Numerical Ward-Type Tornado Simulator and its Application to Transient Wind-Induced Response of Long-Span Bridges

Yu Feng, Jianming Hao

Chang'an University, Xi'an, Shaanxi, China

Teng Wu

University at Buffalo, Buffalo, USA

Contact: jianminghao@chd.edu.cn

Abstract

In this study, the tornado-like wind field is simulated by the numerical Ward-type tornado simulator based on computational fluid dynamics (CFD) techniques. To minimize the discrepancy between the simulated and field-measured tornado winds, the optimization strategy is developed to achieve optimal parameters of the numerical Ward-type tornado simulator, namely the inflow angle and translation speed. To facilitate the optimization process, a multi-fidelity surrogate model is utilized to effectively integrate both low-fidelity and high-fidelity data for accurate and efficient simulations. The "best" parameters based on the multi-fidelity surrogate model is input to the numerical Ward-type tornado simulator (using LES technique). Finally, the transient wind field generated using the validated numerical Ward-type tornado simulator is employed as the dynamic inputs to the finite element (FE) model of a long-span bridge.

Keywords: tornado-like wind; transient wind-induced response; optimization; surrogate model; multi-fidelity data; computational fluid dynamics; long-span bridges.

1 Introduction

Tornadoes are the most destructive storm with typical three-dimensional funnel-shaped vortex, and would cause the serious collapse of civil engineering structures due to high wind velocity with short duration. The long-span bridges, constructed as the critical connection for transportation infrastructures, usually play a significant role in emergency transportation and evacuation. Hence the damage or collapse of long-span bridges would cause a substantial hazard to a community. However, there has been relatively scant knowledge on the response analysis of long-span bridges immersed in tornadic wind field. Hao and Wu [1] implemented aerostatic and aeroelastic analysis of long-span suspension bridge under tornado event based on nonlinear aerostatic relationship and two-dimensional (2D) indicial response function.

In order to obtain accurate tornadic wind field input, field measurements of real-world tornadoes would be a useful resource. Unfortunately, direct field measurements are challenging due to the unpredictable, localized and violent nature of tornadoes, and the measurements are usually inaccurate in the near ground region. Therefore, physical and numerical simulations have become

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