Suppression of flow-induced vibrations of a flexible cylinder with an attached flexible splitter plate

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ABSTRACT

Flow-induced vibration (FIV) is a common problem in offshore and marine structures, which can lead to fatigue and decrease the structure’s lifespan. In this study, we investigate the FIV response of a flexible circular cylinder with an attached flexible splitter plate through a series of water tunnel experiments. The system’s dynamic response is studied for three different splitter plate widths (1D, 2D, and 3D, where D is the cylinder’s diameter). The fully coupled fluid-structure interaction response is analyzed, taking into account the interaction between the structural response and the flow field in the wake of the structure. Our results show that attaching a splitter plate with a width equal to the cylinder’s diameter can significantly reduce oscillations across a wide range of flow velocities. This study provides insights into passive FIV suppression techniques for flexible offshore structures and can help engineers design more reliable and efficient structures in the future.

KEY WORDS: Flow-induced vibration (FIV); Splitter plate; FIV suppression

INTRODUCTION

Flow-induced vibration (FIV) is a common phenomenon in offshore and marine engineering applications due to low structural damping and low mass ratio of the structure compared to the surrounding flow. FIV can result in undesired large amplitude oscillations, leading to fatigue and a decrease in the structure’s lifespan. Therefore, discovering FIV suppression techniques for offshore structures is of great significance.

Two main strategies for FIV suppression are active and passive methods. Active methods involve real-time monitoring of the flow field and altering the vortex shedding and flow features around the structure by implementing an external energy input into the system. Some active methods include heating of the body, acoustic excitation, blowing or suction of the boundary layer, and steady rotation of the body [Chen, Xin, Xu, Li, Ou, and Hu, 2013; Lou, Chen, and Chen, 2016; Venkatraman and Narayanan 1993]. Passive methods suppress FIV by altering the vortex formation and shedding mechanism through modifications to the structure’s shape or additional devices mounted on the main structure [Liang, Wang, and Hu, 2018; Assi and Bearman, 2015; Chung and Whitney 1993]. One passive method is the near-wake stabilizer, which involves adding a splitter plate, guide wing, and fairings [Kumar, Sohn, and Gowda, 2008]. Several studies have investigated the effect of adding a splitter plate to a rigid circular cylinder on FIV suppression, both numerically [Sahu, Furquan, and Mittal, 2019] and experimentally [Huera-Huarte, 2014; Assi and Bearman, 2015; Liang, Wang, and Hu, 2018; Liang, Wang, Xu, Wu, and Lin, 2018]. The effect of splitter plate width, coverage ratio, and location of the splitter (upstream or downstream of the cylinder) for a rigid or flexible splitter on FIV suppression of the cylinder has also been studied. However, in some real-world applications, the spanwise flexibility of the offshore structure cannot be neglected, and thus, the structure should be modeled as a flexible cylinder. This research aims to study and characterize the FIV response of flexible cylinders when a flexible splitter plate is added to their structure. The effect of adding a flexible splitter plate, with varying widths, on the FIV response of the flexible cylinder is studied through a series of experimental tests.

METHODOLOGY

We conducted a series of water tunnel experiments to study the flow-induced vibration (FIV) of a flexible circular cylinder with an attached flexible splitter plate. The water tunnel had a test section of 0.45 m x 0.45 m x 1.5 m (width, height, length) with a turbulence intensity of less than 1% for velocities up to 1 m/s. The flexible cylinder was fully-submerged and horizontally placed in the test section, with both ends fixed. To fabricate the cylinder, we used flexible silicone material, resulting in a low flexural rigidity that allowed high structural modes to be excited along the short spanwise length of the cylinder. We obtained the elasticity modulus of the cast cylinder experimentally using the technique by [Paidoussis, 1998], which yielded E=300 KPa. We measured the system’s natural frequency and damping ratio using the free decay test. The reduced velocity was calculated as \( U^* = U/(D\cdot f_0) \), where \( U \) is the flow velocity, and \( f_0 \) is the system’s natural frequency. The damping ratio of the system, obtained using free decay tests, was calculated to be \( \zeta = 0.003 \).

To measure the spanwise structural dynamic response of the flexible cylinder, we marked it with uniformly-distributed black dots at 0.04\( \pm \)0.001 m intervals. A total of 7 points were marked along the length of each side of the cylinder, and the oscillations of these dots were captured using high-speed cameras (Victorem 32B216MCX) in...