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Study of a non-linear mechanical system using Boubaker polynomials expansion scheme BPES

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ABSTRACT

Differential equations governing mechanical system behaviours have to be transformed into algebraic equations using the appropriate analytical and numerical tools. This study is concerned with the identification of a non-linear 2-degree-of-freedom mechanical system using the Boubaker polynomials expansion scheme (BPES). Solutions are plotted in the frequency–energy plane and are compared to other results published so far.

1. Introduction

In the last decades, predicting complex mechanisms dynamic behaviours became of high interest. Since such systems involve uncertain parameters and non-linear structures, several identification models have been proposed and discussed [1–10].

One common difficulty evoked by most of these models is the transformation of the initial differential equation set into solvable algebraic equations. The last century literature presents panoplies of resolution-identification protocols based on sampling, transforms and mapping techniques [11–19].

Recently, the use of special functions expansions (polynomials, wavelet bases, elementary orthogonal functions, etc.) yielded interesting results. In the particular domain of non-linear systems behaviour identification [21–23], the works of Masri and Caughey [20], Ghanem and Romeo [21,22] and Horng and Chou [23] gave an important contribution to expansion methods.

In this paper, a polynomial expansion scheme is proposed for identifying a coupled linear-non-linear oscillating system. The advantage of the used method lies in yielding continuous, infinitely integrable and differentiable solutions.

2. Problem presentation

The studied system consists of two coupled oscillators (Fig. 1). The first oscillator is defined by the parameters

M	mass
k_1	spring 1 stiffness coefficient
h_1	damping coefficient
x	t-dependent position mass

The second oscillator is defined by the parameters

m	mass
k_2	spring 2 stiffness
h_2	damping coefficient
y	t-dependent position

The non-linearity is expressed by the additional binding term $\Delta\vec{F}$

$$\left|\Delta\vec{F}\right| = \left|k_2(x(t)-y(t)^3)\right|$$

The dynamic behaviour of this 2-DOF mechanical system is governed [24–26] by the following coupled equations:

$$\begin{cases} M\dot{x}(t)+h_1(\dot{x}(t)-\dot{y}(t))+k_1(t)+k_2(x(t)-y(t))^3=0 \\ m\ddot{y}(t)+h_2(\dot{y}(t)-\dot{x}(t))+k_2(y(t)-x(t))^3=0 \\ x(t)\big|_{t=0}=x_0; \quad \dot{x}(t)\big|_{t=0}=0; \\ x(t)\big|_{t=0}=x_0; \quad \dot{x}(t)\big|_{t=0}=0 \end{cases} \tag{1}$$

For simplification purposes, system (1) is first simplified to

$$\begin{cases} \ddot{x}(t)+\frac{h_1}{M}\dot{x}(t)+\frac{h_2}{M}(\dot{x}(t)-\dot{y}(t))+\frac{4\pi^2}{T_0^2}x(t)+\Lambda(x(t)-y(t))^3=0 \\ r\times\ddot{y}(t)+\frac{h_2}{M}(\dot{y}(t)-\dot{x}(t))+\Lambda(y(t)-x(t))^3=0 \\ r=(m/M); \quad \Lambda=(k_2/M),\ T_0=2\pi\sqrt{M/k_1} \end{cases} \tag{2}$$

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