An Enhanced Nonlinear Strip Method for Seakeeping Analysis

Volker BERTRAM, *HSVA, Hamburg/Germany, bertram@hsva.de*
Ricardo PEREIRA, *MTG, Hamburg/Germany, pereira@mtg-marinetechnik.de*
Maurizio LANDRINI, *INSEAN, Rome/Italy, maulan@waves.insean.it*

Available methods for calculating motions, shear forces and bending moments of a ship in waves are usually based on linear (small wave amplitude) theory. However, for dimensioning ship structures the loads in extreme waves are needed. Also for ship safety in sea waves, we need to consider extreme motions, particularly extreme roll motions up to capsize angles.

The computational effort for a three-dimensional field method or even boundary element method simulating the motions and loads on a ship at each time instant over a long time appears still beyond our current and near future computational capabilities. Thus we try to introduce simplifications that reduce the computational effort drastically without losing too much of the physical significance of the model. The tool of choice appears then to be a nonlinear strip method of some sort. The nonlinear strip method SIMBEL dates back to Söding (1982) and has been extended over the past two decades to include internal forces, propulsion system dynamics and manoeuvring, e.g. Pereira (1988). A long-term goal is to have a tool which can simulate also broaching and capsizing of vessels, i.e. a combination of extreme manoeuvring and seakeeping motions.

The method is a simulation in which large-amplitude rigid-body motions of the ship in 6 degrees of freedom, shear forces and bending moments are determined under the influence of forces and moments due to weight, Froude-Krylov pressure, radiation and diffraction pressure, speed effects (resistance and manoeuvring forces and moments due to oblique forward motion) and propeller and rudder actions. For large amplitude motions, the diffraction and radiation forces cannot be determined independently. But in principle we still couple forces $\underline{F}$ and (derivatives of) motions $\underline{u}$ using basic differential equations.

The forces can be determined by integrating the pressure over the instantaneously wetted surface of the ship. Unfortunately, the pressure distribution does not depend only on instantaneous position, velocity and acceleration of the ship, but also on the history of the motion (memory effects). This affects particularly heave and pitch motions. For linear computations in regular waves, this memory effect results in the frequency dependence of added mass and damping. For nonlinear simulations this is not quite as simple as many frequencies are present at the same time and the superposition principle no longer applies. The memory effects can be expressed in terms of convolution integrals, alternatively one considers 0 to n time derivatives of the force $\underline{F}$ and 1 to $n+1$ time derivatives of the motion $\underline{u}$:

$$B_0\underline{F}(t) + B_1\dot{\underline{F}} + B_2\ddot{\underline{F}} + ... = A_0\dot{\underline{u}}(t) + A_1\ddot{\underline{u}}(t) + ...A_2\,\dddot{\underline{u}}\,(t) + ... \qquad (1)$$

The matrices A_i and B_i are determined in a preprocessing step for various drafts and inclination angles for each section. This procedure is called state space model. It is far more efficient than approaches using convolution integrals. Typical values for n (terms on left and right side) are 2 to 4. We chose 3. With increasing n problems appear with numerically induced oscillations which grow and make the simulation instable.

Now stability and prediction accuracy of SIMBEL shall be improved by using some more advanced numerical methods to derive coefficients in the preprocessing stage. The added mass and damping coefficients for the linear radiation problem are now derived for each section by a three-dimensional Green-function method without forward speed. The forward speed effects are kept as before in the framework of the strip method. The hope is that the three-dimensional method will improve accuracy nevertheless at the ship ends and may actually also improve the stability of the nonlinear strip method procedures. As a first step a standard Green function method following Landrini (1996) was used to define the hydrodynamic coefficients. This was validated for a Series-60 $C_B = 0.7$ against experiments, Vugts (1971), and a standard close-fit strip method. To the best of our knowledge, this is the first time that such a validation for individually strips has been performed. Heave added mass for sections are improved especially at the ship ends Fig.1, and also sway damping coefficients are well reproduced, Fig.2. However, roll is naturally predicted badly by both potential flow approaches.

In addition RANSE computations shall compute the drift force coefficients on the hull for various drafts and inclinations. These are again computed for the 3-d hull as a preprocessing step. It is crucial to include the speed effect here in the RANSE computations as the separation characteristics and thus drift force coefficients change drastically with speed and forward speed.

