



**HAL**  
open science

# Effect of parametric uncertainties on vibration mitigation of a rod with interconnected piezoelectric patches

Marcelo A Trindade, Boris Lossouarn, Jean-François Deü

► **To cite this version:**

Marcelo A Trindade, Boris Lossouarn, Jean-François Deü. Effect of parametric uncertainties on vibration mitigation of a rod with interconnected piezoelectric patches. 30th International Conference on Adaptive Structures and Technologies, ICAST2019, Oct 2019, Montreal, Canada. hal-03196646

**HAL Id: hal-03196646**

**<https://hal.science/hal-03196646>**

Submitted on 13 Apr 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## Effect of parametric uncertainties on vibration mitigation of a rod with interconnected piezoelectric patches

Marcelo A. Trindade<sup>1\*</sup>, Boris Lossouarn<sup>2</sup>, Jean-François Deü<sup>2</sup>

<sup>1</sup>*Department of Mechanical Engineering, São Carlos School of Engineering, University of São Paulo,  
Av. Trabalhador São Carlense, 400, São Carlos, SP, 13566-590, Brazil  
e-mail: trindade@sc.usp.br (\*Corresponding author)*

<sup>2</sup>*Laboratoire de Mécanique des Structures et des Systèmes Couplés (LMSSC),  
Conservatoire national des arts et métiers (Cnam), 292 Rue Saint-Martin, 75003 Paris, France  
e-mail: boris.lossouarn@cnam.fr, jean-francois.deu@cnam.fr*

### Abstract

This work aims to present an analysis of the effect of parametric uncertainties on the vibration control performance of a rod with periodically distributed piezoelectric patches that may be either independently connected to electrical shunt circuits or interconnected through an electrical line of inductors. In both cases, the capacitance of piezoelectric patches are considered as stochastic parameters following a known probability density function distribution. Then, Monte Carlo simulations are performed to evaluate mean values and confidence intervals of the frequency response functions to assess the robustness of each solution and to compare different solutions in terms of nominal and robust performances. The effect of other electrical components, such as circuits resistances, on the robustness is also analyzed.

### Introduction

Piezoelectric materials have been widely used as distributed sensors and actuators to control structural vibrations of flexible structures. They are normally bonded to a host structure and connected to an electrical circuit. Therefore, they provide an electromechanical coupling to the host structure that, depending on electrical connections, may be used for several purposes such as passive, semi-passive, active or active-passive vibration control (Santos and Trindade, 2011).

In the case of passive vibration control applications, most studies focused on shunt circuits that connect the two electrodes of each piezoelectric patch. The most common circuits are resistive and resonant (resistive-inductive) ones but several research works proposed more sophisticated circuits using, for instance, switch or negative capacitance circuits. More recently, Lossouarn et al. (2015) considered the interconnection of a network of piezoelectric patches through resonant electrical circuits in a way that good multimodal vibration attenuation performance may be obtained with much smaller inductance values, compared to resonant shunt circuits.

However, as for the shunted case, the vibration control performance is dependent on the adequate tuning between electrical circuit components and structure's mechanical properties. Thus, variabilities and/or uncertainties on material properties, boundary conditions, and environmental conditions may have a major effect on reducing the expected or predicted performance of such devices. Nevertheless, few studies attempted to analyse the effect of parametric uncertainties on passive vibration control using shunted piezoelectric patches (Santos and Trindade, 2011; Andreus and Porfiri, 2007).

### Problem description

A free-free AU4G duraluminum rod in longitudinal vibration with length 1000 mm, width 20 mm and thickness 20 mm is considered. The rod has mass density 2780 kg m<sup>-3</sup> and Young modulus 73.9 GPa. 20 pairs of PIC151 piezoelectric patches are bonded to the rod. Each patch has the following dimensions:

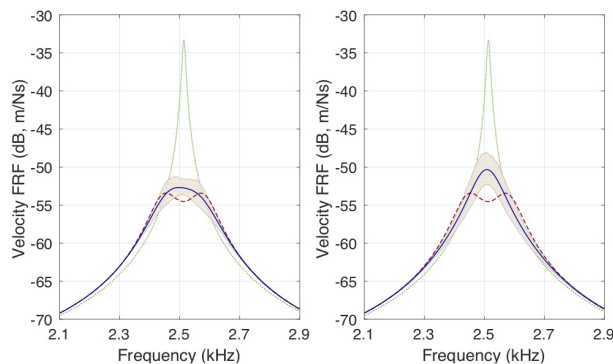
length 30 mm, width 20 mm and thickness 0.5 mm. The piezoelectric patches are considered to be equal with mass density  $7800 \text{ kg m}^{-3}$ , Young modulus 66.7 GPa, piezoelectric charge constant  $-210 \text{ pC N}^{-1}$  and dielectric permittivity  $21.2 \text{ nF m}^{-1}$ .

