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Damage Detection in Flexible Risers Using Statistical Pattern Recognition Techniques

Carlos Alberto Riveros and Tomoaki Utsunomiya*
Department of Civil and Earth Resources Engineering, Kyoto University, Kyoto, Japan

Katsuya Maeda
Deep Sea Technology Research Group, National Maritime Research Institute, Tokyo, Japan

Kazuaki Itoh
Marine Technology Research and Development Program, Marine Technology Center, JAMSTEC, Yokosuka, Japan

A statistical pattern recognition technique based on time series analysis of vibration data is presented in this paper. A 20-m riser model experimentally validated is used for the numerical implementation of this technique. The dynamic response of the riser model is assessed using a semi-empirical approach with an increased mean drag coefficient model during lock-in events. Because structural damage is associated with fatigue damage, hinge connections are used to represent several damage scenarios. Then, the statistical pattern recognition technique is used to identify and locate structural damage using vibration data collected from strategically located sensors. Sensor locations are obtained from an optimum sensor placement method. The numerical results show that structural degradation due to fatigue in oscillating flexible risers can be assessed using the presented statistical pattern recognition technique.

INTRODUCTION

A flexible riser is currently receiving considerable attention by the research community due to its complex dynamic response and its economical impact when large structural degradation, mainly caused by Vortex-Induced Vibrations (VIV), affects its structural integrity. Several response prediction models for risers have been developed in the last 3 decades. Among them, an innovative numerical approach consists of the use of Computational Fluid Dynamics (CFD) to compute the hydrodynamic forces acting on a riser and solve the dynamic problem employing a coupled model. However, there are still some limitations in the computational resources needed for practical applications, and some difficulties in accurately modeling lock-in events. The semi-empirical approach is also used to predict the VIV response of risers. Current semi-empirical programs usually employ large databases of experimentally determined coefficients to predict VIV.

Emerging sensor technologies are making possible the use of powerful and affordable sensing systems to assess the current health state of a structure using vibration data in order to identify if the structure has deviated from its normal operating condition. On the other hand, current visual inspection methods involve uncertainties related to inspection of riser systems due to the relatively high level of dependency on the practical skills of the engineers who carry out structural inspections, and the potential danger that the accessibility conditions represent to inspectors. Thus the use of vibration-based damage detection methodologies is a good alternative to improve current inspection methods while monitoring the riser's health condition in real time.

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A reliable vibration-based damage detection system is divided into 4 levels (Rytter, 1993): Identification of damage that has occurred at a very early stage (Level I), localization of damage (Level II), quantification of damage (Level III), and prediction of the remaining useful life of the structure (Level IV). There are basically 2 approaches widely used in vibration-based damage detection of structural systems. The first approach is referred to as modal-based. This approach employs the dynamic properties of a structure to detect structural damage sites; the main idea behind this approach is that considerable changes in the modal properties such as natural frequencies, mode shapes and damping ratios provide quantitative information about the health condition of a structure.

Modal-based damage detection methods, which are able to locate and quantify structural damage, are based on the premise that the mass of a structure does not change appreciably as a result of structural damage. This assumption may not be true for offshore structures due to variation of structural mass or marine growth, which can cause uncertainty in the measured modal parameters. Further, structural damage usually causes changes in the order of the mode shapes; this highlights the importance of identifying a mode shape as well as its corresponding resonant frequency to accurately track its changes, which is not easy considering the adverse marine conditions commonly affecting offshore structures.

The second approach is based on the statistical analysis of the measured data. This approach has several advantages over existing modal-based damage detection methods. Modeling errors and modal identification limitations are avoided in this approach, making it more attractive and affordable for the development of a vibration-based damage detection framework for flexible risers. Riveros et al. (2007b) numerically implemented 2 vibration-based damage detection methodologies in flexible risers. The first methodology performs system identification and damage detection using a widely recognized (Level II) method known as the