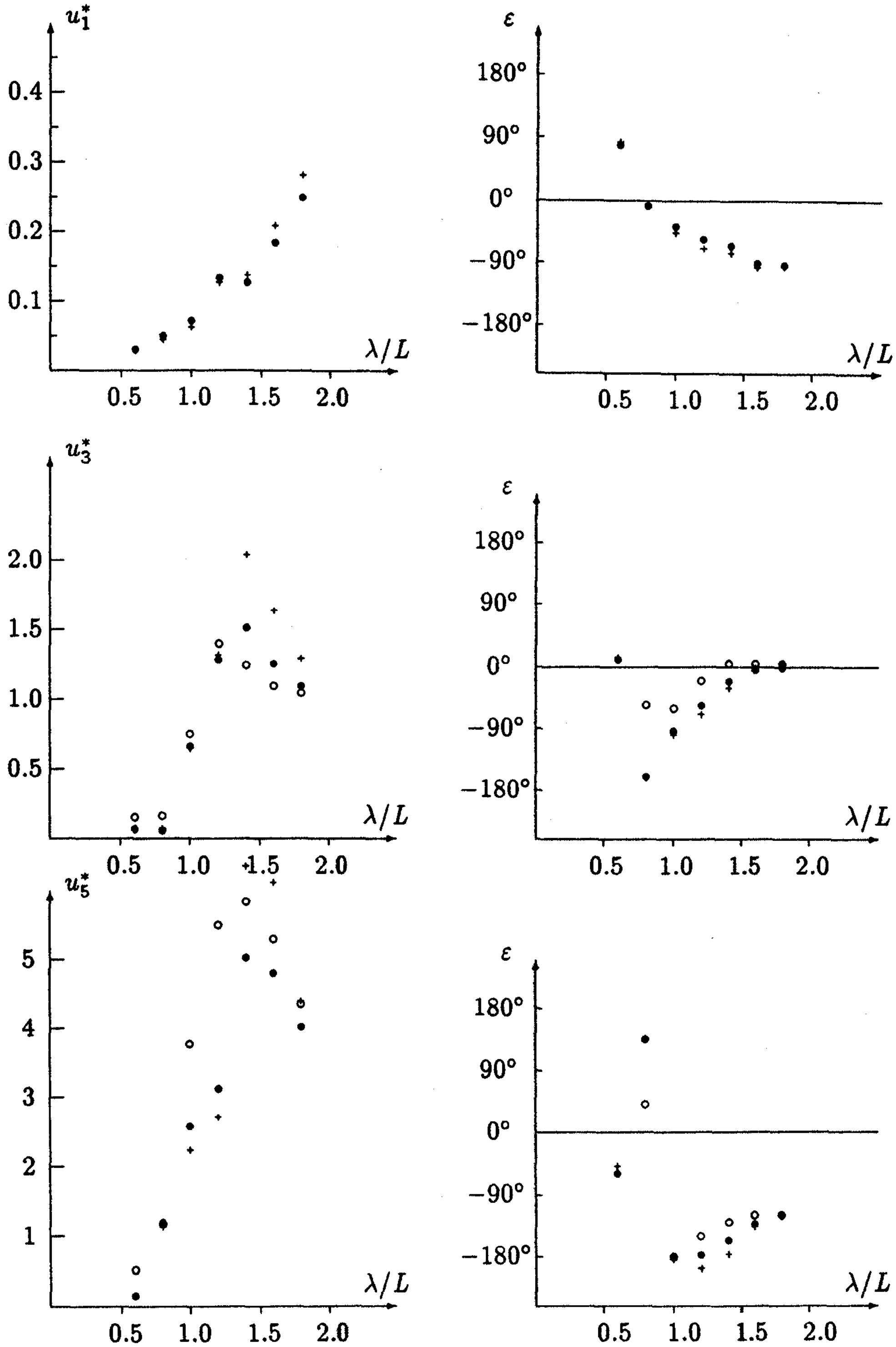


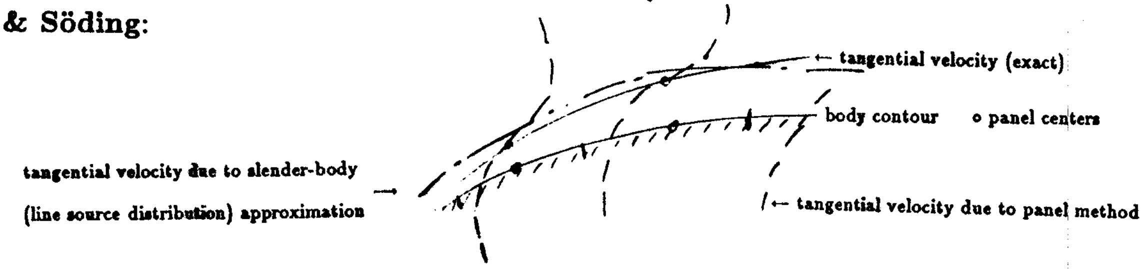

Fig.2: Response amplitude operators for Series 60, head sea, $F_n = 0.2$
∘ experiment, • panel method, + simplified panel method
$u_1^* = |\hat{u}_1|/h$, $u_3^* = |\hat{u}_3|/h$, $u_5^* = |\hat{\mathbf{u}}_5|L/h$

**Newman**: Why do you simplify the m-terms in the hull boundary condition?

**Bertram & Söding**: Because we do not trust our first-order panel method to give correct approximations to velocity gradients.

**Faltinsen**: I understand from your talk that you calculated the m-terms by representing the steady flow by a source distribution along the centerline of the ship. This solution does not satisfy the body boundary condition on the mean position of the ship. Since the m-terms represent the fact that the steady part of the velocity potential does not satisfy the body boundary condition at the instantaneous oscillatory position of the ship, and given your method for calculating the steady flow, how can you claim that the steady part of your velocity potential satisfies the boundary condition on the instantaneous oscillating position of the body?

**Bertram & Söding**:




The line source distribution gives less accurate velocities at panel centers, but due to its smoothness (contrary to the panel velocity) approximates the derivatives of velocity much better than the panel method. Because the line source distribution generates the correct section area curve, one can hope for a certain degree of cancellation of errors along a section contour. The line source distribution is to be replaced by a higher-order panel method in future.

**Nakos**: (1) As a comment, I would like to mention that the need to evaluate second gradients of the basis flow on the body may be eliminated by appropriate application of Stokes' theorem (see Nakos & Sclavounos 1990, ONR, AnnArbor); (2) The diffraction problem in your formulation will have forcing on the free surface. How important is this compared to the usual forcing over the body (excluding Froude-Krylov, of course).

