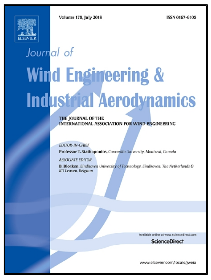
Accepted Manuscript



Numerical simulation of windless-air-induced added mass and damping of vibrating bridge decks

Fuyou Xu, Zhanbiao Zhang

PII:	S0167-6105(18)30228-9
DOI:	10.1016/j.jweia.2018.07.011
Reference:	INDAER 3676
To appear in:	*Journal of Wind Engineering and Industrial Aerodynamics*
Received Date:	29 March 2018
Accepted Date:	17 July 2018

Please cite this article as: Fuyou Xu, Zhanbiao Zhang, Numerical simulation of windless-air-induced added mass and damping of vibrating bridge decks, *Journal of Wind Engineering and Industrial Aerodynamics* (2018), doi: 10.1016/j.jweia.2018.07.011

Numerical simulation of windless-air-induced added mass and damping of vibrating bridge decks

Fuyou Xu , Zhanbiao Zhang*

School of Civil Engineering, Dalian University of Technology, Dalian 116024, China

Abstract: The windless-air-induced added mass/mass moment of inertia (m_a/I_a) and damping (c_a) effects on mechanical parameters of a vibrating bridge deck are usually ignored in wind tunnel tests. In this paper, for three typical deck sections, computational fluid dynamics simulations are carried out to study the vertical/torsional single degree-of-freedom forced vibration under windless conditions, and further to reveal the effects of m_a, I_a, and c_a on the modal parameters. The influences of turbulence model, computational domain size, grid resolution, and time step size are analyzed. For the addressed issue, the Reynolds stress equation model (RSM) is found to be more suitable than the shear stress transportation (SST) k-ω model. A mathematical model for aerodynamic forces at zero wind speed is presented by using the dimensionless m_a, I_a, and c_a, and they can be extracted by combining the motions and the numerically simulated aerodynamic forces using the least squares method. The numerically simulated results for an ideal plate under small amplitudes are very close to the theoretical values, and consequently verify their accuracy. The causes for the non-zero values of flutter derivatives H_4^* and A_3^* at zero wind speed are revealed. In the windless air, the added damping almost linearly increases with the vibration amplitude. Five existing long-span bridge deck models are taken as examples to investigate the effects of m_a, I_a, and c_a on structural frequencies and damping ratios.

Keywords: Computational fluid dynamics; Bridge deck; Mechanical parameter; Added mass/mass moment of inertia; Damping ratio.

1. Introduction

Structural dynamic parameters including mass (m), mass moment of inertia (I), mechanical frequencies, and mechanical damping ratios are of great significance for aerodynamic performance of long-span flexible bridges. Wind tunnel tests for spring-suspended rigid segmental deck models are usually carried out for the study of wind induced vibrations and identification of aerodynamics parameters, usually involving both vertical bending and torsional modes. In wind tunnel tests, mechanical frequencies and damping ratios are usually determined according to the recorded free decay vibration signals at zero wind speed, i.e., windless condition. If the vertical and torsional vibration amplitudes (A_h, A_α) are not too large, e.g., $A_h/B < 0.01$ (B is deck width), $A_\alpha < 2^\circ$, the amplitudes have negligible influence on the extracted frequencies and damping ratios, and they are commonly assumed to be constants. However, some studies (Cao and Ge, 2017; Zhang and Xu, 2018) found that the frequencies and damping ratios are amplitude-dependent, and related analyses are currently inadequate. Furthermore, the identified system frequencies (stiffness) and damping ratios under zero wind speed condition actually contain two components of contribution: (1) the mechanical part, i.e., m, I, spring rigidity, material, connection, etc.; (2) the aerodynamic part, originates from the interference effect

* Corresponding author.

E-mail address: zzbiao@mail.dlut.edu.cn