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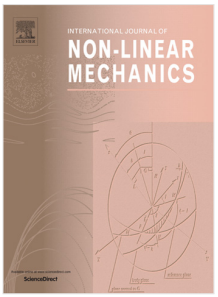

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Analytical threshold for chaos in a Duffing oscillator with delayed feedbacks

Yong-Jun Shen[1)†] Shao-Fang Wen[2)] Shao-Pu Yang[1)] Shu-Qi Guo[3)] Lin-Ru Li[4)]

1) (Department of Mechanical Engineering, Shijiazhuang Tiedao University, Shijiazhuang 050043, China)

2) (Department of Traffic and Transportation, Shijiazhuang Tiedao University, Shijiazhuang 050043, China)

3) (Department of Engineering Mechanics, Shijiazhuang Tiedao University, Shijiazhuang 050043, China)

4) (School of Information Technology, Hebei University of Economics and Business,Shijiazhuang 050043, China)

Abstract

In this paper, the bifurcation and chaotic behaviors of a Duffing oscillator with delayed displacement and velocity feedbacks under harmonic excitation are investigated. The analytically necessary condition for the chaos in the sense of Smale horseshoes is established based on Melnikov method. It could be found that the delayed displacement and velocity feedbacks affect the necessary condition respectively, so that the analysis on the effects of the two kinds of feedbacks is presented individually. The effects of displacement feedback coefficient, velocity feedback coefficient and their time delays on the analytically necessary condition are analytically discussed. Furthermore, some typical numerical results, including the bifurcation diagrams, Poincaré maps and the largest Lyapunov exponents of the delayed oscillator are also presented and compared. The satisfactory qualitative agreement between the analytical and numerical results verify the correctness of the analytically necessary condition.

Keywords: Melnikov method; Duffing oscillator; time delay; homoclinic orbit

1. Introduction

There are many kinds of typical factors in engineering systems, such as nonsmoothness, discontinuity, backlash, parametric excitation and time delay, etc [1-6], which will make the system responses complicated and may deteriorate the