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Amplification/suppression of flow-induced motions of an elastically mounted circular cylinder by attaching tripping wires

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ABSTRACT

This study has experimentally studied the effect of tripping wires on the vibration of a circular cylinder subject to flows. We placed a pair of tripping wires onto the surface of a circular cylinder symmetrically about the stagnation point, and submerged the cylinder clamped or elastically mounted. The test for the clamped cylinder (hereinafter stationary cylinder test) covered a wide domain of angular position from 15° to 165° to find what angular positions enhance or weaken hydrodynamic forces acting on the cylinder. The test for the moving cylinder used four angular positions: 60°, 75°, 105° and 120° to examine how the tripping wires amplify or suppress the flow-induced vibration of the cylinder. The stationary cylinder test revealed that with the angular position ranging from 20° to 52.5° or greater than 97.5° the hydrodynamic forces diminish and with the angular position ranging from 52.5° to 97.5° the forces increase. Particularly, positioning the tripping wires at 75° maximally increases the lift and drag coefficients by 63% and 44%, respectively, in comparison with the coefficients produced without the tripping wires, and these coefficients are maximally reduced by 67% and 20%, respectively, by positioning them at 112.5°. The moving cylinder test has elucidated that the angular positions at 60° and 75° intensify the vibration of the cylinder, involving a monotonic increase in the amplitudes with an increase in reduced velocity and wide lock-in range. With the tripping wires attached at 105° and 120° the vibrations of the cylinder are considerably suppressed, particularly when the angular position is 120° the vibration completely disappears.

1. Introduction

Flow-induced vibration (FIV) is of much importance in a design of structures that include long slender bodies such as a marine riser or a cable. FIV exerts large steady and oscillatory forces that can cause structural failure and material fatigue. Considerable efforts have been devoted to figuring out its fundamentals in search of a way to reduce or, under optimal circumstances fully suppress it. On the other hand, we can intend to enhance FIV in order to harvest renewable energy from fluid flows. Although these two research branches have the opposite objectives, both use the same principle of adding attachments or roughness onto a body's surface to alter a flow field around it. The changes in the flow field can increase or decrease the FIV depending on the size, form, and position of the attachments.

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The study of vortex-induced vibration (VIV), a kind of FIV was pioneered by Feng (1968) and good reviews on FIV were provided by Blevins (1990) and Wu et al. (2012a). To date, some methods of attaching a device around a cylinder have been proposed to realize the VIV mitigation: suction of flow around a circular cylinder (Chen et al., 2013); a pair of cylinders in cruciform arrangement with a strip-plate (Kato et al., 2012); and moving surface boundary-layer control (Korkischko and Meneghini, 2012). Wu et al. (2012b) experimentally investigated how four rods arranged with an angular interval of 90° on the surface of a riser pipe model affect the VIV of the pipe. Oruç (2012) proposed the surrounding of a circular cylinder with a screen, which diminishes vortex formation.

Zdravkovich (1981) presented several methods of suppressing FIV and classified a tripping wire as a device that disturb the spanwise correlation of vortex shedding. Igarashi (1986) and Nebres and Batill (1993) studied the effects of attaching a single tripping wire parallel to the main cylinder axis. In the tripping wire attachment, angular position of tripping wire, the definition of which is depicted in Fig. 1, is one of the principal design parameters. Igarashi (1986) examined tripping wires of several diameters positioned at the angular position of 50° and 60° with Reynolds numbers (Re) ranging from 1.3×10^3 to 9.6×10^4. Through the experiment he showed three flow patterns (Fig. 2) that transfer as a function of Reynolds number, angular position, and diameter ratio d/D defined as the ratio between the diameters of the tripping wire d and cylinder D. The first pattern referred to hereafter as pattern A (Fig. 2a) includes a separation over the tripping wire and an immediate

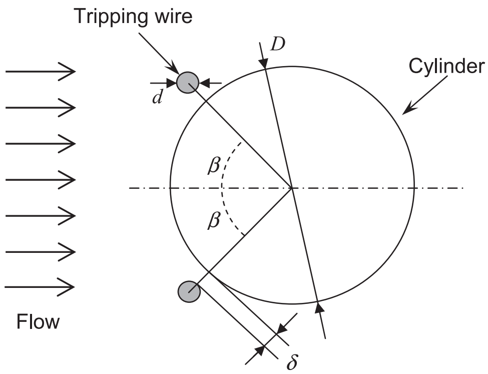

Fig. 1. Cross section of cylinder and tripping wires. Angular position of tripping wires and a few symbols of lengths are defined.

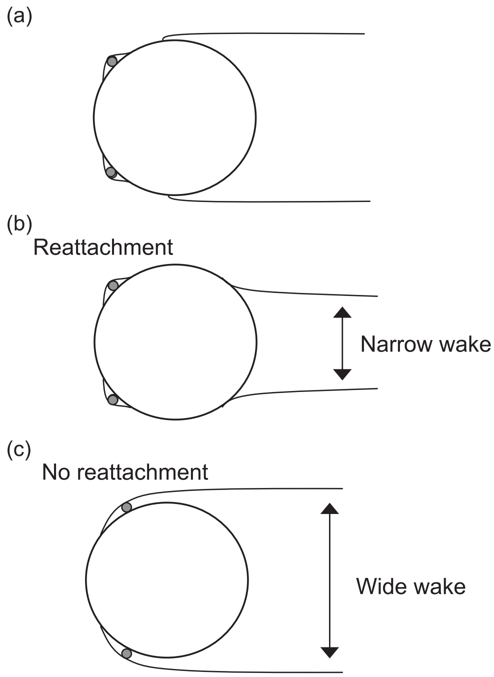

Fig. 2. Flow pattern classification proposed by Igarashi (1986). (a) Pattern A: Separation, reattachment, and laminar reseparation. (b) Pattern B: Separation, reattachment, and turbulent reseparation further downstream, resulting in a narrow wake region. (c) Pattern C: Separation point at tripping wire's position and wide wake region.