Response evolutionary power spectrum determination of linear and nonlinear structural systems with singular matrices subjected to non-stationary stochastic excitation

George Pasparakis[1*], Vasileios C. Fragkoulis[1], Liam Comerford[2], Ioannis P. Mitseas[3], Michael Beer[1, 2, 4]

[1]Institute of Risk and Reliability
Leibniz Universität Hannover
Hannover, Germany
george.pasparakis@irz.uni-hannover.de, fragkoulis@irz.uni-hannover.de

[2]Institute of Risk and Uncertainty
University of Liverpool
Liverpool, UK
l.a.comerford@liv.ac.uk

[3]School of Engineering
University of Leeds
Leeds, UK
I.Mitseas@leeds.ac.uk

[4]International Joint Research Center for Engineering Reliability and Stochastic Mechanics
Tongji University
Shanghai, China
beer@irz.uni-hannover.de

ABSTRACT

An approximate analytical technique is proposed for determining the response evolutionary power spectrum of stochastically excited linear/nonlinear, structural multi-degree-of-freedom systems with singular matrices. When the problem of deriving the equations of motion of complex, multi-body systems is considered, it can be argued that utilizing more than the minimum number of degrees-of-freedom potentially results to enhanced modeling flexibility; further, it results to reduced computational cost solution frameworks for the system stochastic response determination. However, a redundant coordinates modeling scheme also yields singular matrices in the system governing equations of motion. Nevertheless, a solution framework based on the mathematical concept of the generalized inverses of singular matrices has been recently developed for deriving the response statistics of linear/nonlinear systems with singular matrices, subjected to stationary excitation [1]. This paper constitutes an extension of the results in [1], to account for linear/nonlinear structural systems subject to non-stationary excitations. In this regard, relying on the theory of locally stationary processes, and employing the family of generalized harmonic wavelets [2], a Moore-Penrose generalized inverse excitation-response relationship is derived for determining the system response evolutionary power spectrum. Further, a recently developed harmonic wavelets based statistical linearization technique [3] is also generalized herein to account for nonlinear multi-degree-of-freedom systems with singular matrices subjected to non-stationary excitation. The validity of the proposed technique is demonstrated by pertinent numerical examples.

References

[1] V.C. Fragkoulis, I.A. Kougioumtzoglou, and A.A. Pantelous. "Statistical linearization of nonlinear structural systems with singular matrices". In: Journal of Engineering Mechanics 142(9) (2016), p. 04016063
[2] P.D. Spanos and I.A. Kougioumtzoglou. "Harmonic wavelets based statisti- cal linearization for response evolutionary power spectrum determination". In: Probabilistic Engineering Mechanics 27(1) (2012), pp. 57–68
[3] F. Kong, P.D. Spanos, J. Li, and I.A. Kougioumtzoglou. "Response evo- lutionary power spectrum determination of chain-like MDOF non-linear structural systems via harmonic wavelets". International Journal

of Non-Linear Mechanics 66 (2014), pp. 3–17.