On the use of Volterra series for modelling of nonlinear self-excited forces

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Abstract

In the following work, three different versions of the Volterra series models have been presented and evaluated for the modelling of nonlinear self-excited forces on bridge decks. Experimental data of a twin deck section model tested in a forced vibration rig has been used to evaluate the models' performance. Self-excited drag force from pitching is studied, and the models are evaluated considering accuracy, computational effort, and robustness. All three models performed sufficient for modelling of the self-excited forces, but the Laguerre model and the regularized model both had their strong points of computational effort and robustness compared to the pure least-squares model.

Keywords: Aeroelasticity, bridge aerodynamics, wind tunnel, nonlinear modelling, self-excited forces

1 Introduction

Evaluation and modelling of nonlinear aerodynamic phenomena have been a vivid research topic in the bridge aerodynamics community in the past decade. There are several different types of nonlinear phenomena seen in experiments and on full-scale bridges, some of them are self-limiting VIV response, nonlinear galloping, nonlinear flutter, harmonic distortion, and nonlinear buffeting force. Common for all these phenomena is that the model predictions fails when utilizing the traditional linear load models as quasi-steady theory or the classic aerodynamic derivatives. Several different nonlinear load models have been suggested in the community, and one of them is the Volterra series model(1,2).

The Volterra series model is a general nonlinear model expanding the linear convolution to higher-order convolution and can often be viewed as a Taylor series with a memory. The model can model a wide class of nonlinearities, but has some drawbacks, mainly: *i)* The computational cost of the model greatly increases with memory lengths, order, and the number of inputs. *ii)* Overfitting can make the model less robust.

This work compares three different types of Volterra models to evaluate their performance of accuracy, computational effort, and robustness. The models used are: 1. The classical full Volterra series description 2. Regularized Volterra series. 3.