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Nonlinear elastodynamics of piezoelectric macro-fiber composites with interdigitated electrodes for resonant actuation

D. Tan[a], P. Yavarow[a], A. Erturk[a,*]

[a] *G.W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA, USA*

Abstract

Macro-fiber composite (MFC) piezoelectric materials are used in a variety of applications employing the converse piezoelectric effect, ranging from morphing and bioinspired actuation to vibration control in flexible structures. Most of the existing literature to date considered linear material behavior for geometrically linear oscillations. However, in many applications, such as bioinspired locomotion using MFCs, material and geometric nonlinearities are pronounced and linear models fail to represent and predict the governing dynamics. The predominant types of nonlinearities manifested in resonant actuation of MFC cantilevers are piezoelectric softening, geometric hardening, and inertial softening. In the present work, we explore nonlinear actuation of MFC cantilevers and develop an experimentally validated mathematical framework for modeling and analysis. In the experimental setting, an in vacuo actuation scenario is considered for a broad range of voltage levels (from low to moderate values) while eliminating nonlinear fluid damping. Experiments are conducted for an MFC bimorph cantilever, and model simulations based on the method of harmonic balance are compared with experimental frequency response curves under resonant actuation. The resulting experimentally validated framework can be used for simulating the dynamics of MFCs under resonant actuation, as well as parameter identification and structural optimization for linear to moderately nonlinear regime.

Keywords: piezoelectricity, actuation, nonlinear, macro-fiber composites

*Corresponding author
Email address: alper.erturk@me.gatech.edu (A. Erturk)