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REAL-TIME MONITORING OF BUILT INFRASTRUCTURE SYSTEMS

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ABSTRACT

Our traditional built infrastructure systems (e.g. roads, pipelines) are degrading and the new, bourgeoning sectors (e.g. renewable energy devices) are adding to this existing burden. We do not have adequate resources to re-build them. Under such circumstances, we must resort to obtaining the best information about them to prioritize decision-making with limited resources.

In this regard, through the review of a number of recent developments [1-6], we demonstrate how a real-time framework can be developed around the concept of monitoring these systems by analyzing their dynamic responses. Real-time damage detection, health monitoring and system identification will be discussed with both numerical and experimental examples. The approach is largely baseline-free and output-only and allows for implementation for a range of systems and sensors.

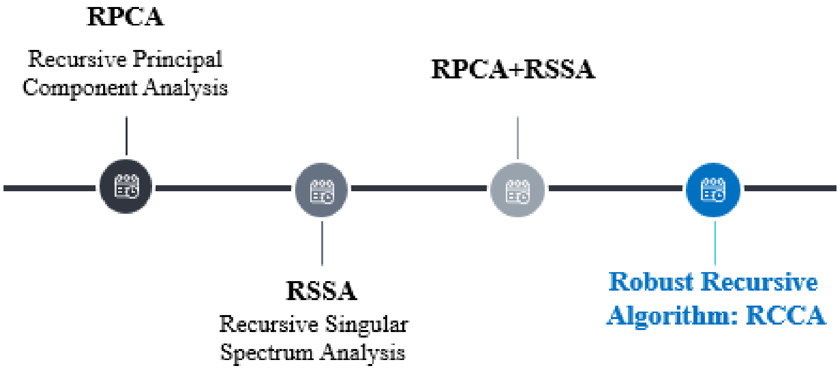

Figure 1: A first-order perturbation family of real-time algorithms

Keywords: Real-time, Structural Health Monitoring, First-Order Perturbation, Output-only

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PIEZOELECTRIC ACTUATOR HYSTERESIS AND ITS INFLUENCE ON EFFICIENCY OF VIBRATION CONTROLLERS

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ABSTRACT

One of the basic properties of piezoelectric actuators is the possibility of hysteresis existence. Many scientific works are devoted to the identification and modeling of this phenomenon. One of the research lines is the use of the Bouc-Wen model to describe hysteresis [1]. The application of a first order nonlinear ordinary differential equation allows to fit the hysteresis loop shape to those observed during experimental tests. An analysis of the influence of piezoelectric actuator hysteresis on the effectiveness of selected control algorithm was presented in article [2]. A reduced nonlinear model of transverse vibration of cantilever beam with Nonlinear Saturation controller was investigated. The one degree of freedom beam model took into account the geometric and inertial nonlinearities. Whereas, the nonlinearities of the controller came from parametric and quadratic coupling between the mechanical and electrical subsystems. Two control cases were considered, the so-called ideal (without actuator's hysteresis) and non-ideal (with actuator's hysteresis). The obtained results were used to compare the system dynamic with and without the Bouc-Wen hysteretic model. It was found that the actuator hysteresis might affect the efficiency of the saturation control. This study is an extension of previous research [2]. The influence of hysteresis phenomenon on effectiveness of various control methods is tested. During the analysis the simple algorithms as proportional or cubic displacement control and also more complex as Positive Position Feedback control and Nonlinear Saturation control are taken into account. Developed numerical models allowed the comparison of beam dynamics with different hysteresis size of the piezoelectric actuator. The advantages and disadvantages of individual controllers are determined on the basis of the obtained numerical resonance characteristics. Finally, this study comprehensively evaluates the effect of hysteresis on the efficiency of the vibration reduction by different kinds of control algorithms.

Acknowledgments.
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Keywords: Nonlinear dynamic, hysteresis, vibration control

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VIBRATING THERMAL ENERGY HARVESTER WITH SHAPE MEMORY ALLOY AND PIEZOELECTRIC TRANSDUCER

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ABSTRACT

Thermal energy harvesters are used to utilize wasted or unused heat from the ambience converting it in small amounts of electric power for feeding sensors and actuators with low energy consumption [1].

The aim of this paper is to present a model concept of a novel energy harvester using shape memory effect to induce vibrations from heat and applying piezoelectric effect to transform the vibrational mechanical energy in output electricity.

The thermal energy harvester contains a shape memory alloy thread (SMAT) and two cantilever beams connected in a bow-similar structure in the way that the cantilevers stretch the SMAT with their free ends (Fig. 1).

Initially a heated solid body gets in contact with the SMAT. Because the temperature of the hot body is higher than the temperatures of the SMAT and the ambient temperature at all, the SMAT starts to heat and undergo transient crystallographic changes from martensite to austenite. The change of the state of the crystallographic phase leads to SMAT's contraction and the distance between cantilever ends decreases. At the same time, the contraction of SMAT causes it to move away from the heated body and SMAT cools. The cooled state of the SMAT corresponds to the soft crystallographic phase martensite. In this state, the SMAT stretches again and touches the heated body. The above-mentioned actions repeat until ambient and heated body temperature equalize. During all above-mentioned processes, elastic cantilevers undergo bending vibrations that induce electric charges in their piezoelectric layers.

