Stress-dependent compensation of magnetostrictive transducers

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I. INTRODUCTION

Magnetostrictive materials have been widely investigated in the last years [1] due to the potentialities they show to the development of smart devices. In fact, they have promising properties such as high energy densities, large strokes and fast responses but, unfortunately, the strong hysteresis phenomena they show yield to a reduction of their application range and performances. To this aim, several papers [2]- [5] tackled the problem of hysteresis compensation and control of these devices, and the goal of improving their performances with constant applied mechanical loads (given pre-stress) was achieved. Unfortunately, the magnetostriction behavior depends on the stress experienced by the active material [1]. Hence, any classical compensation algorithm applies when forces are much smaller than the applied pre-stress. In actual dynamic conditions such as in applications of active vibration suppression of structures, the device could experience forces of comparable magnitude and therefore a generalization of compensation algorithms, with two input variables (magnetic field and stress) should be defined. In the present paper a new algorithm based on the model proposed in [6] is presented. It gathers both good performances and low computational effort and seems quite promising in the definition of new control systems of magnetostrictive devices when time-varying mechanical loads are taken into account.

II. STRESS-DEPENDENT MODEL AND COMPENSATION ALGORITHM

A quite simple model for magnetostriction, taking the elastic response can be conceived, as [6]:

$$\epsilon(t) = \lambda(\sigma) + \Gamma[f(i,\sigma)](t), \quad (1)$$

where i is the current, σ the applied mechanical load, λ is a pure elastic response and Γ is the classical Preisach operator.

The operator Γ admits the inverse, [7] so eqn. (1), can be re-arranged as follows:

$$\Gamma^{-1}\left(\epsilon(t) - \lambda(\sigma)\right) = f(i,\sigma). \quad (2)$$

Assuming the function f continuously differentiable in Ω, i.e. $f \in C^1(\Omega)$, the following domain $W \subseteq \Omega$ can be defined:

$$W = \left\{P_0 \in \Omega | J_f(P_0) \neq 0\right\}, \quad (3)$$

where $J_f(P_0)$ is the Jacobian of f in P_0. This guarantees that f is locally invertible for every $P \in W$ or, in other words, that

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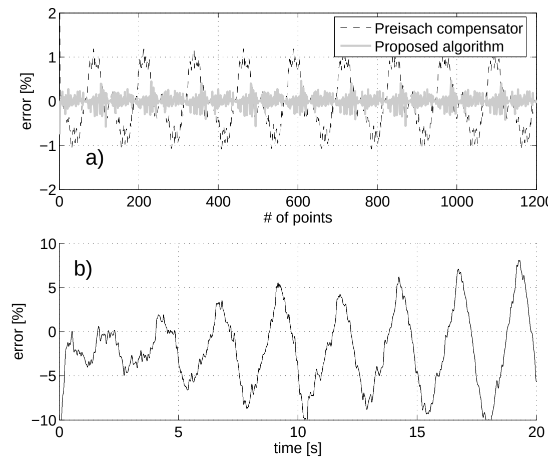

Fig. 1. a) Comparison of the tracking error of a sinusoidal strain waveform performed by the proposed compensation algorithm (gray) and by the operator $i(t) = \Gamma[\varepsilon](t)$ without any stress-dependence (black); b) tracking error of a strain waveform generating high order reversal branches

eqn.(2) with assigned σ admits a unique solution i. For sake of example, Fig. 1 shows the performances of the open loop control system employing a stress dependent compensation algorithm. Fig. 1a) shows the tracking of a sinusoidal strain variation at a constant applied load F = 300N, very far from the applied prestress employed for the identification of the Preisach model Γ. The stress compensation model is compared with the $i(t) = \Gamma[\varepsilon](t)$ output without any stress-dependence.

Conversely, Fig. 1b) shows the tracking of a non-sinusoidal strain variation, generating higher order reversal branches. In the complete paper the compensator algorithm will be discussed in detail and further tests on its performances in more general conditions will be provided.

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