**Bertram & Söding**: (1) Is it possible to do so even if you are interested in forces and moments within cross-sections of the body or in the body surface pressure distribution? (2) We did not investigate this effect separately, but due to small differences between full circles and + symbols in Figure 1, we think the effect is rather small for the relatively long incident waves (compared to bow waves, *e.g.*) investigated by us.

**Nakos**: The particular application of Stokes theorem, which I mentioned in my comment, may be used to transfer derivatives away from the basis flow potential even if the integral under consideration is over part of hull surface. Of course, in such a case one should also include an appropriate line integral over the "cut" of the hull.

**Kim**: Recently, a higher-order boundary element method has been developed at Texas A&M, and our preliminary study shows that the velocity and its derivatives on the body surface can be accurately calculated (*e.g.*, with a typical error of 1% for a translating sphere in an unbounded fluid) using quadratic and cubic variations of the potential. This method may resolve the difficulties of calculating so called "m terms" in the forward speed problem.

**Zhao**: In the 5-th International Conference on Numerical Ship Hydrodynamics (Japan 1989), we presented a method by which the m-terms may be calculated in a very stable way. I think that this method may also be applied to your case.

**Bertram & Söding**: Indeed, you gave two different methods for determining the m-terms. The first one (extrapolation from the interior of the fluid to the body surface) seems to require a relatively fine panel mesh. The second one (involving Green's second identity) seems suitable for determining the velocity potential, but not the forces and moments due to the motion of the body in a stationary pressure field where second derivatives of the steady potential occur.