Riser VIV Induced Fatigue Assessment by a CFD Approach

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ABSTRACT

This paper presents a CFD based fatigue analysis approach for riser VIV induced fatigue assessment in uniform current. The riser has a L/D of 1400. It is horizontally positioned and constant tensioned. The flow field around the riser was discretized into 1.5 million elements, and was solved using an unsteady Navier-Stokes numerical method on an overset (Chimera) grid system. The drag and lift coefficients at each time step were then calculated and applied to the riser structural FEA model through load mapping. Runge-Kutta scheme was employed to integrate the riser beam motion equation in time domain and determine the riser dynamic responses. The bending stress time histories were then generated based on the riser's instantaneous displacements, and the fatigue damages were predicted through Rain Flow Counting technique and Palmgren-Miner's rule. The predicted fatigue results were compared to the previous publications and shear 7's results. General agreements were observed. We also investigated the convergence of the fatigue results, the stress histogram characteristics, and the relation between in-line and cross flow VIV induced fatigue. It is concluded that the presented numerical method is valid and feasible for riser VIV induced fatigue calculation.

KEY WORDS: riser, vortex induced vibration (VIV), Chimera, time domain, computational fluid dynamics, fatigue.

INTRODUCTION

Numerical simulation of the vortex induced vibration of cylinders has been studied in numerous publications. A good summary of the publications in the area of the cylinder flow simulations at high Reynolds number can be found in Dong et al. (2005). Chaplin et al. (2005) described and presented the comparisons of some of the popularly used CFD tools for riser VIV prediction. Holmes et al. (2006) has successfully simulated riser VIV in fully 3D by using 10 million unstructured elements and compared results to experimental data (Trim et al. 2005). We also demonstrated that the long riser VIV could be analyzed by using Chimera (overset grid) technique embedded CFD approach and Finite-Analytic Navier-Stokes (FANS) code (Huang,

Chen & Chen, 2006, 2007a, 2007b, 2007c, 2007d). This method has been previously validated and applied to different riser VIV studies (Pontaza, Chen & Chen, 2004, 2005a, 2005b; Pontaza, Chen & Reddy, 2005; Pontaza & Chen 2006). In this paper we study the feasibility of using the FANS code for practical riser VIV induced fatigue assessment.

Riser VIV is a primary concern in offshore oil and gas industry because the vibrations are in high frequency and generates large quantity of stress cycles within the riser pipe. Many of the existing software tools for riser VIV analysis are based on modal superposition and heavily rely on model test data calibration, hence difficult for deepwater riser VIV assessment. In this paper we present an alternative CFD approach for deepwater riser VIV induced fatigue assessment, especially under complex current conditions. We have demonstrated the capability of this CFD approach for riser VIV simulations (Huang, Chen & Chen 2007a, 2007b, 2007c, 2007d). In order to extend this approach to fatigue calculation, we focus on the accurate prediction of stress cycles. First, we refined the data grids for better fluid field resolution. Second, we utilized a load mapping technique to facilitate the riser motion and curvature calculation. Third, we increased the simulation durations to demonstrate the convergence of the fatigue results.

For comparison purpose, we selected the same riser used for the Trim's experiment (Trim et al. 2005). It is a long cylinder with L/D = 1400 and constant tension about 500kg. Uniform current profiles with speed of 0.4m and 0.8m are used for the study. We have previously compared the riser VIV motions with the experimental data and general agreements have been observed (Huang, Chen & Chen, 2007b). In this paper we improved the data grid resolution in riser spanwise direction such that the riser curvatures could be calculated more accurately. The concerned fluid domain is discretized into 1.5 million elements. We also discretized the riser into 500 segments, and the fluid pressure and viscous force acting on the riser surface are integrated and mapped to the corresponding riser segments as uniform loads. The riser segment number is comparable to typical deepwater riser global dynamic FEA analyses. In other words, the riser segments are sufficiently fine for the practical riser global analysis, and capable of handling the details such as stress joint taper section and tension joints, where high curvatures and bending stress are expected.