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An experimentally validated piezoelectric nonlinear energy sink for wideband vibration attenuation

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Abstract

Various researchers have investigated the behavior of a linear mechanical oscillator coupled to a nonlinear mechanical attachment that has essential stiffness nonlinearity. Under certain conditions, the essentially nonlinear attachment acts as a nonlinear energy sink (NES) and one-way energy transfer from the main structure to the nonlinear attachment can be achieved. An important characteristic of an essentially nonlinear attachment is that it does not posses any preferential resonance frequency, resulting in increased robustness against detuning, thereby enabling frequency-wise wideband performance. This work presents an experimentally validated piezoelectric-based NES for wideband vibration attenuation. The electrical circuit consists of a negative capacitance shunt (introduced for cancelling the piezoelectric capacitance) combined in series with a nonlinear capacitance of cubic order that is realized using operational amplifiers. Design and practical implementation of the NES shunt circuit are discussed in detail. The performance of the piezoelectric NES to attenuate vibrations over a wide range of frequencies is numerically simulated and experimentally validated for a cantilever in the absence and presence of tip mass attachments.

Keywords: nonlinear energy sink; piezoelectricity; targeted energy transfer; vibration attenuation

1. Introduction