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Simulation of unsteady 2-D wind by a vortex method

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Abstract

The flexibility of some modern structures, such as long-span bridges, allows them to respond to wind forces and requires engineers to include an assessment of potential wind-induced aero-elastic phenomena in their design-stage analyses. In recent years a 2-D numerical method of analysis called the Discrete Vortex Method (DVM) has been used successfully to supplement wind tunnel tests in assessing wind-induced structural response. The method offers easy sampling of all points within the flow field at any time and its grid-free nature adapts easily to moving cross-sections.

Traditionally, DVM bluff-body flow simulations are subject to the limitation of a steady incident flow velocity. This project develops an unsteady wind model which provides a homogeneous 2-D approximation to 3-D turbulence in the atmospheric boundary layer.

A model to sample an unsteady flow velocity field over time and transform it to a vortex representation, which can be evolved using traditional vortex dynamics and which preserves the main characteristics of the original flow, is developed. A method of generating realisations of correlated random processes based on the energy in their cross-spectral density matrix is investigated and used to create representative boundary layer wind velocity histories. The wind velocity samples are transformed to a vortex representation and released into a DVM flow creating an unsteady flow which can be applied as an incident flow in bluff-body flow simulations.

Large scale unsteady DVM flow studies were run using an existing DVM solver. An analysis of the simulated unsteady flows is presented which shows that the target wind properties are well modelled in the range of interest. Results of aero-static bluff-body flow simulations are presented which demonstrate the effect of incident gusts and changing angle of wind attack on body forces. Visualisation techniques, including streak-line plots and iso-velocity contour plots, are used throughout the dissertation to gain insight into aerodynamic phenomena.

Keywords: Bluff-body wind engineering, discrete vortex method, random processes, unsteady wind simulation