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A CFD Study on the Influence of Free-stream Deterministic Gusts on the Critical Flutter Velocity of Streamlined Bridge Decks

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1 Abstract

In the design of super-long-span bridges, the wind actions are commonly a governing criterion. Critical design checks for wind-induced vibrations involve experimental and numerical procedures for determination of the flutter instability threshold, commonly under laminar free-stream. The influence of free-stream turbulence on the critical flutter velocity of bridge decks still represents an open topic in bridge aerodynamics. This paper presents an investigation of the influence of free-stream deterministic gusts on the critical flutter velocity using Computational Fluid Dynamics (CFD). Deterministic free-stream harmonic gusts are simulated by modelling the wake of two flapping airfoils using the two-dimensional Vortex Particle Method (VPM). These gusts are then applied to a streamlined bridge deck and the oscillation amplitudes are studied for various gust amplitudes and frequencies. The results indicate that the critical flutter velocity is reduced for harmonic gusts with a frequency similar to the critical frequency under laminar free-stream, while it is not in affect for gust frequencies corresponding to the structural frequencies. By dissecting the random free-stream into harmonic gusts, this study aims to provide a deeper understanding of the physical processes occurring in the fluid-structure interaction near the instability threshold.

Keywords: Flutter, Long-span bridges, CFD.

2 Introduction

Since the Tacoma Narrows incident back in 1940, engineers have been trying to understand flutter as a phenomenon that causes violent bridge vibrations at potential design wind speeds. Much research has been done on the front of flutter for laminar free-stream in the past few decades; however, the influence of free-stream turbulence yet remains not fully understood. Experimental tests have shown results that turbulence can both increase and decrease the critical flutter wind speed, depending on the ratio between the turbulent length scales and span/width of the deck [1,2]. Most of the studies agree that the 3D effects are a key factor; however, it is complicated to separate their influence from the 2D turbulent effects experimentally for a dynamic model.

Apart from experimental tests, simulation models based on CFD has also become an important tool to investigate the fluid-structure interaction. As one of the numerical discretization schemes, the 2D VPM has been extensively used to under both laminar and turbulent free-stream [3,4]. The VPM discretizes the Navier-Stokes equations by circulation-carrying particles.

In this paper, we utilize a recently developed method for simulation of deterministic free-stream turbulence [5], based on the VPM, to study the influence of incoming sinusoidal gusts on the critical flutter velocity. By dissecting the frequency content of the free-stream turbulence, an attempt is made to study its influence on the flutter limit.

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