Numerical study on passive VIV suppression effect via special-shaped surface structure

Jia-Si Zheng, Zheng-Shou Chen*, Shuai Wang
Department of Naval Architecture and Ocean Engineering, Zhejiang Ocean University
Zhoushan, Zhejiang Province, China

Xiao-Li Tan, Feng Jiang
PaxOcean Engineering Zhoushan Co.Ltd, Zhoushan, Zhejiang Province, China

ABSTRACT

Vortex-induced vibration (VIV) is prone to be induced along marine pipelines under the influence of ocean currents, leading to fatigue damage. In this paper, a comparative study of the VIV response in relation to airfoil, textured and smooth pipes is carried out using the CFD method. Its main purpose is to investigate the effectiveness of special-shaped surface structures, such as airfoil structure and surface textures, on passive VIV suppression. The simulation results show that both the airfoil and textured surface structures can significantly reduce the vibration amplitude, drag and lift coefficients compared to the smooth surface structure.

KEY WORDS: Marine pipe; vortex-induced vibration; passive VIV suppression; special-shaped surfaces structure.

INTRODUCTION

Flexible pipe/pipelines generate periodic vortex-induced vibration (VIV) under certain incoming flows (Duanmu et al., 2018; Ji et al., 2011; Lie and Kaasen, 2006; Low and Srinil, 2016; Sarpkaya, 2004), which causes significant fatigue damage to the pipe structure. In recent years, researchers have paid much attention to VIV suppression in relation to flexible pipes (Quen et al., 2014; Sui et al., 2016; Wang et al., 2019). Khalilpasha and Albermani (2013) proposed a method to suppress VIV by texturing the surface of the pipe body. Since the textured pipe (shown in Fig. 1(c)) has an origami shape with local facets in both the longitudinal and cross-sectional directions. This kind of surface structure can significantly increase the propagation buckling capacity compared to the equivalent smooth pipe (shown in Fig. 1(a)), and it also improve the energy absorption capacity when it is under axial loading and improve the crushing performance (Yang et al., 2016). Through numerical simulation work, Nikoo et al. (2020, 2022) found that the textured pipe is able to eliminate the upper part of the branch that appears in the conventional smooth pipe. The vibration amplitude is dramatically reduced when the pipe structure vibrates under conditions of the larger velocity, where the vibration suppression effect is more significant. Liu et al. (2013) conducted a simulation of 2D flow around submarine pipeline with spoilers by numerical method. The numerical results indicate that the spoiler has a better vibration suppression effect and force condition when the gap ratio is 0.3; especially the pipeline with Δ60° (Δ denotes the angle between the direction of the water flow and the axis of symmetry of the first airfoil by counterclockwise rotation) is most effective, shown in Fig. 1(b).

The two special-shaped surface structures mentioned above have proven to be effective in suppressing VIV without the need for additional devices. Given their outstanding performance, they warrant more attention and further exploration of their potential for wider application. This paper aims to investigate the impact of surface modification and section deformation on the vibration response of long flexible pipes. Specifically, the VIVs of three types of flexible pipes (i.e. textured, airfoil, and smooth pipe) with equivalent performance were investigated. The numerical results are analyzed and compared to validate the VIV suppression effectiveness of the proposed method.

* Corresponding author. aaaczs@163.com

Fig. 1 Schematic views of three types of pipes

NUMERICAL METHOD