An Experimental Investigation on Characteristics of Flow Field of Wake Galloping

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Summary

The characteristics of the wake galloping phenomenon are evaluated for twin circular cylinders via two-dimensional wind tunnel tests. The twin cylinders are deployed parallel, which simulates the closely spaced stay cables of a cable-stayed bridge. At first, the upstream and downstream displacements of the cylinder are observed with varying center-to-center distance between the two cylinders. As a result, the occurrence of the wake galloping is very sensitive to the change of center-to-center distance between the two cylinders. The wake galloping is observed at the downstream cylinder for small center distances of three to six times the diameter of the cylinder. As the spacing ratio increases, wake galloping is weakened gradually, and disappeared for spacing ratio over seven times the diameter of the cylinder. The overall results conformed to the conventional design practice for the wake galloping of parallel cables. Next, flow visualization tests with a particle image velocimetry equipment are conducted by varying the spacing ratio to investigate on characteristics of a flow field of wake galloping. Test results show that there is a complex interaction between shear layer and the downstream cylinder when the cylinders are closely located and wind velocity is over the critical velocity of wake galloping. This flow-structure-interaction causes aerodynamic lift force on the downstream cylinder, which is synchronized with a motion of downstream cylinder. When the spacing ratio is high enough not to induce wake galloping, however, the shear layer is not observed and the overall flow seems to induce a buffeting vibration on downstream cylinder.

Keywords: Stay cable, parallel cable, wake galloping, wind tunnel test, flow visualization, shear layer, particle image velocimetry (PIV).

1. Introduction

Wake galloping occurs at closely spaced circular cylinders at high wind speed and causes large amplitude oscillations in downstream cylinders in vertical direction. This phenomenon has been observed at the stay cables of cable-stayed bridges in Japan and showed a risk to cause fatigue problems on strands of bridge hangers at end clamps.

Many parameters are involved in the occurrence of wake galloping. Several guidelines [1, 2, 3] propose the formula for the onset wind velocity of wake galloping in terms of the natural frequency, diameter, mass and the damping ratio of a cable. Among these parameters, the spacing ratio (L/D) is the dominant parameter for the occurrence of wake galloping, where L is the center-to-center distance of twin cylinder and D is the diameter of the cylinder. Field observation in Japan [4] reported that wake galloping was observed when the spacing ratio is within 4 to 5. The guideline of FHWA [5] also investigates that the onset velocity of wake galloping increases about 3.2 times if the spacing ratio grows 2~6 to 10. In the Korean guidelines [6], the stay cable is subjected to wake galloping when the space between two cables are located within 3~6 times of the cable diameter. Tokoro et al. [7] carried out full-scale wind tunnel tests, in which the downstream cylinder was subjected to the wake galloping with the 1st vertical mode for L/D=4.3 and the larger amplitude is measured with the increase of wind velocity.

To perform the aerodynamic mitigation method efficiently, clear understanding on flow-structure

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