For the considered thermal energy harvester a dynamical model based on Lagrange-Maxwell equations of second order is presented. The solutions of the model are used to determine multiphysical connections between the mechanical, electrical, and thermal parameters. Furthermore, using model investigations some optimization problems of the design have been solved.

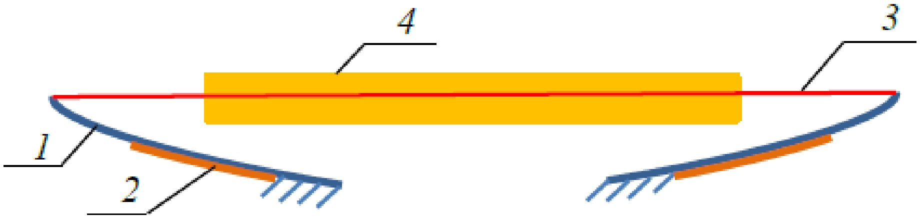

Figure 1 Schematic view of the presented energy harvester: 1 Cantilever; 2 Piezoelectric layer; 3 Shape Memory Alloy Thread (SMAT); 4 Hot body.

Keywords: Thermal Energy Harvester, Vibration, Shape Memory alloy, Piezoelectric transducer.

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OPTIMIZATION OF AN ENERGY HARVESTER VIA THE CROSS-ENTROPY METHOD

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ABSTRACT

Vibration energy harvesting has the potential to provide energetic solutions for low power autonomous systems, such as small electronics devices, sensors, medical implants, etc. For this reason, this technology attracted the interest of researchers over the last two decades, with special focus on the analysis and optimization of nonlinear systems [1]. In this sense, this work deals with the formulation and numerical solution of a nonlinear non-convex optimization problem which seeks to maximize the recovery of electrical power from the bistable energy harvester illustrated in Fig.1a (see Erturk et al. [2] for details), which evolves according to

$$\ddot{x} + 2\,\xi\,\dot{x} - \frac{1}{2}\,x\,(1 - x^2) - \chi\,v = f\,\cos(\Omega t) \quad \text{and} \quad \dot{v} + \lambda\,v + \kappa\,\dot{x} = 0, \tag{1}$$

where x is the beam tip displacement; v the output voltage; t the time; ξ the damping ratio; χ a piezoelectric coupling term; λ the reciprocal time constant; κ a piezoelectric coupling term; f the external excitation amplitude; Ω the external excitation frequency. All of these parameters are dimensionless. This optimization problem is formulated in terms of the response of the harvester dynamics and a classifier obtained from 0-1 test for chaos [3]. The objective function is defined as the mean value of the output power

$$P \;=\; \frac{1}{T}\int_{t_i}^{t_f} \lambda\, v\,(t)^2\; dt, \tag{2}$$

while the 0-1 test classifier defines the nonlinear constraint (with jump discontinues). A stochastic strategy of solution, combining penalization and the cross-entropy (CE) method is proposed [3, 4]. Numerical experiments considering f and Ω as design variables, with or without noise in the external forcing, demonstrate the accuracy of the method (see in Fig1c that CE method is able to go in the direction of the global optimum shown in Fig 1b). Besides that, its computational efficiency is significant when compared to a direct search in a 256×256 numerical grid (which produces Fig 1b), with speed-up of up to two orders of magnitude. Further results can be seen in [3].

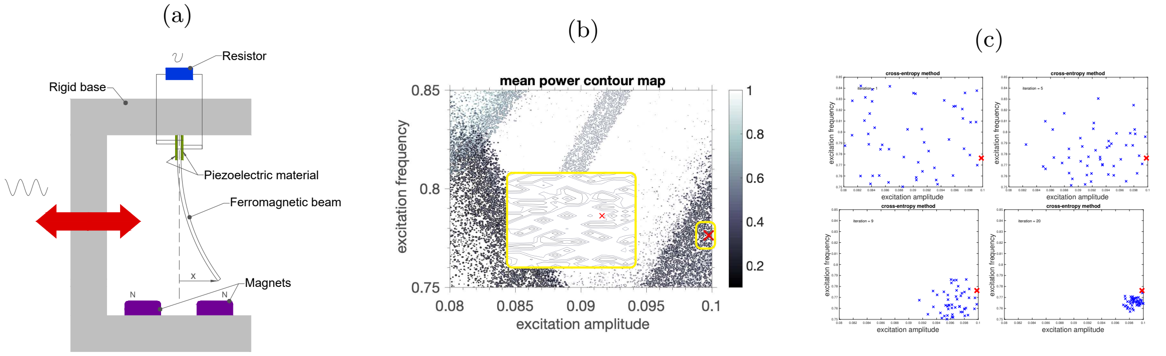

Figure 1: (a) Bistable energy harvester; (b) Contour map of the mean power recovered by the harvester, the global optimal (computed via directed search) is indicated with a red cross; (c) CE method search for the optimal value.

Keywords: energy harvesting, bistable system, global optimization, cross-entropy method

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