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Fatigue Life Calculations of Risers by Taking into Account the Higher Harmonic Force Components

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ABSTRACT

We apply systematic diagnostics obtained form laboratory experiments at MIT to the strain and acceleration signals of model scale experiments on a riser, in order to assess the predictability of the response, and also extract the contribution of the higher-harmonic force components. A large third-harmonic contribution is observed for the majority of the cases, suggesting the importance of considering the influence of higher harmonic force components, when analyzing the fatigue life of a riser subjected to uniform or linearly sheared current. The region of excitation for various sheared flow cases remains almost constant, independent of the maximum sheared flow, suggesting about half of the riser is excited. The excited part covers the region where counterclockwise figure-eight motions are observed. Sample fatigue life calculations show a decrease of orders of magnitude when the high frequency forcing is taken into account for a model scale experiment.

KEY WORDS: vortex induced vibrations; risers; higher harmonics; fatigue; figure-eight motions.

INTRODUCTION

Vortex Induced Vibrations (VIV) of long flexible cylinders (risers) has been recently studied extensively mainly due the growing interest in deep water oil exploration among other industrial applications. VIV of short rigid cylinders, on the other hand, is a relatively older problem and is much more well-understood than that of long flexible cylinders. Papers by Sarpkaya (2004) and Williamson and Govarhan (2004) on rigid cylinders and by Vandiver (1993) on flexible cylinders give comprehensive reviews on VIV problems. The majority of works on VIV of flexible cylinders (similar to those on rigid cylinders until very recently) have been focused on cross-flow oscillations, with neglecting the relatively small in-line oscillations. Recently it has been shown (see, e.g., Dahl et al., 2007) that for rigid cylinders, if the IL oscillations are allowed, a non-negligible 3^{rd} (or even 5^{th}) harmonic force component is observed, which can influence the physical behavior of the rigid cylinder. In this paper the existence of these higher harmonic force components in the case of long flexible risers is investigated.

The idea here is to collect all the available information (strain and acceleration signals measured at a few points along the riser in the field, physical properties of the riser, experimental results of Vortex Induced Vibrations of a flexibly mounted rigid cylinder, etc.), analyze them and gain as much information as possible about the higher harmonic components of the force in riser oscillations and then use this information to conduct a fatigue life calculation along the riser's length by taking into account all the higher harmonic force components. In this paper, first the information obtained from experimental cases (uniform flow and linearly sheared flow profiles) are presented. Then, these experimental data are analyzed both quantitatively and qualitatively. Quantitative analysis gives the contribution of higher harmonics in measured signals, while in qualitative analysis the motion trajectories along the length are investigated. This is then followed by introducing a methodology for fatigue life calculation for the riser by taking into account the higher harmonic force components using a forced rigid cylinder database. Two sample cases are given to show the importance of taking into account the higher harmonics of the forcing.

EXPERIMENTS

The analyzed cases here are from NDP Riser High Mode VIV tests (Braaten and Lie, 2004), which comprise uniform flow cases (where the flow velocity is constant along the riser and varies from U=0.3 to 2.2 m/s with 0.1 steps in various cases) and linearly sheared flow cases (where the flow velocity is zero at one end and increases linearly along the length, where the maximum flow varies from U=0.3 to 2.2 m/s with 0.1 steps). Physical properties of the riser used in these experiments are given in Table 1. In each case, there are 40 experimental measurements of the in-line strain along the length, 24 measurements of the cross-flow strain, and 8 measurements of the in-line and cross-flow accelerations. There are 8 points along the length with measurements of both strain and acceleration, and in both cross-flow (transverse) and in-line directions. Table 2 provides the locations where the measurements were obtained in NDP experiments.