1077. Ride comfort analysis of a nonlinear vehicle excited by the consecutive speed-control humps

Shan Liang1, Yongsheng Sun2, Qin Zhu3, Zhiyong Yang4, Cheng Zeng5
1, 2, 4, 5 College of Automation, Chongqing University, Chongqing 400044, China
3 Department of Mechanical Engineering, Oyama National College of Technology, Oyama 323-0806, Japan
4 College of Information and Engineering, Chongqing Vocational Institute of Engineering
Chongqing 400037, China
1 Corresponding author
E-mail: 1 lightsun@cqu.edu.cn, 2 sunyongs_9566@cqu.edu.cn, 3 zhu@oyama-ct.ac.jp,
4 yzy023@yahoo.com.cn
(Received 18 June 2013; accepted 5 December 2013)

Abstract. The consecutive speed-control humps (SCHs) possess the function of controlling speed forcibly, but cause violent vibration of a vehicle inevitably. This paper tries to further explore the inherent link among parameters of the SCHs, velocity and vehicle vibration. A 4-DOF nonlinear half-vehicle model with nonlinear springs and nonlinear dampers is established. The consecutive SCHs-speed coupling excitation function is presented by combination of trapezoidal and sine wave of constant amplitude and variable frequency. The nonlinear dynamics of half-vehicle model is investigated by numerical simulation. It reveals that various forms of vibrations, such as periodic, quasi-periodic and chaotic vibrations, could appear in the system with the change of the velocity. Further it is found that quasi-periodic motions will affect vehicle ride comfort most and can be avoided by changing parameters of the consecutive SCHs. Results are conductive to deep understanding of nonlinear vibration in vehicle and rational design of the consecutive SCHs.

Keywords: ride comfort, consecutive speed-control humps, nonlinear vibration, half-vehicle model.

1. Introduction

The speed-control hump (SCH) which is installed on highway is currently widely used as one of the compulsive speed control facilities. In general, the consecutive SCHs are local elevations of residential road surface of limited height, which are placed in series at hundreds or thousands of meters with a fixed interval. When the automobile passes over the consecutive SCHs at a certain velocity, the impact from the uneven road surface will inevitably bring to the vehicle unwanted vibrations and noise. Prolonged exposure to repeated vibrations and impacts of whole-body nature when vehicle travels on uneven road has been associated to occupational health disorders [1]. Therefore the effect of the consecutive SCHs on vehicle vibrations, and in particular on the ride comfort, is still needed to be further studied [2-5].

Since the automobile is a kind of highly nonlinear system, the vibrations caused by road surface will appear in nonlinear characters, such as chaos and bifurcation. To investigate nonlinear response of vehicle model excited by road surface, some productive works have been done by scholars. In these studies researchers often rely on the quarter-car model for studying heave motion as this model is the simplest to analyze and yet can reasonably predict the response of a system [6-8]. However the actual vehicle is a more complex nonlinear system than a quarter-car model system. The vehicle speed, pitch motion, roll motion and the impact of front and rear wheels are also important to the dynamics of actual vehicle. Zhu et al. [9, 10] have investigated the possibilities of chaotic vibrations which existed in half-car and full-car models under sine wave excitations. However the influence of vehicle speed on vehicle dynamics and how the nonlinear vibrations affect the vehicle ride comfort have rarely been investigated in the current studies.

In this paper the nonlinear vibration behaviours of the 4-DOF half-vehicle model with nonlinear springs and damping elements through the excitations from the consecutive SCHs are investigated. The study begins by establishing a combined consecutive SCHs-speed dynamic