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Piezo-actuators modeling for smart applications

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ABSTRACT

This paper deals with piezoelectric actuators modeling. The objective is to contribute in piezo-models library construction. Compared to existing models in commercial packages, the proposal model integrate nonlinear effects, especially hysteresis, while not requiring high computing efforts. This will help in the generalization of piezo-actuator usage for smart applications. Our methodology and approaches are clearly justified in the paper.

1. Introduction

A piezoelectric material changes its shape when subjected to an electric field. Conversely, it induces electrical charges when subjected to mechanical solicitations.

Such devices are useful in advanced and complex mechanical structures design and their machining process. Their application scope includes all fields [1]. They are especially used for vibratory drilling where they offer a controllable solution since the generated vibrations are electrically driven.

During these last years, the techniques evolve from the step of laboratories concepts and experiences to industrial applications. Everyone is enthusiastic. However, lots of obstacles do not ease the use of these devices. As a matter of fact, the complex phenomena taking place into these materials are under investigation for years. However the existing literature shows that researchers mostly pay attention to meticulous description of the phenomena in atomistic or nano scales. The diffusion of the science-based knowledge for technological realizations has been largely ignored.

Therefore, there is a gap between materials specialists and engineers, the users of these devices. However the user needs at their disposal simple tools to handle these devices in order to integrate them into systems. For this purpose, the availability of models can be of great aid. They allow dimensioning, simulation of interaction between the device and the others parts of the system. They allow to optimize the system [2]. Moreover, these models help for knowledge capitalization. However they should be appropriate to the context and established in formalisms more accessible for users.

This lack of models concerns many scientists and industrialists. For example, piezoelectric and magnetostrictive materials models are more than more included in engineering software.

For a realistic and detailed study of physical systems involving partial differential equations, a numerical method must be used to solve the problem. The finite-element method is often found to be the most appropriate [3]. Nowadays, many commercial FEA (Finite Element Analysis) packages include piezoelectric coupling. For example many codes have been implemented in ANSYS [4].

However, FEA models are positioned at a high level of details in design process. By contrast, we are concerned with the earliest stage of design process. This stage is difficult because at this level, decisions are made in an environment where few elements are defined. Therein, high level details are not useful. Moreover, FEA models require high computation effort and they are not usable for real time controller synthesizing.

In this case, automatists would have used identification tools considering the system as a black box. They have at their disposal many techniques and tools for this purpose [5,6]. Nowadays, Matlab-Simulink [7] integrated several identification toolboxes. These tools usually provide robust models for control loops elaboration.

However, system identification approach provides a model in which we cannot dissociate the system's parts. With such an approach, we would obtain a model of the whole system (piezo-actuator + mechanism + sensor). If the mechanism is changed, another identification process will then be compulsory. There is no notion of modularity in this. Therefore, this approach should be used at the end of the design process, after the system assembly.

All these reasons explain the choice of physics-based lumped-parameters approach. Many lumped-parameters system models exist that have provided satisfaction. For example the reader could

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