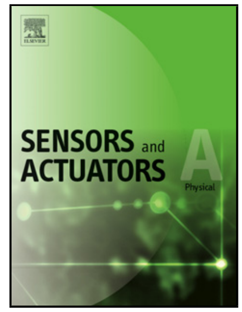

Title: Self-heat generation of embedded piezo ceramic patches used for fabrication of smart materials

Authors: Antonino Quattrocchi, Fabrizio Freni, Roberto Montanini

PII: S0924-4247(18)30559-4
DOI: https://doi.org/10.1016/j.sna.2018.08.022
Reference: SNA 10946

To appear in: *Sensors and Actuators A*

Received date: 30-3-2018
Revised date: 11-7-2018
Accepted date: 13-8-2018

Self-heat generation of embedded piezo ceramic patches used for fabrication of smart materials

Antonino Quattrocchi, Fabrizio Freni, Roberto Montanini*

Department of Engineering, University of Messina, Messina, Italy

HIGHLIGHTS

- Embedded piezo ceramic flexible patch (PFP) actuators for smart materials
- Effect of the surrounding material on PFP self-heating
- Infrared thermography used to evaluate surface temperature distribution
- Theoretical model based on energy balance for retrieving the temperature of the embedded PFP
- Sensitivity analysis to evaluate the effect on self-heating of amplitude and frequency of the driven voltage

Abstract

The use of smart structures, with embedded sensors and active actuators to provide real-time monitoring and controlling capabilities, has greatly increased in last decades. Piezo ceramic flexible patches (PFPs) are particularly suitable for these applications due to their low thickness and intrusiveness. A critical point when they are used as embedded actuators is their self-heating, which can be a concern especially when structural materials with very low thermal conductivity such as plastic reinforced composites are considered. This paper aims to investigate this issue by examining three paradigmatic case studies: a) PFP in a "free" exposed to static air; b) PFP enclosed between two skins of polymeric material and c) PFP embedded into a glass fibre reinforced plastic (GFRP) composite panel. The main goal of the research has been to assess how the temperature produced by self-heating of the piezo ceramic is influenced by the surrounding material as the patch is enclosed or embedded into a structural element. A sensitivity analysis was performed to evaluate the effect on self-heating of either the amplitude or the frequency of the driven voltage. Moreover, a simple theoretical model, based on energy balance, has been derived in order to estimate the actual PFP temperature in both the b) and c) configurations.

Keywords: piezoelectric transducers; piezo ceramic actuators; self-heating; heat dissipation; lead zirconate titanate (PZT); smart structures.

1. Introduction

A piezo ceramic flexible patch (PFP) is a multilayered device composed by a lead zirconate titanate (PZT) thin film interposed between two electrodes and insulated by a polymeric case. When driven by an alternate voltage, PFP reacts with a multi-axes strain that depends on the amplitude and frequency of the electric signal [1]. Common applications of PFPs can be found in the field of electronic systems, automotive and medical devices [2], as well as to control complex systems when fast, reliable and accurate performances are needed [3–5]. As examples, Basdogan et al. [6] employed PFPs to design a vibration control system for plate-like structures, while Askin at al. [7] extends this concept to complex 3D structures with complex boundary conditions. Spiga at al. [8] ideated an active system to correct mirror deformations in large telescopes; a similar application was proposed by Koh at al. [9] to drive a silicon micromirror. Luo et al. [10] designed, fabricated and tested a small-scale PFP probe that could be implanted in the inner ear for hearing rehabilitation. Furthermore, PFPs, functionalized as sensors or actuators, has been embedded into composites materials in order to create smart structures with active control capability for suppression of noise and vibration [11].
Although low excitation signals are normally involved, as a PFP works as actuator part of the electric power used to drive it is dissipated into heat, thus resulting in a potential modification of the device's thermal state. This issue has been the subject of a limited number of papers, that put into evidence the effect of specific parameters on the PFP self-heating and tried to investigate its genesis. Senousy et al. [12] proposed a 1D

Abbreviations: Piezo ceramic flexible patch (PFP); lead zirconate titanate (PZT); glass fibre reinforced plastic (GFRP).

* Corresponding author: roberto.montanini@unime.it; tel.: +39-090-397-7248