Proceedings of the Twenty-eighth (2018) International Ocean and Polar Engineering Conference **www.isope.org**
Sapporo, Japan, June 10-15, 2018
Copyright © 2018 by the International Society of Offshore and Polar Engineers (ISOPE)
ISBN 978-1-880653-87-6; ISSN 1098-6189

Bending Dominated Flexible Cylinder Experiments Reveal Insights into Modal Interactions for Flexible Body Vortex-Induced Vibrations

Ersegun Deniz Gedikli[1, 2], *David Chelidze*[3], *Jason M. Dahl*[2]
(1) Sustainable Arctic Marine and Coastal Technology (SAMCoT), Centre for Research-based Innovation (CRI), Norwegian University of Science and Technology (NTNU), Trondheim, Norway
(2) Department of Ocean Engineering, University of Rhode Island, Narragansett, RI, USA
(3) Department of Mechanical, Industrial and Systems Engineering, University of Rhode Island, Kingston, RI, USA

ABSTRACT

The dynamics of offshore structures resemble to the dynamics of long flexible cylinders. However, the complexity of flexible body interactions have pushed industry to rely on the dynamics of rigid cylinders ignoring the effect of spatial response of such structures completely. In this work, we aim to clarify the dynamics of a flexible cylinder that undergoes vortex-induced vibrations in a systematically designed experiment to see the effect of structural mode shape on the excitations. In the experiments, we test three bending dominated flexible cylinders and compare the results with a tension dominated flexible cylinder under uniform flow conditions. We study the nonlinear modal interactions by means of analyzing the spatial response using a multivariate analysis technique called generalized smooth orthogonal decomposition. Using this technique, we show that a flexible cylinder is unable to oscillate with an even mode excitation in the in-line direction, although it has second mode frequency characteristics. It is also shown that a mode switch in the in-line direction is highly dependent on the cross-flow motion where for a possible mode switch in the in-line direction, a mode switch in the cross-flow direction is necessary. In other words, a cylinder cannot oscillate with higher modes in the in-line direction keeping the cross-flow shape constant. This shows the inherent coupled response of in-line and cross-flow motions.

KEY WORDS: Vortex-induced vibration; flexible; multi-mode; generalized smooth-orthogonal decomposition

INTRODUCTION

Technology, law, and world's appetite for more energy pushed oil and gas exploration farther from the shores. This need—moving into deeper waters—brought extra challenges with it, for example, offshore structures inherently became more prone to environmental loads that may easily lead to nonlinear responses. Therefore, understanding the nonlinear interactions of such structures became more important than ever.

Vortex-induced vibration (VIV) is an inherent problem seen in offshore structures where coupled fluid-structure interaction may lead large structural motions that can have a significant effect on structural fatigue and offshore operations. Majority of previous research initially focused on understanding the response of a flexibly mounted rigid cylinder that is allowed to move only in cross-flow (CF) direction (also known as one-degree-of-freedom (1-DOF) response), and later concentrated on understanding combined in-line (IL) and CF responses (also known as two-degrees-of-freedom (2-DOF) response). Papers by Bearman (1984), Sarpkaya (2004), Williamson and Govardhan (2004) give insights into 1-DOF cylinder dynamics, and papers by Jauvtis and Williamson (2004), Dahl et al. (2006), etc. illustrate how a rigid cylinder behaves in 2-DOF VIV system.

Dahl et al. (2006) investigated the effect of different IL:CF frequency ratio combinations to the dynamics of the body. Dahl et al. (2006) showed that when this frequency ratio gets close to 2, cylinder oscillates with similar to figure-eight type of response, and inherently oscillates in counter-clockwise direction at the top and bottom of the cylinder (Dahl et al., 2007). Although, these studies provide insights into 2-DOF rigid cylinder experiments, it is not clear if a flexible structure undergoing multi-mode excitations could lead similar results along the length of the body.

Since the real offshore structures behave similar to long flexible cylinders with the same mass, damping, and mechanical characteristics in both IL and CF directions, they can undergo complex multi-mode type of motions, which illustrates the complexity of the motion as a canonical problem. Such responses were observed both in field (Vandiver and Jong, 1987, Vandiver et al. 2005, 2009, Lie and Kaasen, 2006, Marcollo