The rod with periodically bonded piezoelectric patches was modeled using the transfer matrix approach. For that, 20 electromechanical unit cells that periodically repeat all along the structure were considered. The unit cell is composed of a portion of the rod with length 50 mm, two entire piezoelectric patches bonded onto the upper and lower surfaces of the rod, centered along the length and poled in opposite through-thickness directions, one (independent) shunt circuit that connects directly the electrodes of these patches and two circuits that connects the pair of patches to left and right neighboring unit cells circuits.

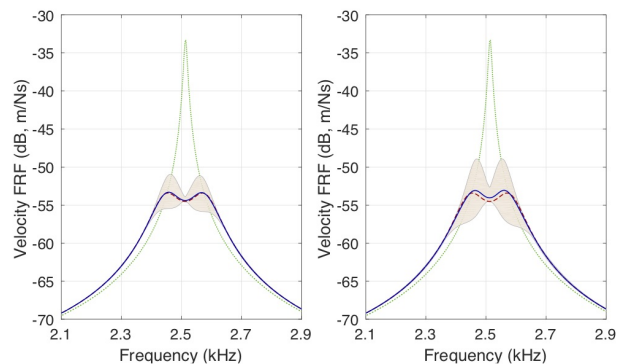
## Methodology and results

The effect of parametric uncertainties in the vibration mitigation performance of independent resonant shunt circuits and interconnected circuits, focusing on the first vibration mode, was evaluated and compared. First, the nominal case was defined using the optimal values for the circuit components. Then, stochastic models were constructed for the uncertain parameters, considering a Gamma p.d.f., and used for Monte Carlo simulations. Finally, the results are used to assess the robustness of the two solutions.

In this extended abstract, results considering uncertain capacitance for each circuit are shown in Figs. 1 and 2. It is noticeable that, for the interconnected circuit, the mean response and the superior of the confidence interval follows the shape of the nominal response with two peaks, while this is not the case for the independent circuit. In terms of the maximum responses, for the independent circuit, the difference between the maximum values of the nominal frequency response and the superior of the 95% confidence interval is 2.2 dB and 5.4 dB for 5% and 10% dispersions, respectively. For the interconnected circuit, these values are 2.5 dB and 4.5 dB. These results suggest that, for capacitance individual variabilities, the interconnected circuit seems more robust, and thus more interesting, than the independent one.



**Figure 1.** Frequency response of rod with independent circuits for uncertain patch capacitance (5% (left) and 10% (right) individual dispersion): open-circuit (short dash), RL nominal (dash), RL mean (solid), 95% confidence interval (fill).



**Figure 2.** Frequency response of rod with interconnected circuits for uncertain patch capacitance (5% (left) and 10% (right) individual dispersion): open-circuit (short dash), RL nominal (dash), RL mean (solid), 95% confidence interval (fill).

Additional analyses considering the effect of uncertain inductance for each circuit and global uncertainties for the capacitances, and also considering the effect of the circuits effective resistances on the robustness of each solution will be also presented.

## References

- Andreus U and Porfiri M (2007) Effect of electrical uncertainties on resonant piezoelectric shunting. *J. Intell. Mater. Syst. Struct.* 18:477-485.
- Lossouarn B, Aucejo M and Deü J-F (2015) Multimodal coupling of periodic lattices and application to rod vibration damping with a piezoelectric network. *Smart Mater. Struct.* 24:045018.
- Santos HFL and Trindade MA (2011) Structural vibration control using extension and shear active-passive piezoelectric networks including sensitivity to electrical uncertainties. *J. Braz. Soc. Mech. Sci. Eng.* 33:287-301.