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A hybrid method for predicting the dynamic response of free-span submarine pipelines

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Abstract. Large numbers of submarine pipelines are laid as the world now is attaching great importance to offshore oil exploitation. Free spanning of submarine pipelines may be caused by seabed unevenness, change of topology, artificial supports, etc. By combining Iwan's wake oscillator model with the differential equation which describes the vibration behavior of free-span submarine pipelines, the pipe-fluid coupling equation is developed and solved in order to study the effect of both internal and external fluid on the vibration behavior of free-span submarine pipelines. Through generalized integral transform technique (GITT), the governing equation describing the transverse displacement is transformed into a system of second-order ordinary differential equations (ODEs) in temporal variable, eliminating the spatial variable. The MATHEMATICA built-in function *NDSolve* is then used to numerically solve the transformed ODE system. The good convergence of the eigenfunction expansions proved that this method is applicable for predicting the dynamic response of free-span pipelines subjected to both internal flow and external current.

Keywords: free-span submarine pipeline; vortex-induced vibration; internal flow; integral transform; pinned-pinned

1. Introduction

The crucial works of a small number of disparate researchers in the late 19th and early 20th centuries marked the beginnings of a concerted attempt to understand the phenomenon of vortex shedding which continues to this day. A great amount of work has been done to study the vortex-induced vibration (VIV) behavior of underwater structures, such as cable arrays, drilling risers, offshore platforms and pile-supported structures.

During the early days, the effect of the internal flow was often ignored. Iwan (1981) proposed a vortex-induced oscillation model that can be used to solve problems involving non-uniform structures and flow profiles. Xu, Lauridsen *et al*. (1999) developed the fatigue damage models for multi-span pipelines detailed both in time and frequency domain approaches. Pantazopoulos, Crossley *et al*. (1993) put forward a Fourier Transformation based methodology to study the VIV of free-span submarine pipelines. Bryndum and Smed (1998) carried experiments in the VIV of submarine free spans under different boundary conditions. Furnes (2003) formulated time domain

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