SHUNTED PIEZOELECTRIC TRAP DEVICE TO ENHANCE ENERGY HARVESTING

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ABSTRACT

Innovative technologies aim at reducing structural masses using composite materials. These new light structures are, however, very sensitive to vibrations. Original fields such as metacomposites or structronics show up from this context in order to explore new vibratory stabilities and its applications to acoustic attenuation, health monitoring, or energy harvesting in order to ensure robustness and autonomy to subsystems. This paper focuses on an academic structure where a piezoelectric transducer frame works as a trap device. The latter concentrate the energy from vibrations to a place where an SSHI (Synchronized Switch Harvesting in Inductor) type harvesting device is located. After a presentation of the structure, and the conversion-extraction device, its capability to improve the harvested energy are verified in comparison with a purely passive structure.

1 INTRODUCTION

In a context of new materials and architectures, fields as structronics or metacomposites aim at explore new vibrating stabilities for various applications such as energy harvesting. A standard harvesting system is hereby applied to a multimodal structure coupled with a trap device. The methodologies and models have previously been tested and validated on a monomodal structure and are in accordance with the theory.
All the results are presented in the case of the weak coupling of the structure, in other words, in a constant displacement case. That means the electronic parts of the system don't affect the dynamics of the structural components.

2 DESIGN OF TRAP DEVICE COMPOSED OF SHUNTED PIEZOELECTRIC CELLS

The global geometry of the studied system and the piezoelectric trap device principle are hereby detailed.

2.1 Structure of interest

The figure 1 displays the structure of interest which consists in a 2.5m long cantilever beam. The two 0.6m long trap devices are composed of gradually varying parameters [1, 2] designed to trap the vibration energy in the 0.4m long trap zone of the structure where a harvesting device is placed. The background beam and the trap zone are made of aluminum.

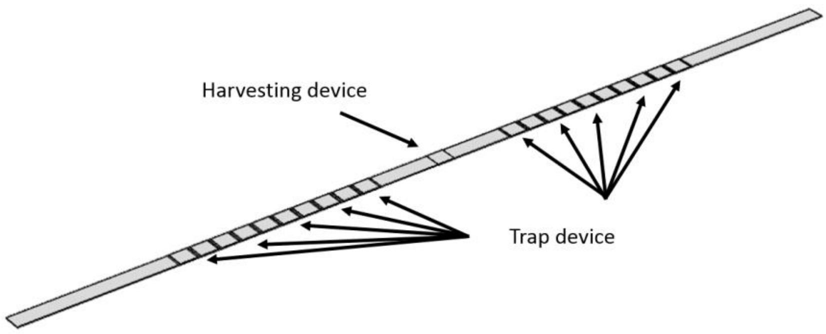

Figure 1. System geometry.

2.2 Shunted piezoelectric cells network for trap device

The above-mentioned trap device can be achieved in different ways, designing geometry parameters or combinations of several ones. Here, the chosen approach is to modify the Young modulus. This parameter has to be continuous in order to avoid reflections in wave's propagation [2]. In figure 2, the black solid lines show this decreasing in Young modulus from the outside to the inside edges of the trap devices.

Due to the difficulty to make a continuously varying parameter all along the two trap devices, each one is divided into ten cells with identical geometrical properties. For each one, the target Yong modulus portion of curve is discretized (red crosses on figure 2) and materially made using a piezoelectric patch. Each one of these patches is shunted in order to realize negative capacitances able to modify the system dynamics [3].

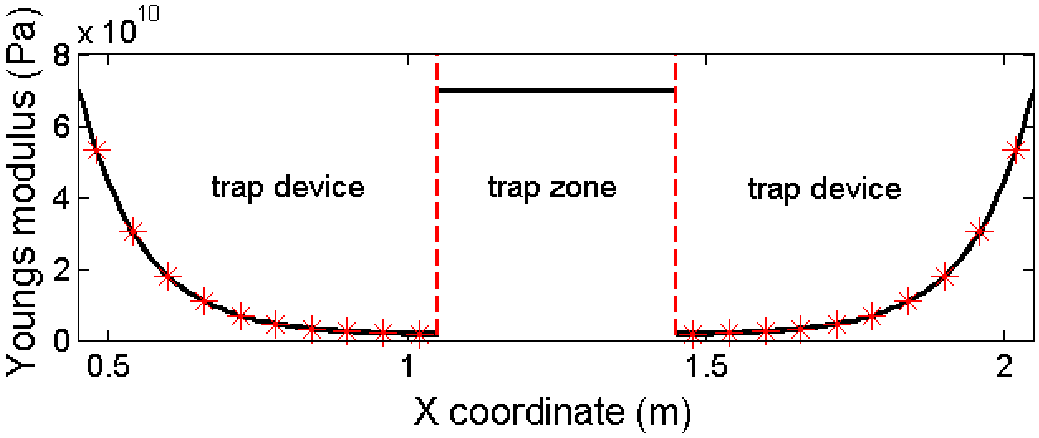

Figure 2. Trap device design.

