Modelling of self-excited wind forces on long span bridges using State-space models

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Abstract

Frequency domain methods, neglecting nonlinear characteristics, can in some cases inaccurately predict the response of long span cable-supported bridges. Time domain methods are commonly applied when nonlinearities need to be considered because it is challenging to include these in frequency domain analysis. In this paper it is shown how a rational function fitted to aerodynamic derivatives can be converted to a state space model to transform the frequency-dependent aerodynamic forces to the time domain. A user element has been implemented in the software ABAQUS in order to include the self-excited forces in the dynamic analysis. The element has been developed as a one node element that is included in the nodes along a bridge deck. The flutter stability limit of the Hardanger Bridge has been calculated in a comprehensive case study to illustrate the performance of the presented methodology.

Keywords: Self-excited wind forces; time domain; state space method

1 Introduction

Flutter instability, which could lead to an unexpected catastrophe, is always one of the main concerns in wind and bridge engineering. The instability problem is caused by the self-excited forces resulting from wind-bridge interaction. When the wind velocity is large enough, the total damping could become negative and the energy input from the wind field could exceed the energy dissipation of the structural damping, leading to bridge instability.

The multi-mode frequency domain method, which is simple and efficient, is a very popular technique used to study the instability problem [1-3]. However, this method cannot correctly account for nonlinear characteristics such as the geometrical nonlinearity due to a large deformation or nonlinear aerodynamic forces induced by the change of attack angle. Therefore, in order to account for important nonlinearities, methods to model the frequency-dependent self-excited forces in the time domain have been developed by many researchers [3-14]. Øiseth O. [11, 12] compared 3 unsteady force models to simulate the self-excited forces and implemented it in ABAQUS by adding aerodynamic degrees of freedom to a beam element. Salvatori L. [3, 13] simulated the self-excited force using indicial functions and analyzed the effects of structural nonlinearity. Chen X. [5, 6] studied the effects of nonlinear, unsteady aerodynamic forces based on a static force coefficient, flutter derivatives and admittance functions, at varying angles of incidence.

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