OTC 18769

Deepwater Riser VIV Assessment by Using a Time Domain Simulation Approach

Kevin Huang, Hamn-Ching Chen, and Chia-Rong Chen, Texas A&M U.

This paper was prepared for presentation at the 2007 Offshore Technology Conference held in Houston, Texas, U.S.A., 30 April–3 May 2007.

Abstract

This paper presents a computational fluid dynamics (CFD) approach, and evaluates its feasibility to assess the deepwater riser VIV. The time domain simulations are performed by using an unsteady, overset-grid (Chimera), Navier-Stokes method. The studied riser is a top tensioned riser in 3,000ft water depth. The fluid domain was descritized to a total of slightly less than 1 million elements. The calculation was performed in time domain. At each time step, the drag and lift forces are computed by solving Navier-Stokes equations. The turbulence flow was solved using Large Eddy Simulation (LES) with Smagorinsky subgrid-scale turbulence model. The instantaneous drag and lift forces along the riser are then applied to riser motion equations. We developed a simplified riser motion solver based on tensioned beam equation and modal decomposition. The motion solver is embedded in the CFD codes, so the calculated riser velocities and displacements are feed back to the fluid domain computation at each time step. Both in-line and cross flow VIV are calculated, but we focus only on the cross flow VIV in this paper. We studied the 3D flow pattern around the riser, riser response and modal excitation, and riser stress distribution that could be used for further fatigue assessment.

The study has been performed on a uniform current and a linearly sheared current. It is found that the dominant mode can be clearly identified in both the uniform and sheared current conditions. At the same time, we also observed that the riser could experience multi-mode vibration. In other words, the dominant mode is not necessarily locked-in. Possible reasons include the riser transient response effect and riser modal coupling effect. It is concluded that the proposed CFD approach is feasible for practical riser VIV assessment. It is also an effective tool to disclose riser VIV details, provide fundamental understanding and insight to VIV phenomena, predict riser VIV for complex current conditions, evaluate sensitivities including vessel motion coupling and transient effect, and verify riser VIV design and analysis.

Introduction

Riser vortex induced vibration (VIV) has been a primary design challenge for deepwater applications. Many software tools have been developed in the oil & gas industry to perform riser VIV analysis. However, majority of them are based on empirical formulas, and heavily relying on model test data. This approach could provide satisfactory VIV predictions for shallow water risers, where their length over diameter ratio (L/D) is fairly small, and model tests could be easily carried out to provide input data and/or verifications. For deepwater risers, they are likely to have high order mode vibration in strong current. Under such condition, even model test in wave tank is difficult either limited by tank sizes or model scale, while field experiment is feasible but costly. Furthermore, there are some important characteristics associated with deepwater riser VIV yet to be studied and understood, such as: (1) deepwater risers tend to experience multi-mode vibration. Therefore, it would be overly conservative to assume single-mode lock-in, and (2) the excited modes in deepwater riser VIV could be very high, while higher modes are more sensitive to damping, hence showing strong nonlinear behavior.

This paper is the first attempt to address the above questions by using a CFD simulation approach and Chimera technique. This method has been previously validated and applied to different riser VIV studies [Huang & Chen, 2006; Huang, Chen & Chen, 2007a, 2007b]. The Chimera technique is particularly well suited for computational fluid dynamics (CFD) involving moving objects such as risers. This paper first describes the computational fluid dynamics (CFD) approach, where overset-grid (Chimera) technique is used to handle the data grid movement due to riser deflections and vibrations. A typical single casing top tensioned riser is then sized for 3,000ft water depth and used for this study. The riser dynamic response under different currents is simulated in 3D. The riser-fluid interaction effect is included through instantaneous drag and lift forces. The riser inline and cross flow responses, including A/D, modal shapes and frequencies, and VIV induced stresses, are studied in detail. Last, the conclusions are drawn. It is demonstrated that the CFD approach provides reasonable results. It is also found that further improvements, for example, refined data grids in riser span direction and more coupled terms in the riser modal equations, are essential for riser VIV assessment in more complex current profiles and riser conditions.