Proceedings of the Ninth (2010) ISOPE Pacific/Asia Offshore Mechanics Symposium
Busan, Korea, November 14-17, 2010

ISBN 978-1-880653-79-1: ISSN 1946-004X. www.isope.org

The Second Order Wave Exciting Force on a Floating Ship Considering Tank Liquid Dynamic Effect

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ABSTRACT

The second order wave exciting force on a floating ship considering tank liquid dynamic effect is examined. The second order drift forces are quadratic products of the first order quantities. The ship motions in wave considering tank liquid dynamic effect are calculated by linear potential theory. Then the second order drift forces are computed by near field method based on the pressure integration and validity is confirmed by far field method. For a numerical calculation example, the motions and drift forces of 250K LNG FPSO in wave condition are demonstrated.

KEY WORDS : Drift force ; Tank liquid effect ; sloshing ; coupling motion ; LNG-FPSO.

INTRODUCTION

To estimate the ship motion in waves containing large liquid tanks are very complex problem. In most seakeeping computations, the liquid inside the tanks has been generally treated as a rigid mass. However, for LNG carriers and FPSO vessels during loading and unloading cargo operations the ship motion is very important topic. Coupled global ship motion and tank liquid dynamic effect have been studied numerically and experimentally by Chen, X. B. et al.(2007), Gaillarde, G. et al.(2004), Rognebakke, O. F.(2003) and Kim J. W. et al (2005).
FPSO vessels are operated at a fixed station point by some kind of mooring systems. Therefore in addition to estimate the ship motion ability the evaluation of the drift force acting FPSO is required from the operational view point. Newman (2005) conducted the ship drift force calculation considering tank liquid dynamic effect based on the commercial program WAMIT. The result showed that the tank liquid dynamic effect on the drift force is significant at sloshing resonance wave period. This suggest that during loading and unloading cargo operations between FPSO and shuttle tanker which are considering the tank liquid dynamic effect on the ship motion and drift forces are essential problem.
This report is concerned with a LNG-FPSO ship motion and drift force analysis considering tank liquid hydrodynamic effect. The methodology is based on 3D potential theory on a coupling model of sloshing and seakeeping in the frequency domain. The sloshing phenomena inside tank are violent and catastrophic liquid motions at heavy sea state. However, the primary concern of sloshing induced force to ship motion is governed by the global fluid motion pressure acting on the tank wall. So that we treat the tank liquid motion as linear potential theory.
The second order drift forces are quadratic products of the first order quantities. We treat the problem with two kind of numerical procedure for calculation of the drift force. The one is computed by the far field angular momenta conservation method introduced by Maruo(1960) and Newman(1967), the other is the near field method based on the pressure integration, for example, Ha M.K. et al. (2004) and Kashiwagi (2002). We confirmed the validity of computations by both method. For a numerical calculation example by the tank liquid dynamic effect on the ship response, the motions and drift forces of 250K LNG FPSO in wave condition are demonstrated.

3D potential theory on a coupling model and sloshing sea keeping

Coordinate system

Let o-xyz be a body fixed coordinate system with origin o placed on the mean water surface along the vertical through the center of gravity of the ship G and the positive z axis directed vertically downward. The x-y plane coincides with the mean free surface. The cargo tank fixed coordinate system, o_T-$x_Ty_Tz_T$ is defined as follows. The origin, o_T is located on the mean free surface of tank liquid along the vertical through the center of gravity of the tank liquid. (Fig. 1).