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Minor loops of the Dahl and LuGre models

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ABSTRACT

Hysteresis is a special type of behavior encountered in physical systems: in a hysteretic system, when the input is periodic and varies slowly, the steady-state part of the output-versus-input graph becomes a loop called *hysteresis loop*. In the presence of perturbed inputs, this hysteresis loop presents small lobes called minor loops that are located inside a larger curve called major loop. The study of minor loops is becoming increasingly popular since it leads to a quantification of the loss of energy. The aim of the present paper is to give an explicit analytic expression of the minor loops of the LuGre and the Dahl models of dynamic dry friction.

1. Introduction

Hysteresis is a nonlinear phenomenon observed in some physical systems under low-frequency excitations. It appears in many areas such as biology, electronics, ferroelasticity, magnetism, mechanics or optics [1–5]. This phenomenon is currently classified into two categories: *rate independent* (RI) and *rate dependent* (RD) hysteresis. For RI hysteresis, the output-versus-input graph of the hysteresis system does not change with the frequency of the input signal. This is the case for example of the Bouc-Wen or the Preisach models, see [6,7] respectively. For RD hysteresis, the output-versus-input graph of the hysteresis system may change with the frequency, but it converges in some sense to a fixed loop called the hysteresis loop when the frequency goes to zero. This is the case for example of the LuGre model and the semilinear Duhem model, see [8–10]. Research in the field of hysteresis has focused mainly on the study of rate-independent hysteresis, and it is only in the last 15 years that the importance of rate-dependent phenomena has been acknowledged, and it constitutes a challenge by itself.

The recent years have witnessed a growing interest in a phenomenon that appears in hysteretic systems under perturbed periodic signals: the hysteresis loop shows to be composed of a big cycle called major loop, and one or several small lobes

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