

Noise-induced basin hopping in a vibro-impact system

Silvio L.T. de Souza ^a, Antonio M. Batista ^b, Iberê L. Caldas ^a,
Ricardo L. Viana ^{c,*}, Tomasz Kapitaniak ^d

^a Instituto de Física, Universidade de São Paulo, C.P. 66318, 05315-970 São Paulo, São Paulo, Brazil

^b Departamento de Matemática e Estatística, Universidade Estadual de Ponta Grossa, 84030-900, Ponta Grossa, Paraná, Brazil

^c Departamento de Física, Universidade Federal do Paraná, C.P. 18081, 81531-990 Curitiba, Paraná, Brazil

^d Division of Dynamics, Technical University of Łódź, Stefanowskiego 1/15, 90-924 Łódź, Poland

Accepted 8 November 2005

Communicated by Prof. M.S. El Naschie

Abstract

The dynamics of vibro-impact systems of engineering interest is numerically studied by means of a prototype consisting of an oscillating cart containing a ball undergoing inelastic collisions with its walls. We have described a multistable regime, for which different attractors coexist with a complicated basin boundary structure in the phase space. We investigated the effect of adding a certain amount of parametric noise in this model, focusing on the basin hopping, i.e., the intermittent switching between basins of different attractors.

© 2005 Elsevier Ltd. All rights reserved.

1. Introduction

Vibro-impact oscillators have moving parts colliding with either moving or stationary components, and are often found in engineering applications, as vibration hammers, driving machinery, milling, impact print hammers, and shock absorbers [1,2]. The practical interest in the study of vibro-impact oscillators lies in both their desirable and undesirable effects. The former are the basis of their operation, like an impact hammer, whereas the latter can be exemplified by large amplitude response leading to material fatigue and rattling in gearboxes, bearings, and fuel elements in nuclear reactors [3]. In both cases, it is of paramount importance to understand how vibro-impact systems behave dynamically, and what is the role of the parameter change on the observed dynamical regimes [4,5]. From the purely theoretical point of view vibro-impact oscillators have received a great deal of interest since they are non-smooth dynamical systems for which usual mathematical methods, like bifurcation theory, are applicable only to a limited extent [6–10].

One of the most conspicuous influences on vibro-impact and, in general, on any oscillator system, is caused by extrinsic noise, which is unavoidable in laboratory and industrial contexts. For simple periodic motions the effects of noise are fairly well understood, and their control or suppression can be achieved by standard procedures, like noise

* Corresponding author. Tel.: +55 41 3613098; fax: +55 41 3613418.

E-mail address: viana@fisica.ufpr.br (R.L. Viana).

filtering [11]. Such treatments may fail, however, for complex motions comprising both periodic, quasi-periodic and chaotic regimes, often coexisting with a complicated basin of attraction structure [12]. One of the outstanding features in noisy multistable systems is basin hopping, which consists of the intermittent switching between two or more basins of attraction, when the system is subjected to noise [13–19].

The effects of basin hopping can be dramatically enhanced if the multiple coexisting basins of attraction have fractal boundaries. In this case, it may well happen that even a small amount of noise is able to drive the oscillator out from its asymptotic state to another state, either periodic or chaotic. In vibro-impact systems, in particular, basin hopping can be highly undesirable and even dangerous, since it may produce large amplitude jumps in the oscillations of the moving parts and a consequent fatigue of the material, if not the complete system breakdown. This paper aims to shed some light on the effects of the parametric noise on the dynamics of a prototypical vibro-impact system, specially the intermittent transitions among different asymptotic states due to basin hopping.

This paper is organized as follows: Section 2 presents the prototypical impact-pair system and its equations of motion [20,21]. The noiseless dynamics of this system is considered in Section 3, whereas the effects of parametric noise are dealt with in Section 4. Our conclusions are left to the last section.

2. Mathematical description

In this section we present the basic equations and an impact map of the impact-pair system [20,21]. The impact map is useful to calculate the Lyapunov exponents [22]. The impact-pair system is shown schematically in Fig. 1 and is composed by a point mass m , whose displacement is denoted by x , and an one-dimensional box with a gap of length v . The mass m is free to move inside the gap and the motion of the box is described by a periodic function, $\alpha \sin(\omega t)$.

Equation of motion of the point mass m in the absolute coordinate is

$$\ddot{x} = 0 \quad (1)$$

Denoting the relative displacement of the mass m by y , we have

$$x = y + \alpha \sin(\omega t) \quad (2)$$

Substituting Eq. (2) into Eq. (1), the equation of motion in relative coordinate is

$$\ddot{y} = \alpha \omega^2 \sin(\omega t), \quad -v/2 < y < v/2 \quad (3)$$

Integrating Eq. (3) and invoking initial conditions $y(t_0) = y_0$ and $\dot{y}(t_0) = \dot{y}_0$, the displacement y and the velocity $\dot{y}$, between impacts, are

$$y(t) = y_0 + \alpha \sin(\omega t_0) - \alpha \sin(\omega t) + [\dot{y}_0 + \alpha \omega \cos(\omega t_0)](t - t_0) \quad (4)$$

$$\dot{y}(t) = \dot{y}_0 + \alpha \omega \cos(\omega t_0) - \alpha \omega \cos(\omega t) \quad (5)$$

An impact occurs whenever $y = v/2$ or $-v/2$. After each impact, we apply into Eqs. (4) and (5) the new set of initial conditions (Newton's law of impact)

$$t_0 = t, \quad y_0 = y, \quad \dot{y}_0 = -r\dot{y}, \quad (6)$$

where r is a constant restitution coefficient.

Therefore, the dynamics of the impact-pair system is obtained from Eqs. (4)–(6) and the system depends on control parameters v , r , α , and ω .

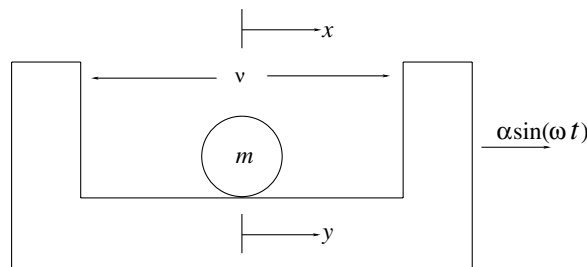


Fig. 1. Model of an impact-pair system.

Download English Version:

<https://daneshyari.com/en/article/1890920>

Download Persian Version:

<https://daneshyari.com/article/1890920>

[Daneshyari.com](https://daneshyari.com)