3 ENERGY HARVESTING DEVICE

As a first step, a very classical harvesting system is used [4]. It is composed of a diode bridge, a smoothening capacitor C_R, the piezoelectrical capacitance C_0 and a resistor R. The whole device is connected to a piezoelectric element placed at the centre of the trap zone. The time constant $\tau=RC_R=10$s in order to guaranty that the output voltage V_s reaches its steady state in an honest amount of time.

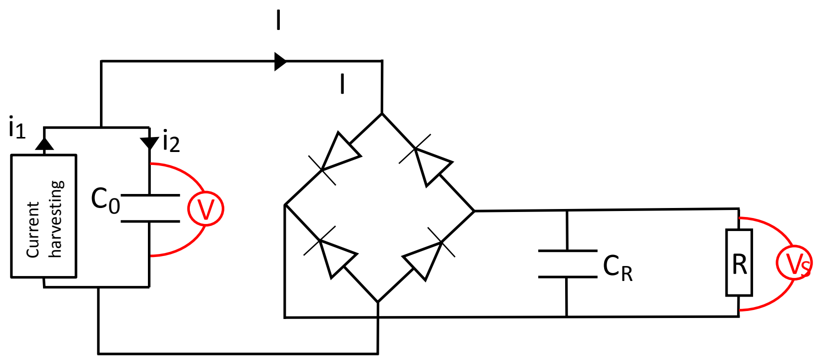

Figure 3. Energy harvesting device.

The tuning of the above electronic device to the natural frequency of interest of the structure implies each time a modification of the R value. C_R has also to be changed for τ to remain a constant. These parameters finally allow computing the performance criteria; the output tension V_s and the harvested power P_{stand}:

$$V_s = \frac{R\Phi^T \alpha}{C_0 R \omega_0 + \frac{\pi}{2}} \omega_0 q_m \qquad P_{s\tan d} = \frac{V_s^2}{R} \tag{1}$$

With the modal matrix Φ, the coupling coefficient α and for the generalized coordinate q_m and a working angular frequency ω_0.

4 PERFORMANCES

The studied system is multimodal with 20 modes but the presented work will focus on the 17^{th} flexure mode at 151.46Hz of the structure which presents good coupling with the harvesting and trap devices. The excitation is made on the free end of the beam. Figure 4 gives the resulting performances. V_s and P_{stand} are displayed for both activated (red) and deactivated (blue) trap devices, in the case of weak coupling.

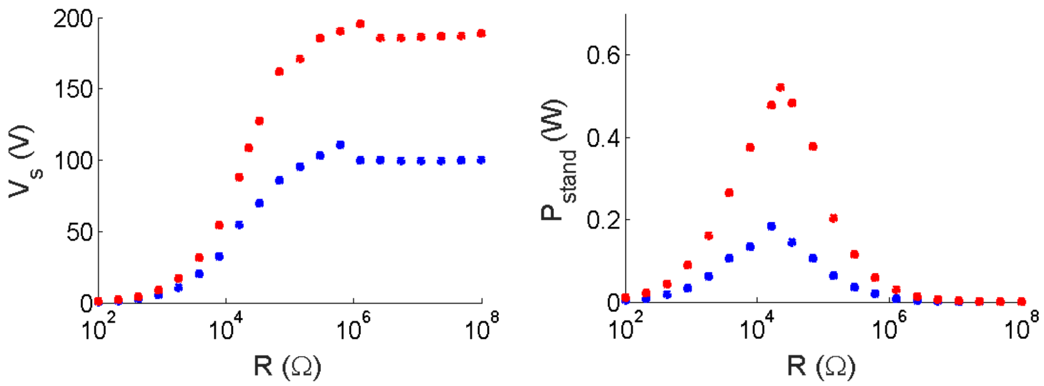

Figure 4. Vs and P.

The topology of the obtained curves fits with the ones from the literature [4]. The harvesting improvement due to the trap device activation can clearly be seen and reaches 0.52W for a 2.26e4Ω resistor. That corresponds to 2.84 times the results obtained without trap.

5 CONCLUDING REMARKS

The improvement in adding a trap device to concentrate the mechanical energy in a place of the structure where the harvester is placed has been demonstrated on an academic multimodal system. Even if only weak coupling has been taken into account, results from strong coupling present some computation issues that will be addressed in further communications.

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