Investigations on Hydrodynamic and Mechanical Coupling Effects for Deepwater Offloading Buoy

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ABSTRACT

The paper deals with the modeling of the response of deepwater offloading buoy. The main hydrodynamic and mechanical aspects of both the buoy itself and the coupled effects provided by the mooring system and the export lines are discussed, using experimental and numerical results derived from the "Offloading Calm Buoy JIP" and several projects as Girassol, Kizomba and Erha. A particular attention is paid on hydrodynamic damping derived from model tests and/or CFD. A methodology, based on a full coupled analysis, is proposed to assess the fatigue damage of the system. The way to model the connected tanker influence is also included.

KEY WORDS: Offloading, deepwater calm buoy, export line, wave response, coupled analysis, fatigue assessment.

INTRODUCTION

Offloading system using a SPM (single Point Mooring) buoy and export lines is the basic solution proposed for the deepwater West Africa fields development (Girassol, Erha, Kizomba, Bonga). A major topic in the design process (in addition to all the hydraulic/thermal issue) is the fatigue life prediction for both the mooring system and the export lines as the system behavior is very sensitive to numerous design and environmental parameters.

Fatigue life of the mooring system and of offloading oil export lines (OOL) is currently assessed using spectral analysis based on the RAOs prediction of the buoy. Indeed the buoy motions is largely affected by the lines dynamics and then a coupled analysis is required. An additional aspect is the drag loads on the hull which govern the buoy response close to its natural periods, mainly in pitch and roll.

Some dedicated tools are now existing but with some uncertainties in the hydrodynamic and mechanical modeling are still remained. Thanks to DeepLines™ developed by IFP and Principia since 5 years, the main aspects of the problem have been more deeply analyzed :

- the mechanical and hydrostatic coupling effects including both the influence of the non-diagonal term in the inertia and stiffness matrices and the influence of the dynamic response of the export and mooring lines
- the hydrodynamic loads on the buoy. A particular attention is paid to the modeling of the drag and damping coefficients as the vortex shedding flow around the skirt could be governed both by KC and Re numbers.

A methodology was derived from the JIP's results to include in a better way the most important effects : drag / damping on the buoy/skirt hull, mechanical and hydrodynamic coupling effects with lines, method for RAOs estimation using time domain analysis (regular wave versus irregular waves approaches), fatigue life estimation (spectral analysis versus rain flow method). Attempts to derive hydrodynamic loads both from model tests, including scale effects, and CFD calculations is also discussed hereafter.

The paper will conclude on the recommended methodology to derive the buoy RAO motions needed for prediction of the fatigue damage of mooring lines. Further works on the shuttle tanker influence plans in a new starting JIP will be also briefly described.

For two years experimental and numerical works have been carried out to assess the coupled analysis, particularly within the JIP "Calm Buoy" including the main oil companies and the buoy / OOL providers (Berhault, 1997). Large benefits were drawn using this methodology in recent projects (Girassol, Kizomba, Erha).

DEEPWATER OFFLOADING BUOY SYSTEM

Basic Characteristics

Recent deepwater project located in West Africa are mainly based upon offloading system including FPSO, export lines and calm buoy (Fig.1) :
- the submerged export lines, composed of risers, of 16" to 20" diameter, are link to the FPSO and to the buoy. The static and dynamic loads transferred to the buoy are depending on the OOLs architecture