

## **Hydrodynamic interaction in a coupled ship / barge system and its effects on the mooring line and fender forces**

*Chen Xie and John M. Niedzwecki*

Zachry Department of Civil Engineering, Texas A&M University  
College Station, Texas, United States

*Per Teigen*

StatoilHydro Research Center, StatoilHydro  
Trondheim, Norway

### **ABSTRACT**

A series of model tests was performed to study a side-by-side moored ship / barge two-body system. Based on the experimental data, the present research investigation focused upon the analysis of the vessel motion response behavior as well as the pattern of the mooring line and fender forces in random seas for different heading conditions and load levels. Statistical parameters and spectral analysis showed that both the motion behavior and the connection force magnitude will be partially conditioned by the shielding effect and the load level of the ship. The time series of the motions near extreme mooring forces and the corresponding coherence functions between these pairs of data allowed for an estimation of the impact of the relative motions on the mooring and fender forces.

**KEY WORDS:** Two-body system; random seas; motion behavior; mooring line force; fender force; statistic analysis; coherence functions.

### **INTRODUCTION**

Interest in two-body hydrodynamic problems is gaining increasing attention due to the frequent use of closely positioned floating platforms in various offshore operations. The complexity of the motion behavior of such systems, especially side-by-side moored systems, is influenced by interaction effects including diffraction, radiation and the wave field between the platforms. The configuration of the two-body system, in particular the size and the shape of the structures, the separation distance between them, the heading condition, as well as the stiffness of the various mooring and docking connections will exert an important influence on the response behavior of the two-body system.

Both numerical and experimental methods were employed to study the side-by-side moored two body system problems. Buchner *et al.* (2001) developed a numerical time domain simulation model for the prediction of the hydrodynamic response of a moored LNG FPSO and LNG carrier system. Koo and Kim (2005) developed an exact method including all the vessel and line dynamics as well as the hydrodynamic coefficients in a combined matrix. It was observed that cross-coupling terms are important in side-by-side mooring configuration. Teigen and

Niedzwecki (2006) investigated numerically the wave loads and wave interaction effects on a side-by-side moored twin barge system using both first and second order hydrodynamic theories. The effect of the water depth on the interaction forces and moments between two floating units was recently studied by Li (2007). A comparison of some existing commercial time domain simulation packages for two-body systems was performed by Naciri *et al.* (2007).

Experimental studies have played an important role in validating and refining the numerical scheme. Van der Valk & Watson (2005) studied experimentally the motion behavior of LNG vessels in both side-by-side and tandem mooring configurations. A higher order boundary element method was used to study the two-body system hydrodynamic response behavior (Hong *et al.*, 2005); the results were compared with experimental ones. Fournier *et al.* (2006) compared the experimental results with several numerical simulation methods used by industry to investigate the resonance between a floating storage and regasification unit and a typical LNG carrier. Teigen and Niedzwecki (1999) and Xie *et al.* (2006) analyzed a coupled mini-TLP and tender barge system subject to benign sea conditions based on the experimental data obtained during model testing. Their study of two-body response behaviour provides a partial basis for the analysis of the experimental data presented in this text.

In the current study, a side-by-side moored ship and barge system was investigated. The two vessels were connected together by mooring lines at fore and aft locations and an instrumental fender system was used to monitor the forces between the vessels. The present study focuses on the analysis of the vessel motion behavior as well as the pattern of the mooring line and fender forces in random seas based on the experimental data obtained during the modeling tests. The causality between them, namely the effect of the relative movement on the connection system, was examined. For this purpose, the motion of the barge and that of the ship, ballast or fully loaded in head and quartering seas, were compared using statistical parameters. The mooring line and fender forces were analyzed in a similar way supported in addition by spectral analysis of the measured time series data. Finally, the time series of the relative motions around the occurrence of maximum mooring line and fender forces were examined for an estimation of the impact of each motion on the connection forces.