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Piezoelectric vibration energy harvesting from a portal frame with a shape memory alloy

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Abstract: In the past decades, there has been an accelerated growth in the development of electronic devices. Generally, these devices are low-power consumptions, consequently easy to be powered. Hence, the demand to obtain the needed energy to power up these devices has increased. In this work, the energy harvesting from a simple portal structure accounting for a shape memory alloy (SMA) in its composition material is presented. The portal frame is subjected to an excitation from a non-ideal DC motor with limited supply. The energy harvesting is obtained through a nonlinear piezoelectric material coupled to the structure. The dynamic response of the system is investigated through the variation of the temperature and geometric parameters of the SMA, which are determined by the length and diameter of the alloy. Numerical simulations show the influence of the introduction of the SMA on the dynamics of the system, leading to undesired chaotic behavior to a periodic one. In addition, the energy available for harvesting is computed.

Keywords: Energy harvesting, Nonlinear Dynamics, Shape Memory Alloy, Piezoelectric devices.

1. Introduction

Figure 1 shows an equivalent physical model to represent a portal frame structure with the a piezoelectric material coupled to a column of the structure supporting a DC motor with limited power supply, and unbalanced rotating mass [1].

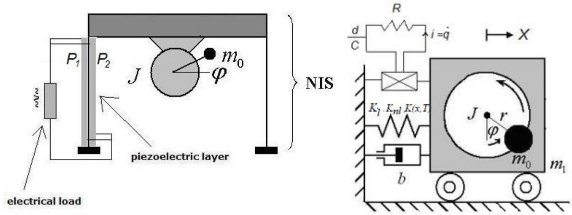

Fig. 1. Schematic of the non-ideal portal frame energy harvester with SMA material

The equations of motion for Fig. 1 can be written as follows:

$$
\begin{aligned}
x_1' &= x_2 \\
x_2' &= \frac{1}{1-\delta_1\rho_1\sin(x_3)^2}\begin{pmatrix} -\alpha_1 x_2 - k_{sma}\left(a\Delta T x_1 - b x_1^3 + c x_1^5\right) + \theta\left(1+\Theta\left|x_1\right|\right)x_5 \\ -\beta_1 x_1 - \beta_3 x_1^{\,3} + \delta_1 \sin(x_3)\left(-\rho_3 x_4 + \rho_2\right) + \delta_2 \cos(x_3)x_4^2 \end{pmatrix} \\
x_3' &= x_4 \qquad\qquad (1) \\
x_4' &= \frac{1}{1-\delta_1\rho_1\sin(x_3)^2}\begin{pmatrix} \rho_1 \sin(x_3)(-\alpha_1 x_2 - k_{sma}\left(a\Delta T x_1 - b x_1^3 + c x_1^5\right) - \beta_1 x_1 \\ -\beta_3 x_1^{\,3} + \theta\left(1+\Theta\left|x_1\right|\right)x_5 + \delta_2\cos(x_3)x_4^2) + \rho_2 - \rho_3 x_4 \end{pmatrix} \\
x_5' &= \frac{\theta(1+\Theta\,|\,x_1\,|)x_1}{\rho} - \frac{x_5}{\rho}
\end{aligned}
$$

The average power is obtained by: $P_{avg} = \frac{1}{T}\int_0^T P(\tau)d\tau$, with $P = \rho v'^2$.

2. Results and Discussion

Figure 1 shows the numerical results considering the parameters: a= 0.00156987, b = 114.367348, c= 7232.49136, $\alpha_1 = 0.1$, $\beta_1 = -1$, $\beta_3 = 0.2$, $\rho_1 = 0.05$, $\rho_2 = 100$, $\rho_3 = 200$, $\delta_1 = 8.373$, $\theta = 0.20$, $\Theta = 0.60$, $\rho = 1.0$, along with the initial conditions: $x_i\left(0\right) = 0$, where i=1:5 [1-3].

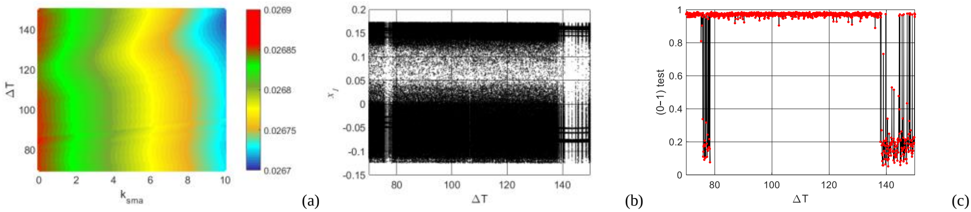

Fig. 1. (a) Average power for (k_{sma}=[0:10] and ΔT =[70:150]), (b, c) Phase diagram and 0-1 test for a_W (k_{sma}=1 and ΔT =[70:150]).

3. Concluding Remarks

The results presented show that the temperature variation of the SMA (ΔT) has little influence on the energy uptake (Fig. 1a), however it has a significant influence on the dynamics of the system (Fig. 1b and 1c). It is also possible to observe that the parameter that represents the dimensions of the SMA (k_{sma}), has a significant influence both in the capture of energy and in the dynamics of the system.

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