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Experimental study of the effect of gap ratio on the vortex induced vibration of two-degree-of-freedom pipe due to waves

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Abstract

When a pipe is located in a current or wave, the flow regime will be changed around it. At special condition, i.e. at Re > 40 for a current, the flow will be separated from the wall of the pipe leading to the generation of a pair of vortices. Further, by increasing the fluid velocity and consequently the related Reynolds number, vortex shedding will happen. The propagating vortices will impose the periodic forces on the pipe, which may lead to the vibration of the pipe. These vibrations are named Vortex Induced Vibrations (VIVs). In literature, most of the research about the VIV is concerned with the behavior of one-degree-of-freedom pipe or somewhat two-degree-of-freedom pipe in steady current and very few studies are performed in unsteady flows. In this paper, the vortex induced vibration of a circular cylinder with two-degree-of-freedom in waves is investigated experimentally. The pipe is made from Plexiglas and experiments are performed for several gap ratios (e/D = (gap between the pipe and bed)/ (pipe diameter)). The wave's characteristics are limited to the capabilities of the wave maker channel at Hydraulic Laboratory of Sahand University of Technology. The image processing technique is used to analyze the pipe's vibrations in both In-Line (IL) and Cross-Flow (CF) directions. Finally, from the time history of the pipe's vibrations, the amplitude and frequency of these vibrations are extracted in two directions. It is observed that the pipe's vibrations are depended to the pipe's gap ratio (e/D) which this dependence itself is in relevance of other dimensionless parameters such as the reduced velocity.

Keywords: Experimental study, Gap-to-diameter-ratio, Vortex Induced Vibration, Wave, Two-degree-of-freedom pipe.

1. INTRODUCTION

During the last century, the demand for the oil and gas has been increased tremendously. This has been attended by major developments in the offshore industry for exploration and production of oil and gas from marine hydrocarbon resources. Pipelines and risers are the most reliable and safe method for transferring extracted oil and gas or any other liquid from one site to another. When an object like a pipe is located in a flow or wave, flow regime would be changed around it which leads to the growth of shear stress and turbulence intensity. As a result, in a special condition, i.e. at Re > 40 for a current, the flow separation and vortex formation in the lee-side of the pipe will happen. The generated vortices will shed with some specified frequencies (Vortex Shedding) and if these frequencies become close or equal to the pipe's natural frequency, this can cause to the phenomenon called resonance, which may lead to the breakage of the pipeline. Flow separation at each side of the cylinder is the main cause for the vortex generation. Stable or instable wakes will be formed by the interaction between two shear layers and these wakes will impose the periodic forces on the cylinder which may lead to the pipe vibration. These vibrations are called Vortex Induced Vibrations (VIVs) [1]. In literature, most of the VIV's studies are about the CF vibrations (one-degree-of-freedom pipes) and somewhat both IL and CF vibrations (two-degree-of-freedom pipes) are considered (refer to Fig). The comprehensive reviews can be found in the papers presented by Sarpkaya (1979) [2], Bearman (1984) [3], Parkinson (1989) [4], Jauvtis and Williamson (2003) [5], Williamson and Govardhan (2004, 2008) [6, 7]. Recent model tests on the free-spanning pipeline performed for the Ormen Lange project have proved that the combined CF and IL motions are important [8].There are even very few studies about the vortex-induced vibration of a pipe with two-degree-of-freedom due to waves which are mainly numerical investigations.