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Numerical and Exprimental Investigations on Deepwater CALM Buoys Hydrodynamics Loads

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Abstract

Principia R.D. is the leader of the CALM BUOY JIP, which purposeis to study the behavior of deepwater CALM Buoys systems. The final objective is to provide guidelines for the analysis of deepwater offloading systems covering the main aspects related to the OOL/mooring lines fatigue analysis. Most of the attention is focused on the buoy hydrodynamics using both experimental campaigns and numerical investigations (full and model scales). Captive tests and forced oscillations tests at scale of 1/25 were performed with different skirt dimensions and drafts characteristic of a typical buoy.

A new methodology and formulation is derived for damping estimation which is a key point of the analysis. The various damping formulations are implementedand tested in a fully coupled buoy / lines finite element solver. The results are validated against experimental measurememts in regular and irregular waves. Recommendations are deduced on the “model of model” approach classicaly used for model tests.

Finally, use of CFD calculations to replace forced oscillations tests is also explored through comparisons with model tests. CFD appears to be a reliable tool to assess scale effects and to compare buoy geometries.

Introduction

Offloading system using SPM (Single Point Mooring) buoy and export lines is the basic solution for most of deepwater West Africa fields developments. A major topic in the design process (in addition to all the hydrodynamic / thermal issues) is the fatigue life prediction for both mooring system and export lines (Ref.1).

Indeed, as deep water buoy motion is largely affected by the semi taut lines dynamics, a coupled analysis is required. Therefore a first phase of the CALM Buoy JIP was dedicated to the identification of the coupling effects and to their modelling based on specific model tests and numerical investigations. The results of this first phase were largely used in recent projects. However, some difficulties / uncertainties on the design of a deepwater offloading buoy remained.

The purpose of the Phase II is to tackle some of the remaining issues and also to derive guidelines for mooring systems of a deep water offloading buoy.

Recent deep water projects tends toward increasing both thefrequency of the offloading tankers and the export lines diameters and therefore the buoy displacement. Then fatigue life becomes even more critical and dependent on the hydrodynamic loads on the buoy. Furthermore, projects are moving to deeper water up to 3000m.

Background Hydrodyanmic loads and damping

Fatigue life of mooring lines and OOLs are mainly induced by the calm buoy motions which have therefore to be estimated with a good accuracy.

Use of a fully coupled model Buoy/Mooring/OOL run in time domain is now a standard way to derive the buoy motions and RAOs (Ref.2). The small size of the buoy associated to a partial taut mooring system and heavy OLLs give heave/ pitch / roll natural frequencies close to the peak frequencies of the most damageable wave spectra (the hydrostatic stiffness fully governs the heave / pitch / roll natural periods). Strictly speaking, the buoy is not acting as a free-floating body as the buoy mass is counteracted not only by hydrostatic but also by mooring loads.

When focusing on regular waves approach, one problem is the damping modeling for the frequencies close to the resonance where the damping level directly affects the resulting motions amplitude. The hydrodynamic damping is mainly induced by viscous flow and vortex shedding around the hull equipped with its horizontal skirt. The general approach is to model the damping with a so-called linear + quadratic formulation applied independently for surge, heave and pitch. However, in reality, the flow is resulting of the superimposition of the 6 d.o.f. buoy motions and of the wave kinematics. The standard way to assess the damping modeling follows 3 main steps:

- Select a formulation for each d.o.f.;
- Perform model tests and calibrate the damping coefficients according to the model tests;
- Use the calibrated formulation at full scale.