Currently we develop the interface between the 3-d preprocessors and the SIMBEL strip method and have prepared already a grid for an actual ro-ro ship. By the time of the workshop, we should have results of the standard strip method and the new "hybrid" approach to see how the changes in the individual hydrodynamic coefficients influence the global simulation.

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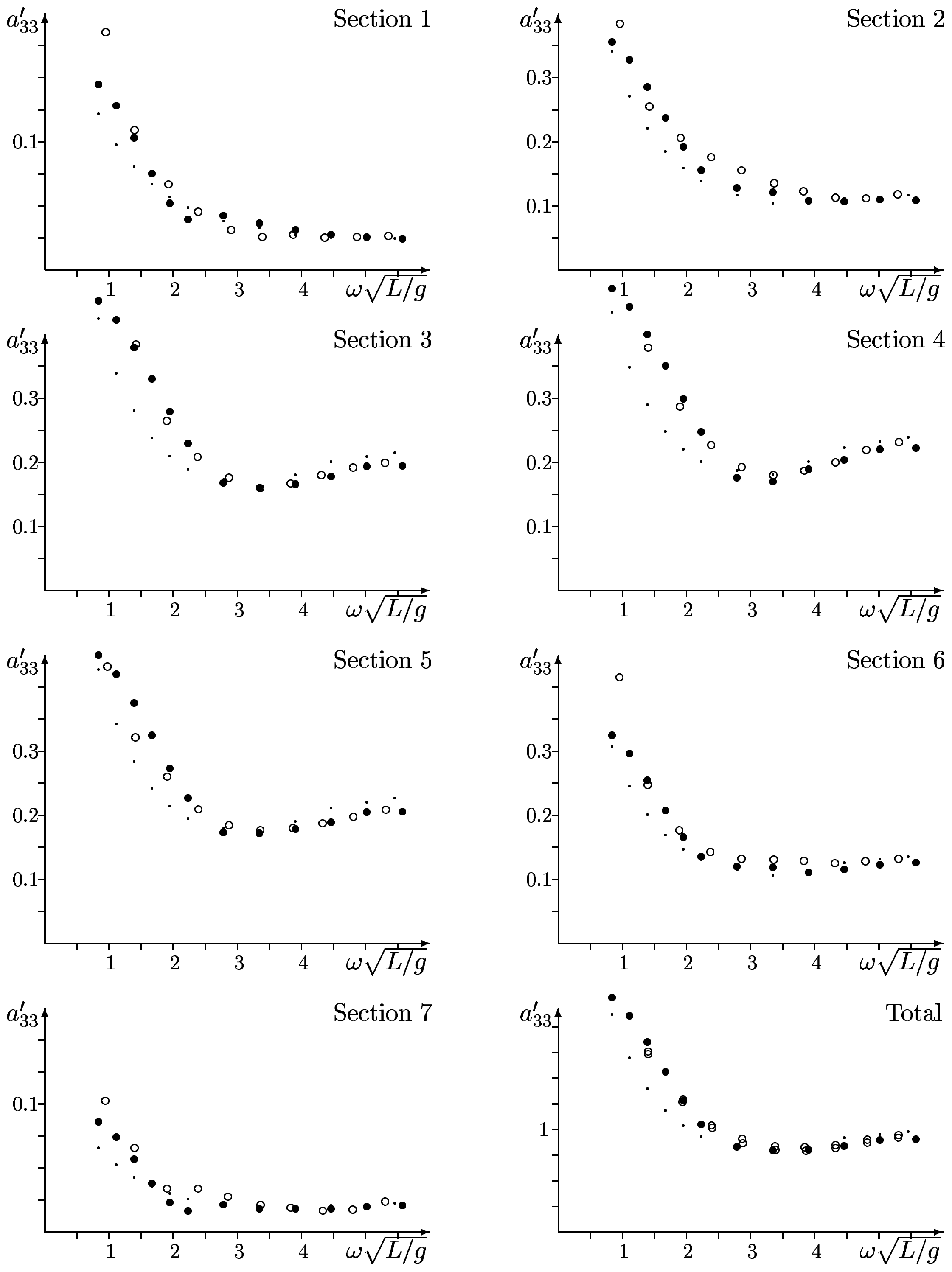

Fig.1: Series-60, $C_B = 0.7$, $F_n = 0$; added mass; $m = \nabla \cdot \rho$
$a'_{33} = a_{33}/m$ for vertical force due to heave motion for strips and total ship;
○ Exp., ● GFM, · strip method

