Sloshing Assessment of LNG-FPSOs for Partial Filling Operations

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ABSTRACT

In general, LNG carriers for ocean going ship with membrane cargo containment system have acceptable tank filling level in the cargo tanks of below 10% and over 70% of tank height. The main reason of the filling restrictions is due to high sloshing impact pressures at low filling levels, which is around 30% filling level. In the case of LNG-FPSOs at specific site operation condition, it is not possible to restrict filling levels of the LNG cargo tank due to production and offloading with LNG carrier.

The practical application for partial filling operation of LNG-FPSOs is to suggest the operational envelop. The method restricts the wave heights and headings during the partial filling operation. The other way is to increase LNG cargo tank numbers or change the shape and dimension of cargo tank to reduce the sloshing impact pressures at low filling levels.

In the present study, the numerical sloshing assessments for LNG-FPSOs are carried out to find the possibility of partial filling operation of LNG cargo tank. The various cargo filling levels and coupled ship motion interaction effects due to sloshing are also considered.

KEY WORDS: LNG-FPSO, Sloshing, Seakeeping, Free surface, coupled motion, Impact pressure.

INTRODUCTION

This report is concerned with a practical sloshing load assessment of LNG-FPSOs for partial filling operations. The procedure of the sloshing load assessment consists of two stages. The first stage is the estimation of global ship motions in wave considering partial filling tank liquid motion. The second stage is the sloshing calculation using SHI-SLOSH CFD code (Ha et al, 2002 and Park et al, 2006) under a selected sea states.

In general, sloshing motions inside tanks have not been included in the conventional seakeeping analysis due to their complexity. In most seakeeping computations, the liquid inside the tanks has been generally treated as a rigid mass. However, theoretical and experimental studies have shown that the interaction effects between sloshing and motion behavior can significant to the extent that they can noticeably affect sway and roll motion (Chen et al., 2007, Gaillarde, et al., 2004, Rognebakke, 2003, Kim et al., 2005 and Kim et al., 2007).

At the first stage, the present study is concerned with a LNG-FPSO ship motion analysis considering tank liquid hydrodynamic effect. The methodology is based on 3-dimensional potential theory on a coupling model of sloshing and motion 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 stage is the sloshing assessment of LNG-FPSOs for partial filling operation with coupled motion results. In the present study, the two different type of LNG-FPSO are suggested. The first one is consisted of the conventional LNG tank and the second one has two-row tanks, which reduced the beam length of LNG cargo tank. The numerical sloshing assessments for two different LNG-FPSOs are carried out to find the possibility of partial filling operation of LNG cargo tank. The assessment of sloshing for partial filling operation is based on comparative approach.

MOTION ANALYSIS WITH SLOSHING EFFECT

3D Potential Theory on a Coupled Motion and Sloshing

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Coordinate System

Let \( o_{x'y'z'} \) be a global coordinate system with origin \( o_0 \) placed on the mean water surface and the positive z axis directed vertically.