Nonlinear Dynamics of Dry Friction Oscillator Subjected to Combined Harmonic and Random Excitation.

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Abstract: A nonlinear dry friction oscillator to combined harmonic and stochastic excitation is considered. The discontinuous oscillator is modelled as a Filippov system. The oscillator exhibits discontinuity induced bifurcations (DIB) such as adding sliding bifurcations under harmonic excitation. The influence of noise on DIB is investigated by numerically integrating the equation of motion by an adaptive variable time stepping method (ATSM) combined with a bisection approach to accurately determine the discontinuity point. A Brownian tree approach is used for the solution to follow the correct Brownian path.

Keywords: Filippov model, Brownian tree, Discontinuity induced bifurcations

1. Introduction

Fig.1 shows a single degree of freedom nonlinear oscillator consisting of a mass, linear Spring, linear dashpot, nonlinear spring and nonlinear damper on a belt with dry friction moving with velocity V subjected to harmonic excitation and additive white noise. The equation of motion is given by[1]

$$\ddot{X}+\gamma_1 X+\gamma_2 X^3+\alpha g\left(\dot{X}-V\right)+\beta g\left(\dot{X}-V\right)^3+\mu g\,\mathrm{sgn}\left(\dot{X}-V\right)=f_0\cos\omega t+\sigma W(t)$$

where $\gamma_1=k_1/m$, $\gamma_2=k_2/m$, $\alpha=c_1/mg$, $\beta=c_2/mg$ and $f_0=F_0/m$ and $W(t)$ is the white noise with intensity σ.

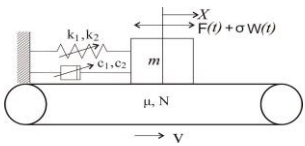


Fig. 1 Schematic diagram of dry friction oscillator with a moving belt.

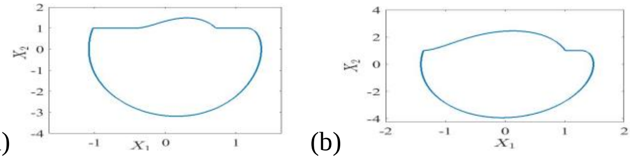
(a) 

Fig. 2 phase space plot for $\sigma = 0$ (a) $\omega = 1.95$ (b) $\omega = 2.44$.

Santhosh *et al*[1] analysed the oscillator by modelling it as a Fillipov system in which the dynamics in the smooth regions are described by two smooth vector fields F1 and F2 and in the discontinuous region by a convex combination of F1 and F2. It is seen that there is relative motion between mass and belt in the sticking phase, which was not observed when the sgn function was approximated by arc tangent function. This is indicative of adding sliding bifurcation which belongs to a class of DIBs. Figs 2(a) and 2(b) show respectively the phase plane diagrams for $\omega = 1.95$ and $\omega = 2.44$ obtained by using the Filippov model and event space numerical integration method. These are also verified by the ATSM, The other parameters adopted are $f_0 = 10m/s^2, \gamma_1 = 10s^{-2}, \alpha = 0.05s/m, \beta = \gamma_2 = 0, V = 1m/s, \mu = 0.6$.

2. Results and Discussion

The system is now investigated with the same set of parameters with noise included and using the Filippov convex combination model. The equation of motion was integrated using the ATSM [2] in combination with bisection method to determine accurately the discontinuity point. A Brownian tree approach is adopted so that the solution follows the correct Brownian path at each integration time step. It is observed that by proper tuning of the noise intensity the sliding region in the sticking phase can be altered. The phase planes for $\sigma = 0.25$ and $\sigma = 0.75$ are shown in Figs 3 (a) and (b) respectively for $\omega = 1.95$ which show chaos like behaviour modifying the motion in the sticking phase.

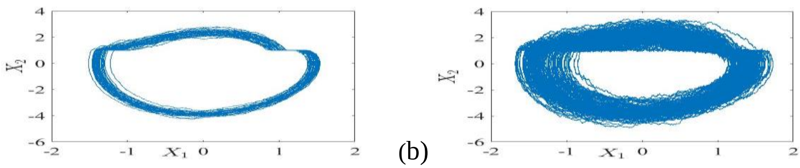


Fig. 3. phase space plot using ATSP for (a) $\sigma = 0.25$ (b) $\sigma = 0.75$.

3. Concluding Remarks

The dynamics of a dry friction nonlinear oscillator subjected to combied harmoinc eccitation and white noise is investigated by using Filippov model. The inclusion of noise alters the motion in the sticking phase considerably. The dynamics is further investigated by solution of corresponding Fokker-Planck equation and computing the largest Lyapunov exponent which are indicative of P and D bifurcations. These will be reported in the full paper.

References

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