Analysis of Half-Car Model with Nonlinear Damper under Sinusoidal Road Excitation

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Abstract. Frequency response of half car model which is moving at constant speed on sinusoidal road surface is investigated. The suspension system is considered with damper having nonlinear stiffness and damping characteristics. Primary and superharmonic resonance with internal resonance between front and rear wheels are studied. The equilibrium analysis is carried out with method of multiple scales. The amplitude response versus frequency at the front and rear wheels is presented for different parameter values to analyse the nonlinear response.

Introduction

A road vehicle vibrates when traversing on sinusoidal road surface. For better passenger comfort the vibration amplitude need to be reduced using the dampers. The dampers are classified as passive, semi-active and active dampers. Although, semi-active and active dampers are known to control vibration of vehicle due to road excitation [1, 2], almost all the road vehicles use passive oil dampers. Thus, due to non-linear characteristics of these dampers, the influence of suspension characteristics with delay in road excitation of front and rear wheels should be studied to understand the vehicle dynamics. In the present work, nonlinear damper with cubic nonlinearity for the stiffness and damping is considered. The system is converted from heave and pitch motions to a two-degree of freedom at the front and rear vertical vibration. The method of multiple scales [3] is used to arrive at the envelope equations by equating the secular terms to zero. The frequency response curves are obtained using the envelope equations..

Results and Discussion

The schematic diagram of half car suspension is shown in the Figure 1(a). The equation of motion for the half car can be derived using Newton's laws for transverse displacement y_c and pitch angle θ. Based on the experimental characteristics of oil damper as shown in Figures 1(b) and (c), the cubic nonlinearity of stiffness coefficient and linear and cubic nonlinearity of damping coefficients of damper are considered Subsequently, equation of motion can be written in-terms of transverse displacements Z_1 and Z_2 of front and rear wheels at distances a and b, respectively, from the centre of gravity subjected to sinusoidal excitation of front and rear wheels with delay angle of ϕ as shown in Figure 1.

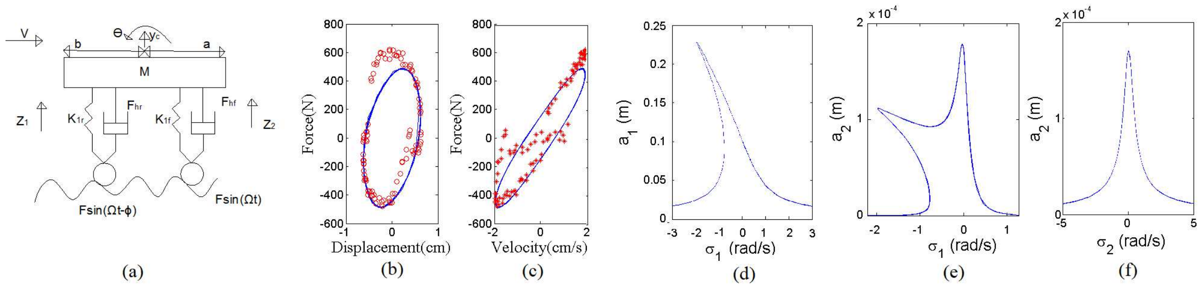

Figure 1: (a) Half car model; (b) Force vs. disp. and (c) Force vs. vel. of damper; (d)-(f) Nonlinear frequency response

Modulation equations are obtained using the method of multiple scales under four different conditions, namely, primary resonance at the front wheels with internal resonance at rear wheel, primary resonance at the rear wheel with internal resonance at front wheel, superharmonic resonance at front wheel with internal resonance at rear wheel, and superharmonic resonance at the rear wheel with internal resonance at front wheel. a_1, a_2, and σ_1, σ_2 are vibration amplitudes and detuning factors of front and rear wheels. After validating the solution of multiple scale with numerical simulation using Runge Kutte method, we obtain the results under different operating conditions by solving modulation equation using MATCONT for delay of $\phi = 0.25\Omega'$ rad, where, Ω' is road excitation frequency. Figures 1(d) and (e) show frequency response curves of front and rear wheels due to primary excitation at front wheel. Figure1(f) shows frequency response curve of rear wheels when excitation is at rear wheel. Similarly, curves in other conditions are obtained. Based on the observation of results, it is found that delay in road excitation between front and rear wheels induces coupled nonlinear response which should be controlled by tuning the vehicle parameters or damper characteristics.

References

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