Perspectives on the acceleration of the numerical assessment of flutter and buffeting response of bridge decks

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The complete flutter analysis of a structure requires the repeated analysis of the aeroelastic response of the structure for various wind velocities. In a spectral approach, each of these analyses is based on the integration of the power spectral density of the aeroelastic response. Traditional integration methods struggle to efficiently estimate these integrals because of the significant peakedness of the function in the neighborhood of the natural frequencies. In this paper, we will present an extension of the Background/Resonant decomposition (which is commonly applied under the quasi-steady assumption), to aeroelastic analysis, where the stiffness and damping of the coupled system changes with frequency [1]. Both the background and resonant components take a more general form than in the well known case presented by Davenport [2]. They remain simple, however, and offer therefore a straightforward understanding of the response. Beyond this gain in physical insight, the derivation of the two components makes possible the analytical integration, which results in a consequent acceleration of the integration (time?) of the acute peaks of the power spectral densities. The proposed formulation is illustrated with several examples of torsional flutter, where the critical state corresponds either to torsional galloping either to divergence. The study is limited to single degree-of-freedom systems but constitute the cornerstone of an extension to multi degree-of-freedom systems, where such an approximation becomes very interesting in terms of computational efficiency.

Besides the projection in the modal basis, the accomplishment of such a challenge for large structural models ($\sim 10^5$ dofs) is conditioned by both the efficiency and accuracy of the integration routine which is invoked to determine all $N \times N$ elements of the covariance matrix of the response. Coupled with a finite element software for the determination of the structural mass, damping and stiffness matrices, the presented method offers a promising perspective for building an automated algorithm able to perform efficiently the flutter design of modern structures with complex profiles and frequency dependent properties, the natural frequency and the damping ratio in particular.

References

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