

## **Prediction of Hydrodynamic Performance for Various Ship-Shaped Hulls under Excessive Roll Motions Using an Unsteady Navier-Stokes Solver**

*Yi-Hsiang Yu and Spyros A. Kinnas*

Ocean Engineering Group, Department of Civil, Architectural, and Environmental Engineering  
The University of Texas at Austin, Austin, TX, USA

### **ABSTRACT**

This paper addresses the hydrodynamic interaction of ship-shaped hull sections in prescribed roll motion and also in transient roll-decay motion. The flow around 2-D hull-section with four different model geometries are studied using a Finite Volume Method (FVM) based numerical model, and the results from the FVM scheme are compared with experimental data and other numerical results. For the prescribed roll motion, the effects of different hull geometries and roll angle amplitudes on the moment histories and corresponding hydrodynamic coefficients are presented, and the highest amplitude of motion studied has been increased to 20 degrees. The relation between the hydrodynamic coefficients and the corresponding roll damping rate and frequency in the case of transient roll response for different hull geometries and different initial displacements is also discussed.

**KEY WORDS:** Bilge keels; ship-shaped hull; prescribed roll; roll decay; Navier-Stokes equations; finite volume method.

### **INTRODUCTION**

Ship-shaped hulls have often been found to be subject to excessive roll motions that inhibit their use as a stable production platform. Bilge keels have been widely used as an effective and economic way of mitigating the roll motions, and their effectiveness lies in their ability to damp out roll motions over a range of frequencies. The performance of roll motion, in a conventional sense, is measured in terms of hydrodynamic added-mass and damping coefficients. (Vugts 1968) was the first to calculate the hydrodynamic coefficients for sharp-edged sections in roll motions and observed the importance of the viscous effect. The estimation of these coefficients through various numerical methods and validation through experiments has been the focus of research over the years, (Na et al. 2002; Wilson et al. 2006; Yeung et al. 1998; Yeung et al. 2000). The estimation of the damping coefficient on a non-conventional hull-section is investigated experimentally by (Yuck et al. 2003), where they found that the roll damping could increase significantly due to the hull geometry.

Two important aspects of the flow associated with the hull motions that influence the hydrodynamic coefficients are (1) the separated flow past

the bilge keels governed by viscous effects and (2) the waves generated at the free surface. The contribution of these two aspects of the flow can be seen as components of the hydrodynamic coefficients. The 2-D Navier-Stokes (NS2D) solver is developed and validated in (Choi and Kinnas 2001; 2003; Kinnas et al. 2003). For the hull motion problem, the hull-forms are assumed to be slender with the longitudinal length-scale exceeding the other two physical dimensions. This assumption allows the modeling of the flow around the hull-form in a 2-D strip-wise manner. Results for moderate roll angles have been studied in (Kinnas et al. 2006; 2007; Yu et al. 2005). A Boundary Element Method (BEM) based potential solver was developed and applied to the forced roll motion problem in (Vinayan et al. 2005), which focused on the effects of nonlinear free surface boundary condition under large roll angle. The BEM solver is used as a verification tool of the results of the current method, in the absence of viscosity.

The first part of the paper focuses on hull response in prescribed roll motion. The convergence of numerical results with change in grid resolution and the correlation with experimental results for different hull geometries are presented. The results are also compared with those obtained from a commercial CFD-solver FLUENT applied to hulls in prescribed roll motions. The effect of turbulence is also examined through a comparison between NS-2D (Laminar) and FLUENT (turbulent) models. The second part focuses on the response of the hull in transient roll-decay. In this case, results are presented for different hull geometries and different initial roll angles.

### **METHODOLOGY**

For incompressible flow, the ship-shaped hull motions are predicted by using the NS2D solver. The governing equation and the present numerical scheme is described in this section. The finite-volume discretization is applied on the collocated grids combined with a pressure-correction scheme (SIMPLEC), and the non-linear free surface is simulated using a free-surface tracking algorithm. The hull motion and the calculation of the corresponding hydrodynamic coefficients are also described in (Wilson et al. 2006; Yeung et al. 2000).