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A Pedestrian-based Forced Vibration Approach for Modal Identification

Andre Jesus (1,2), Amir M. Alani (1,2), and Stana Zivanovic (3)

(1) University of West London (UWL), School of Computing and Engineering, London, United Kingdom , (2) The Faringdon Centre - Non-destructive Testing Centre, University of West London (UWL), United Kingdom (andrehjesus@gmail.com; Amir.Alani@uwl.ac.uk), (3) College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter EX4 4QF, United Kingdom (S.Zivanovic@exeter.ac.uk)

A wide number of applications in vibration analysis rely on estimation of modal properties, such as natural frequencies, mode shapes, damping ratios and modal masses [1]. Identified modal parameters form an information baseline for model updating [2], sensor placement, damage detection [3] and structural performance evaluation [4]. Thus, the relevance of modal testing keeps increasing, particularly for slender and wobbly structures such as long bridges.

At the same time, modal identification often relies on expensive and difficult-to-operate technical equipment, such as shakers or impact hammers. Other drawbacks of these methods include high sensitivity to non-linearities, time-consumption and susceptibility to human-structure interaction effects.

As a consequence, this work investigates the applicability of a new spectral approach for modal identification in slender structures. The approach is fast, cost-effective and easy-to-perform. It questions if is it possible to identify modal properties, with a reliability comparable to standard modal tests, using only a human induced excitation. The identification process requires two main inputs: recordings of structural responses under passage of a given pedestrian at a timed pacing rate; and the pedestrian's walk forces at the same pacing rate (which can be recorded with an instrumented treadmill). Validation of the methodology is illustrated with a 16.9 m long fiber reinforced polymer footbridge, instrumented with accelerometers, on which standard modal tests have been performed.

One of the most significant aspects of the proposed approach is its probabilistic treatment of the identification process, which allows to learn the modal properties from data, while accounting for their estimation variability and measurement noise. Moreover, the human excitation is described with a power spectral density model, based on recorded pedestrian walk forces. In essence, a complex Gaussian log-likelihood function of the dynamic response power spectrum is established and then sampled with the Metropolis–Hastings [5] algorithm. Future developments aim to also account for identification bias.

Results indicate that the pedestrian-based approach can identify natural frequencies and damping ratios with a reliability comparable to reference values, obtained with an impact hammer modal test. On the other hand, modal masses are biased relatively to reference values. However, it is noted that even on standard tests, modal masses pose a challenging identification problem. Consequently, the pedestrian-based approach developed in this work is believed to pave a new way for modal identification in structural dynamics.

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