An efficient computational procedure for random vibro-acoustic simulations

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Vibro-acoustic models are often subjected to random excitations. Examples are acoustic diffuse fields (e.g. in reverberant test chambers) and turbulent boundary layer excitations (e.g. in aerodynamic noise studies).

The framework for modelling such distributed excitations is the mathematical concept of (weakly) stationary random process. Such processes are usually characterized, in the frequency domain, by power spectra and are practically defined by referring to a reference power spectrum and a suitable spatial correlation function. The power spectral density (PSD) is the Fourier transform of the auto-correlation function and is the characterization of a random process in the frequency domain.

In a finite element context, the random excitation is usually defined on a part of the boundary surface. With this random excitation a cross PSD matrix is associated. The response PSD matrix can be very large. Note that it is not feasible storing this matrix, since it is a dense matrix of very high dimensions. On the other hand, the excitation cross PSD matrix can be stored explicitly, since its size is typically much lower. The goal is to approximate the response PSD matrix by a low rank matrix in factored form, whose storage requirements are low.

In earlier work [1], the pseudo load-case method was proposed that aims at producing a low rank approximation of the response cross PSD matrix from a low rank partial eigendecomposition of the excitation PSD matrix. However, for turbulent boundary layers, such decomposition can be very expensive and does not always lead to a significant reduction of the memory consumption.

We discuss a new method for handling random acoustic excitations in finite element models. The idea is to directly approximate the cross PSD matrix of the response by a low rank matrix. We illustrate the low rank approximation can be computed efficiently by the implicitly restarted block Lanczos method. The novelty lies in applying the Lanczos method to the cross PSD matrix of the response rather than the excitation. We give a theoretical explanation for finite element models with modal damping.

We also show numerical examples that show a significant reduction in computation time compared to the pseudo load-case method.

The scientific details are published in [2].

References

[1] J.P Coyette, T. Knapen, G Lielens, K. Meerbergen, and P. Ploumhans. Simulation of randomly excited acoustic insulation systems using finite element approaches. ICA Conference, Kyoto, April 4-9, 2004.

[2] J.P. Coyette and K. Meerbergen. An efficient computational procedure for random vibro-acoustic simulations. *Journal of Sound and Vibration*, 310(1–2):448–458, 2008.