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Linear & Nonlinear Analysis of Motions and Loads of A Ship with Forward Speed in Large-Amplitude Waves

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1. Introduction

The knowledge of nonlinear ship motions and hydrodynamic loads of a ship operating in severe seas is of critical importance. Although the nonlinear effects of large-amplitude ship motions and the associated hydrodynamic loads are generally recognized, and there are substantial advances in the development of nonlinear free surface hydrodynamics computation methods in recent years, the specific nature and magnitude of many of the nonlinear effects are not well documented in the literature. The purpose of this paper is to systematically document the nonlinearity in ship motions and hydrodynamic loads of a ship with forward speed in large-amplitude waves and to evaluate the validity of the numerical methods used for computing these nonlinearities. Different levels of numerical methods — linear, linear hydrodynamics with nonlinear hydrostatic restoring and Froude-Krylov wave forces, and body-nonlinear — are applied and evaluated. A typical container ship, S175, is used in this study. Numerical results are analyzed and compared with available experimental data. Key results to be discussed and presented in the Workshop include the importance of nonlinear hydrostatic restoring and Froude-Krylov wave forces, the importance of body nonlinear boundary conditions, the dependency of motions and loads on wave amplitude and slopes, and the effect of non-wall-sided bow and stern geometry on nonlinearities.

2. Multi-Level Motion and Load Computation Method

For the current study, a large-amplitude motion program (LAMP) developed in Lin & Yue (1990) is used. LAMP uses potential flow three-dimensional time-domain approach for predicting motions and loads of floating bodies in waves. In LAMP's "body-nonlinear" approach, the body boundary condition is satisfied exactly on the instantaneous surface of the moving body under the mean free surface while the free-surface boundary conditions are linearized. The problem is solved by using a transient free-surface Green function singularity distribution method.,The validity and practical utility of LAMP have been demonstrated by several studies including predictions of large-amplitude motion coefficients, motion history of a ship advancing in an irregular seaway, as well as dynamic loads and the effects bow flare (see Lin & Yue 1990, 1992).

An extension to LAMP was proposed by Lin & Yue (1993) for computing ship motions and loads in large-amplitude waves under the assumption of weak scattering. Instead of satisfying the body boundary condition on that portion of the hull which is below the *mean* free surface as in LAMP, in the new approach, the body boundary condition is satisfied on

Table 1: Computation Methods and Descriptions for the LAMP Code.

Method	Hydrodynamic, Restoring and Froude-Krylov Wave Forces
LAMP-4	Free Surface Boundary Conditions on the Incident Wave Surface 3-D Large-Amplitude Hydrodynamics Nonlinear Restoring and Froude-Krylov Wave Forces
LAMP-3	Free Surface Boundary Conditions on the Mean Water Surface 3-D Large-Amplitude Hydrodynamics Nonlinear Restoring and Froude-Krylov Wave Forces
LAMP-2	Free Surface Boundary Conditions on the Mean Water Surface 3-D Linear Hydrodynamics Nonlinear Restoring and Froude-Krylov Wave Forces
LAMP-1	Free Surface Boundary Conditions on the Mean Water Surface 3-D Linear Hydrodynamics Linear Restoring and Froude-Krylov Wave Forces

the instantaneous wetted hull under the *incident* wave profile. At each time step, local free surface elevations are used to transform the body geometry into a computation domain with a deformed body and a flat free surface. By linearizing the free surface boundary conditions about this incident wave surface, the problem is solved in the computation domain using a linearized free-surface transient Green function. In this new approach, the correct hydrostatic and Froude-Krylov wave forces are readily included.

In the process of its development, LAMP has now become a multi-level code system with LAMP-4 being the most complicated and LAMP-1 the simplest. Table 1 gives a summary of the four different levels of approximation under LAMP.

3. Results

The S175 containership (see Figure 1), is chosen for the current study. The S175 containership has a moderate U/V-shaped bow with considerable flare and a small bulb. The stern is a typical cruiser stern with moderate overhanging portion. One of the reason for us to choose the S175 hull form is the availability of experimental data about nonlinear effects. In particular, the experimental data include heave and pitch data in regular head waves with increasing wave steepness (O'Dea, *et al*, 1992). The complexity in the S175 hull form geometry makes the nonlinear effects more pronounce and important and also makes the computation very challenging.

We report systematic computations of the S175 hull form with forward speed in large-amplitude waves using numerical approaches with different levels of nonlinearity. Our discussions will concentrate on: (1) how good the results are using methods with increasing sophistication in approximating nonlinear effects: and (2) the importance of nonlinear effects on motions and loads. For the former, we study the importance of nonlinear hydrostatic restoring and Froude-Krylov wave forces, the importance of nonlinear body boundary condition, and the range of applicability of the weak scattering approach. For the latter, we examine the nonlinear effects associated with the non-wall-sided hull geometry such as bow

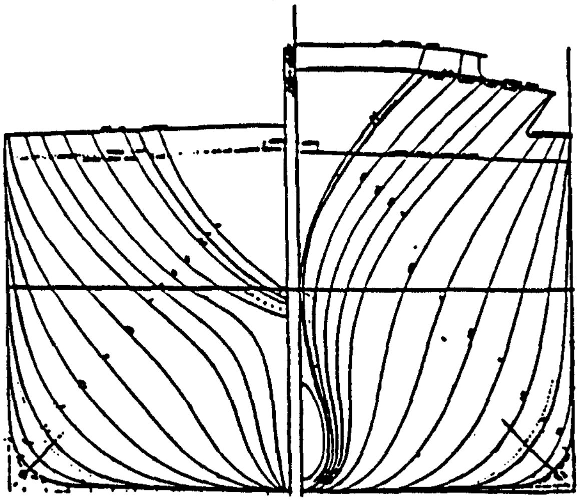

Figure 1: Body Plans for the S175 Containership.

flare and overhanging stern, incident wave amplitude and slope, and forward speed.

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DISCUSSION

S. Ando: How are the pressure fields above the calm-water line modelled in your computer codes?

Lin et al.: In LAMP-1, we do not have the pressure field information above the calm-water line. In LAMP-2, hydrostatic and Froude-Krylov pressures are calculated exactly below the incoming wave surface, hydrodynamic pressure is calculated below the calm-water line. However, an option is available in LAMP-2 to stretch the hydrodynamic pressure to the incoming wave surface. In LAMP-4, all pressures are computed below the incident wave surface.