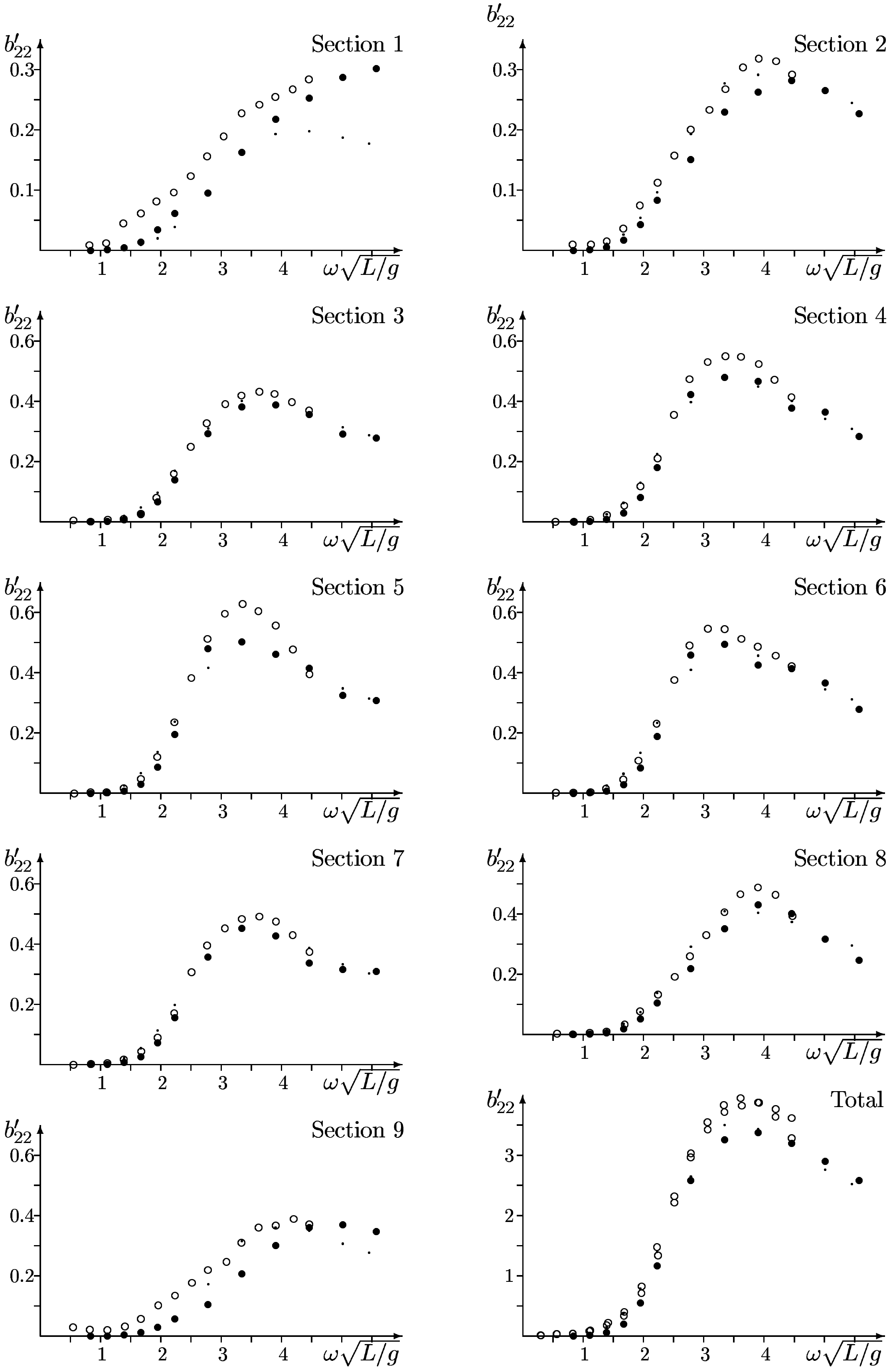

Fig.2: Series-60, $C_B = 0.7$, F_n; hydrodynamic damping
$b'_{22} = b_{22}/(m \cdot \sqrt{g/L})$ for sway force due to sway motion for strips and total ship;
○ Exp., ● GFM, · strip method