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Numerical and Experimental Transient Tests for Ship Seakeeping

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ABSTRACT

A potential flow model for linearized ship seakeeping in time domain is presented. The numerical algorithm is briefly described. The transient-test technique, based on the interaction of a mathematical wave packet with the advancing ship, is numerically simulated and allows to recover the efficiency of frequency-domain models. Solutions are presented for a frigate, a container ship and a mathematical tri-hull. A set of experiments, also of the transient type, has been performed to support the numerical findings.

INTRODUCTION

So-called practical ship-motion simulation tools have to be efficient enough to provide results in a relatively short time. On this basis, linearized frequency-domain strip theories are largely employed because of the good compromise between simplicity, accuracy and computer requirements.

On the other hand, the fully nonlinear 3-dimensional simulation in time domain is the natural avenue to deal with extreme wave conditions. For ship motions, a fully nonlinear approach was through a desingularized Rankine panel method (Scorpio et al., 1996). A (weakly) nonlinear code SWAN2 (Sclavounos, 1996) is the most extensively tested time-domain code documented in the literature.

Here, we present our attempt to develop a time-domain algorithm for a ship of arbitrary geometry and speed (Colagrossi and Landrini, 1999). To recover the efficiency of 2-dimensional (Salvesen et al., 1970) and 3-dimensional (Bertram, 1998) frequency-domain methods, we determine ship behavior by studying the response to incoming wave packets (Clauss and Vannahme, 1999).

Three categories of ships have been considered. The first, the DDG51, is representative of a modern frigate-type ship. The second ship is the well-known container vessel S175, for which experimental data are available both for head and following seas. Finally, a tri-hull ship made by assembling Wigley models is considered. For the combatant and the trimaran, we have also performed an extensive set of experiments based both on the transient-test technique and on more conventional tests in regular and irregular waves.

The good agreement between experimental data and numerical results validates the computational procedure and presents the latter as a useful alternative tool to seakeeping tests.

NUMERICAL TREATMENT OF PROBLEM

The unsteady motion of a ship in a seaway is studied by an inviscid model. In this framework, the nonlinear problem is stated in Newman (1978). Here, we consider the case of small oscillations $\vec{\alpha} = \vec{\xi} + \vec{\Omega} \times \vec{R}$ with respect to the mean trim and sinkage attained by the ship when advancing in a calm sea, with constant forward velocity $\vec{U}$ in the x-direction. In the following, $\vec{W}$ denotes the basis-flow. The perturbation velocity potential φ satisfies the Laplace equation:

$$\nabla^2 \varphi = 0 \tag{1}$$

with the standard no-penetration boundary condition on the mean wetted hull ∂H:

$$\partial\varphi / \partial n = \left\{ \vec{\alpha}_t + \nabla \times \left(\vec{\alpha} \times \vec{W} \right) \right\} \cdot \vec{n} - \partial\varphi_0 / \partial n \tag{2}$$

and with the linearized kinematic and dynamic free-surface conditions on the mean free-surface level ∂F

$$\begin{aligned} \eta &= \varphi_z - \nabla\eta \cdot \vec{W} + \eta \vec{W}_z \cdot \vec{k} + \nabla W^2 \cdot \nabla\varphi / 2g \\ \varphi_t &= -g\eta - \vec{W} \cdot \nabla\varphi \end{aligned} \tag{3}$$

In Eq. 3, g is the gravity acceleration, ρ is the fluid density, η is the wave height and t the time. Lower suffices stand for partial derivatives. The above problem describes the induced motion $\vec{\alpha}$ of the ship under the action of incoming waves with potential φ_0. The fluid-dynamic problem is coupled with the body motion through the hydrodynamic loads $\vec{F}, \vec{M}$ (evaluated by direct pressure integration in the numerical procedure). In turn, body motions affect the flow field via the body boundary condition (Eq. 2). To evaluate the pressure $p = -\rho\,(\varphi_t + \vec{W} \cdot \nabla\varphi)$ on the hull, the time derivative of the potential, φ_t, is computed by solving the auxiliary boundary-value problem:

$$\begin{aligned} &\nabla^2 \varphi_t = 0 \\ &\partial\varphi_t / \partial n = \left(\vec{\alpha}_{tt} + \vec{\Omega}_t \times \vec{W} \right) \cdot \vec{n} \quad \text{on } \partial H \\ &\varphi_t = -g\eta - \vec{W} \cdot \nabla\varphi \quad \text{on } \partial F \end{aligned} \tag{4}$$

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