International Journal of Non-Linear Mechanics 46 (2011) 800–806

Contents lists available at ScienceDirect

International Journal of Non-Linear Mechanics

journal homepage: www.elsevier.com/locate/nlm

Random impacts of a complex damped system

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ARTICLE INFO

Article history:
Received 4 March 2010
Received in revised form
9 March 2011
Accepted 18 March 2011
Available online 1 April 2011

Keywords:
Random impacts
Complex damped dynamical system
Stabilization
Top Lyapunov exponent
Poincaré map analysis
Random phase
Time evolution

ABSTRACT

We investigated the random impacts of a complex damped system. Firstly the interested deterministic complex damped system was revisited and the unstable periodic attractors could be found by means of Poincaré map, time evolution and phase plot since the top Lyapunov exponent could not be applied to decide the unstable states of the proposed system. Secondly the stochastic complex damped system was examined and random impacts would be discovered, namely, the initial deterministic system will be stabilized using the stochastic force properly. The top Lyapunov exponent versus the noise intensity will be observed and one can find the change of dynamical behaviors from instability to stability. Also we implemented Poincaré map analysis, time history and phase plot to confirm the obtained results of top Lyapunov exponent, and we can find excellent agreement between these results. Therefore random noise can be applied to control the dynamical behaviors.

1. Introduction

Chaos has been found in many physics, biology, economics, mechanics and engineering systems [1–3]and even in social dynamical systems [4–6], and it is very interesting in non-linear phenomenon, exhibiting sensitive dependence on initial conditions. Over the past decades many investigators have devoted much effort to the study of non-linear chaotic systems and their applications especially the control of chaos. Several control methods leading to suppression/generation of chaos have been presented and the first method was proposed by Ott et al. [7], which has been developed and used extensively in many fields [8–10]. It is a kind of feedback control, which uses some weak feedback control to make the chaotic trajectory approach and settle down finally to a desired stabilized periodic orbit, formerly unstably embedded in the chaotic manifold. The other one is a kind of non-feedback control, which usually uses given external or parametric excitations to control the behaviors of a system. For more details for these two kinds of chaos control, see Refs. [11–15].

Effects of random noise on non-linear dynamical systems have been greatly examined by a lot of authors. For instance, Wei and Leng [9] studied the chaotic behavior in Duffing oscillator in the presence of white noise by the Lyapunov exponent. Ramesh and Narayanan [10] explored the robustness in non-feedback chaos control in presence of uniform noise and found that the system would lose control while noise intensity was raised to a threshold level. Xu et al. [11,12] explored the random impacts of two different complex dynamical systems and used the random force to suppress/generate chaos. Qu et al. [13] further applied weak harmonic excitations to investigate the chaos control of non-autonomous systems, and especially observed that the phase control in weak harmonic excitation may greatly affect taming non-autonomous chaos. Lei et al. [15] studied a class of non-linear systems in the presence of random phase and applied stochastic phase to control chaos in this system. Liu et al. [16] investigated the generation of chaos in a kind of Hamiltonian system subject to bounded noise by the criterion of stochastic Melnikov function and Lyapunov exponent.

Complex dynamical systems recently attracted a number of investigators, which appear in very important applications in physics and engineering [17–24] such as rotor dynamics and colliding particle beams in high-energy accelerators. For more details we refer the readers to the review paper for complex dynamical systems by Mahmoud and Bountis [25] and the references therein. However, stochastic complex dynamical systems or chaos control for random complex systems have not been examined and to our knowledge little is known about the stochastic complex dynamical systems [11,12,14,26,27].

In this paper, we consider a class of stochastic complex damped non-linear dynamical systems governed by the complex differential equations of the form:

$$\ddot{z}+\omega^2 z+\varepsilon\dot{z}f(z,\bar{z},\dot{z},\dot{\bar{z}})P(\Omega t+\sigma\xi(t))=0, \tag{1.1}$$

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doi:10.1016/j.ijnonlinmec.2011.03.007