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Dynamic properties of the hysteretic Bouc-Wen model☆

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Abstract

The Bouc-Wen model, widely used in structural and mechanical engineering, gives an analytical description of a smooth hysteretic behavior. In practice, the Bouc-Wen model is mostly used within the following black-box approach: given a set of experimental input–output data, how to adjust the Bouc-Wen model parameters so that the output of the model matches the experimental data. It may happen that a Bouc-Wen model presents a good matching with the experimental real data for a specific input, but does not necessarily keep significant physical properties which are inherent to the real data, independently of the exciting input. This paper presents a characterization of the different classes of Bouc-Wen models in terms of their bounded input-bounded output stability property, and their capability for reproducing physical properties inherent to the true system they are to model.

Keywords: Hysteresis; Bouc-Wen model; Dynamics

1. Introduction

The Bouc-Wen model for smooth hysteresis [13] has received an increasing interest due to its capability to capture in an analytical form a range of shapes of hysteretic cycles which match the behavior of a wide class of hysteretic systems [12]. In particular, it has been used experimentally to model piezoelectric elements [9], magnetorheological dampers [14], wood joints [4] and base isolation devices for buildings [10]. The obtained models have been used either to predict the behavior of the physical hysteretic element [10] or for control purposes [1,5,6].

In the current literature, the Bouc-Wen model is mostly used within the following black-box approach: given a set of experimental input–output data, how to adjust the Bouc-Wen model parameters so that the output of the model matches the experimental data [11]? The use of system identification techniques is one practical way to perform this task. Once an identification method has been applied to tune the Bouc-Wen model parameters, the resulting model is considered as a "good" approximation of the true hysteresis when the error between the experimental data and the output of the model is small enough. Then this model is used to study the behavior of the true hysteresis under different excitations.

By doing this, it is important to consider the following remark. It may happen that a Bouc-Wen model presents a good matching with the experimental real data for a specific input, but does not necessarily keep significant physical properties which are inherent to the real data, independently of the exciting input. In this paper we draw the attention to this issue, with the particular focus on the following two properties which are shared by most of the hysteretic mechanical and structural systems:

Property 1. Let us conceptualize a nonlinear hysteretic behavior as a map $x(t) \mapsto \Phi_s(x)(t)$, where x represents the time history of an input variable and $\Phi_s(x)$ describes the time history of the hysteretic output variable. For any bounded input x, the

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