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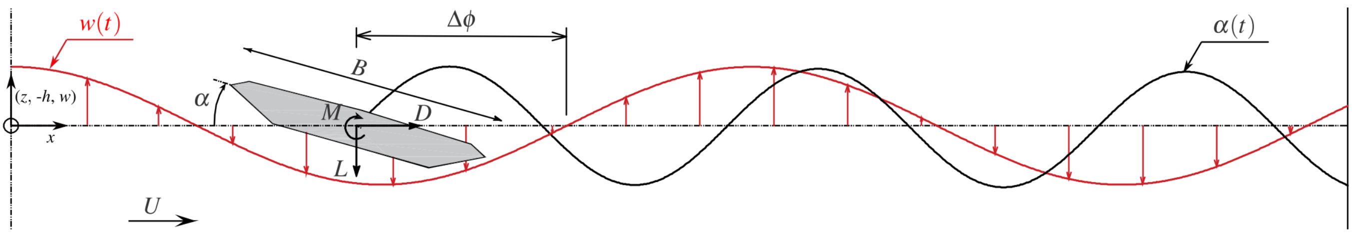
Nonlinear interaction between motion-induced and gust-induced forces of long-span bridges.

Abstract

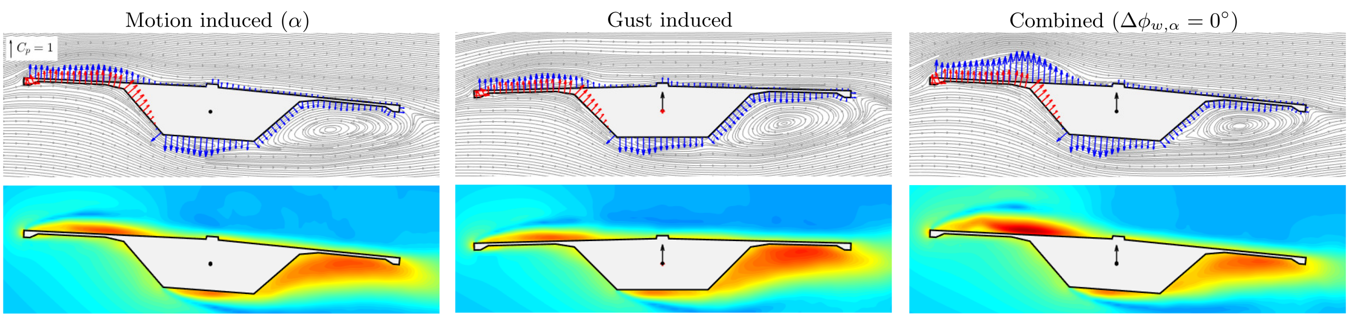
With the increasing spans and complex deck shapes, aerodynamic nonlinearity becomes a crucial concern in the design of long-span bridges. Along with wind tunnel testing and computational fluid dynamics (CFD), semi-analytical models are an integral part of the wind load analysis framework. In the linear unsteady-semi analytical model (LU), the unsteady buffeting and self-excited forces superimposed linearly to give the total force. Understanding the nonlinear interaction of these forces, particularly for bluffed bodies, still represents an open topic in bridge aerodynamics.

For conventional bridge decks, the LU model has proven its utility for a wide range of global metrics with acceptable accuracy. Remarkable developments were made in identifying the aerodynamic coefficients in both experimental and CFD methods. Nevertheless, the model does not account for the two crucial interaction aspects closely tied to aerodynamic nonlinear behavior: the effect of large-scale sinusoidal vertical gusts on the shear layer of a moving body and the nonlinear dependence of the aerodynamic forces on the effective angle of attack. It is vital to study the wind-induced vibration problem in a turbulent environment synergistically to capture these effects.

Using the Vortex Particle Method (VPM), the nonlinear interaction between the gust-induced and motion-induced forces acting on bridge decks investigated. To excite such interaction, a harmonically oscillating bridge deck is subjected to sinusoidal vertical gusts. Two distinct aspects are studied: The influence of large-scale sinusoidal vertical gusts on the shear layer of a moving body and the nonlinear dependence of the aerodynamic forces on the effective angle of attack. The methodology is first employed to verify the linear behavior of a flat plate and then used to study the nonlinear behavior of two bluff bridge decks. The outcome of this study aims to provide a deeper understanding of the complex nonlinear fluid-structure interaction occurring for bluff bodies subjected to motion and free-stream gusts.



Schematics of forced pitch motion under free stream harmonic large scale vertical gust.



Mean instantaneous pressure and velocity field for input pitch motion and vertical gust of $V_r = 10$. The black arrow in the centre of the section represent the direction of the gust at the selected time instant.

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