

Structural Condition Identification for Free Spanning Submarine Pipelines

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ABSTRACT

The operational performance of the free spanning submarine pipeline is closely related to the structural condition. However, due to the underwater environment and condition evolution, it is very difficult to exactly obtain the information about the structural condition of the free spanning submarine pipeline. In this paper, we propose a novel methodology to identify the structural condition with the vibration responses of the free spanning submarine pipelines. Firstly, the nonlinear kernel discriminant analysis (KDA) was adopted to identify the structural condition of the free spanning submarine pipelines. Secondly, the condition-sensitive features, such as natural frequencies, normalized frequencies and frequency change ratios, were proposed in the study. Finally, the feasibility and effectiveness of the proposed approach was numerically studied. The analytical results demonstrate that the proposed approach can identify effectively each condition of free span for on-line monitoring of the submarine pipelines.

KEY WORDS: Structural condition identification; free spanning submarine pipeline; nonlinear kernel discriminant analysis; condition-sensitive feature.

INTRODUCTION

Submarine pipelines play an important role in the process of oil and gas exploitation, which is regarded as the lifeline of sub-sea oil and gas transmission. Over a rough seabed or on a seabed subjected to scour, pipeline free span is unavoidable when contact between the pipeline and seabed is lost over an appreciable distance. If natural frequency of free span is approximately equivalent to the vortex shedding frequency, the free span may suffer the vortex-induced resonance and consequently fatigue damage can occur, which severely threatens normal operation in a submarine pipeline system.

A substantial research effort related to various aspects of free span pipelines have been seen during past years. Park et al.(1997) studied static and dynamic behavior of free spanning pipeline, and proposed an allowable length of free span. Meanwhile, the variation of allowable

lengths is examined for specialized boundary conditions. Xu et al.(1999) addressed theoretical issues of a detailed mathematical model and its closed form solutions for free span movement, developed an approach to determine span length of multi-span pipelines in view of in-line wave-induced fatigue. Choi (2001) derived a closed form solutions of the beam-column equation under the various boundary conditions, applied energy balance idea to obtain natural frequencies of the free spans. The axial force effects on the natural frequencies and allowable spanning lengths are discussed. The structural dynamic behavior of the free span was investigated by Fyrilev and Mork (2002) using improved beam theory formulations. The updated boundary condition coefficients were found to be general and fit all types of oil for lower vibration modes. Furnes and Berntsen (2003) examined the performance of coupling between the in-line and the cross-flow motion of free span pipelines under the current force excitation. The results demonstrated the coupling effects can be significant and not negligible. Vortex induced vibrations (VIV) for free span pipeline were analyzed by Larsen et al (2002) utilizing frequency and time domain approach. Interaction between pipe and seafloor were found to be great influence on stress calculation. Then, Larsen et al.(2004) further investigated VIV for free span by using nonlinear time domain analysis. Nonlinear behavior of free span, such as tension variation and pipe-seafloor intervention at the span shoulders, were taken into consideration. Afterwards, Aronsen and Larsen (2007) presented hydrodynamic coefficients for in-line VIV using a large set of experimental investigations. On the basis of which, the in-line VIV of free span was studied by Larsen and Aronsen (2007), significant effects of in-line response as compared to cross-flow were discussed. When very long and/or multiple span appearance, several vibration modes of free spans may be activated. Det Norske Veritas (DNV) issued The DNV guideline no 14 for free spanning pipeline in 1998 and has been updated and issued an recommend practice (DNV-RP-F105) in 2002 and 2006 respectively. The main changes in the updated DNV-RP-F105 (2006) contain calculation procedures and design acceptance for long free spans with muti-mode response, and detailed calculation procedure for pipe-soil interaction.

Most of the previous researches have been mainly focus on the dynamic behavior of free spans in view of direct problem. However, little attention has been devoted to structural condition identification for free spans (SCIFS) from inverse problem insight. So far, system