Li, Xiuchun; **Gu, Jianhua**; **Xu, Wei**; **Ma, Fai**

Stochastic stability of viscoelastic systems under Gaussian and Poisson white noise excitations. (English) Zbl 1398.74041

Nonlinear Dyn. 93, No. 3, 1579-1588 (2018).

Summary: As the use of viscoelastic materials becomes increasingly popular, stability of viscoelastic structures under random loads becomes increasingly important. This paper aims at studying the asymptotic stability of viscoelastic systems under Gaussian and Poisson white noise excitations with Lyapunov functions. The viscoelastic force is approximated as equivalent stiffness and damping terms. A stochastic differential equation is set up to represent randomly excited viscoelastic systems, from which a Lyapunov function is determined by intuition. The time derivative of this Lyapunov function is then obtained by stochastic averaging. Approximate conditions are derived for asymptotic Lyapunov stability with probability one of the viscoelastic system. Validity and utility of this approach are illustrated by a Duffing-type oscillator possessing viscoelastic forces, and the influence of different parameters on the stability region is delineated.

MSC:

74D10 Nonlinear constitutive equations for materials with memory
93E15 Stochastic stability in control theory
93D20 Asymptotic stability in control theory

Keywords:

stochastic stability; Gaussian and Poisson noise; Lyapunov function; stochastic averaging; viscoelastic system

Full Text: DOI

References:

[1] Xie, WC, Moment Lyapunov exponents of a two-dimensional viscoelastic system under bounded noise excitation, ASME J. Appl. Mech., 69, 346-357, (2002) · Zbl 1110.74765

[2] Deng, J; Xie, WC; Pandey, MD, Stochastic stability of SDOF linear viscoelastic system under wideband noise excitation, Probab. Eng. Mech., 39, 10-22, (2015)

[3] Zhu, WQ; Cai, GQ, Random vibration of viscoelastic system under broad-band excitations, Int. J. Non-Linear Mech., 46, 720-726, (2011)

[4] Zhao, XR; Xu, W; Gu, XD; Yang, YG, Stochastic stationary responses of a viscoelastic system with impacts under additive Gaussian white noise excitation, Phys. A, 31, 128-139, (2015) · Zbl 1400.74018

[5] Wang, DL; Xu, W; Gu, XD; Yang, YG, Stationary response analysis of vibro-impact system with a unilateral nonzero offset barrier and viscoelastic damping under random excitations, Nonlinear Dyn., 86, 891-909, (2016)

[6] Zhao, XR; Xu, W; Yang, YG; Wang, XY, Stochastic responses of a viscoelastic—impact system under additive and multiplicative random excitations, Commun. Nonlinear Sci. Numer. Simul., 35, 166-176, (2016)

[7] Ling, Q; Jin, XL; Huang, ZL, Response and stability of SDOF viscoelastic system under wideband noise excitations, J. Frankl. Inst., 348, 2026-2043, (2011) · Zbl 1358.74011

[8] Potapov, VD, On almost sure stability of a viscoelastic column under random loading, J. Sound Vib., 173, 301-308, (1994) · Zbl 1078.74595

[9] Floris, C, Stochastic stability of a viscoelastic column axially loaded by a white noise force, Mech. Res. Commun., 38, 57-61, (2011) · Zbl 1272.74311

[10] Khasminskii, R.: Stochastic Stability of Differential Equations. Springer, Berlin (2012) · Zbl 1241.60002

[11] Zhu, WQ, Nonlinear stochastic dynamics and control in Hamiltonian formulation, Appl. Mech. Rev., 59, 230-248, (2006)

[12] Khasminskii, RZ, Necessary and sufficient conditions for the asymptotic stability of linear stochastic systems, Theory Probab. Appl., 12, 144-147, (1967)

[13] Mitchell, RR; Kozin, F, Sample stability of second orderlinear differential equations with wide band noise coefficients, SIAM J. Appl. Math., 27, 571-605, (1974) · Zbl 0318.60053

[14] Nishioka, K, On the stability of two-dimensional linear stochastic systems, Kodai Math. Sem. Rep., 27, 211-230 , (1976) · Zbl 0344.60037

[15] Arnold, L; Papanicolaou, G; Wihstutz, V, Asymptotic analysis of the Lyapunov exponent and rotation number of the random oscillator and applications, SIAM J. Appl. Math., 46, 427-450, (1986) · Zbl 0603.60051

[16] Ariaratnam, ST; Xie, WC, Lyapunov exponents and stochastic stability of coupled linear systems under real noise excitation, ASME J. Appl. Mech., 59, 664-673, (1992) · Zbl 0766.70017

[17] Zhu, WQ, Lyapunov exponent and stochastic stability of quasi-non-integrable Hamiltonian systems, Int. J. Non-Linear Mech., 39, 569-579, (2004) · Zbl 1348.70064

[18] Liu, WY; Zhu, WQ; Xu, W, Stochastic stability of quasi non-integrable Hamiltonian systems under parametric excitations of Gaussian and Poisson white noises, Probab. Eng. Mech., 32, 39-47, (2013)

[19] Liu, WY; Zhu, WQ, Stochastic stability of quasi-integrable and resonant Hamiltonian systems under parametric excitations of combined Gaussian and Poisson white noises, Int. J. Non-Linear Mech., 67, 52-62, (2014)

[20] Huang, ZL; Jin, XL; Zhu, WQ, Lyapunov functions for quasi-Hamiltonian systems, Probab. Eng. Mech., 24, 374-381, (2009)

[21] Ling, Q; Jin, XL; Wang, Y; Li, HF; Huang, ZL, Lyapunov function construction for nonlinear stochastic dynamical systems, Nonlinear Dyn., 72, 853-864, (2013) · Zbl 1284.93207

[22] Liu, WY; Zhu, WQ, Lyapunov function method for analyzing stability of quasi-Hamiltonian systems under combined Gaussian and Poisson white noise excitations, Nonlinear Dyn., 81, 1879-1893, (2015) · Zbl 1348.37023

[23] Jia, WT; Zhu, WQ; Xu, Y, Stochastic averaging of quasi-nonintegrable Hamiltonian systems under combined Gaussian and Poisson white noise excitations, Int. J. Non-Linear Mech., 51, 45-53, (2013)

[24] Paola, M; Vasta, M, Stochastic integro-differential and differential equations of non-linear systems excited by parametric Poisson pulses, Int. J. Non-Linear Mech., 32, 855-862, (1997) · Zbl 0891.70014

[25] Paola, M; Falsone, G, Stochastic dynamics of nonlinear-systems driven by non-normal delta-correlated processes, ASME J. Appl. Mech., 60, 141-148, (1993) · Zbl 0778.70022

[26] Hanson, F.B.: Applied Stochastic Processes and Control for Jump-Diffusions: Modeling, Analysis, and Computation. Society for Industrial and Applied Mathematics, Philadelphia (2007) · Zbl 1145.60003

[27] Liu, ZH; Zhu, WQ, Stochastic averaging of quasi-integrable Hamiltonian systems with delayed feedback control, J. Sound Vib., 299, 178-195, (2007) · Zbl 1241.93021

[28] Wong, E; Zakai, M, On the relation between ordinary and stochastic differential equations, Int. J. Eng. Sci., 3, 213-229, (1965) · Zbl 0131.16401

[29] Zeng, Y; Zhu, WQ, Stochastic averaging of quasi-non integrable-Hamiltonian systems under Poisson white noise excitation, ASME J. Appl. Mech., 78, 021002, (2010)