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Implementation of Non-Linear Energy Sink in Damping and Harvesting of Acoustic power

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Abstract

Non-linear Energy Sinks (NES) is a new approach in the field of vibration isolation which allows an irreversible transfer of vibration energy from a primary linear system (e.g. a mass -spring where a harmonic excitation is applied) to a secondary non-linear system (e.g. a mass -spring with variable compliance and a damper) where the energy is finally transferred and dissipated. The phenomenon taking place in NES is referred to as Non-linear Energy Transfer (NET). Main applications of NET in the field of engineering range from aero-elastic instabilities control to seismic mitigation in civ il engineering to drill-string systems stabilization. Recent applications in the field of acoustics have seen the use of a thin visco-elastic membrane as NES, where a high amount of the acoustic power provided by waves propagating in a duct is dissipated in NES. However, the use of NES is new in the field of applied acoustics. For this reason, the objectives of this research proposal are investigating the potentiality of NES for both harvesting and dampening the acoustic power.

Introduction

An essentially nonlinear oscillator with relatively small mass, attached to a primary mechanical system to passively absorb the energy of oscillations under various forcing conditions is defined as nonlinear energy sink (NES) [1]. These forcing designs may be relatively varied: impulsive or steady-state external excitation, broadband excitation and self-excitation. An almost irreversible flow of energy into the NES is usually related to 1:1 transient resonance between the primary system and the NES. This mechanism is particularly the case of targeted energy transfer (TET). This TET has two specific features. First, it involves only two degrees of freedom. Then, properly selected damping ensures almost complete irreversibility: only a tiny share of the initial energy can be ‘‘rebounded’’ back to the primary system from the NES. Various designs and applications of the NES have been deliberated in the works over the past 10 years. These suggested designs include continuous NES with cubic nonlinearity, vibro-impact NES, acoustic NES, piecewise-linear NES, and some others [2]. Recently, it was demonstrated that a simple eccentric rotator can also be efficiently used as the NES. The dynamics of this latter system under externa l forcing have been explored in Manevich papers [3]. The main goal of this study is, to investigate the TET regime in duct acoustics then designing and testing acoustic non-linear energy sinks (NES) able to dampen and harvest acoustic power of in-duct propagated waves.

Research Hypothesis

Regarding to damping, it’s motivated by the fact that acoustic pollution produced by the human activities has an enormous impact on terrestrial environment as well as on well-being of people. Despite the possibility to have materials and acoustic devices with high absorption coefficients at mid-high frequencies, the acoustic pollution at low frequencies is still an unresolved problem in several engineering applications. In this sense, the use of NES in acoustics represents a new approach to passive sound control in the low frequency domain. The second objective of this study is perhaps even more challenging, since it consists of efficiently harvesting the acoustic power provided by sound propagating in ducts. Piezoelectric devices can be coupled to NES in order to convert the transferred acoustic power into electric power. Even though the power of acoustic waves in exhaust ducts and urban environment is of the order of fractions of Watts, the situation can radically change in case of thermo-acoustic engines and refrigerators, where the powers involved are much higher and the NET could effectively help to increase the efficiency of these machines. A special ocus will be given to the damping/harvesting phenomena in ducts where a mean flow is present, because this can have a huge industrial impact (e.g. for in internal combustion engines and power plants). Moreover, the use of NES in these applications has not been studied yet at the present date. The presence of a mean flow, thus of a mean static pressure acting on the NES, can result in a static load on the NES which can alter the vibration behaviour of the NES itself. For this reason, new NES must be designed by using the concept of quasi-zero stiffness mechanism which can allow compensating the initial static load while still keeping a very low dynamic stiffness. The phenomenon of NET takes place at the frequency of resonance of the primary linear system, when the sound excitation reaches a certain threshold. Another objective of this study is investigating the dependence of this threshold from the parameters of the system, in order to set it at the values occurring at the conditions where the damping / harvesting is desired. Finally, frames for multi-layer glass panels used for windows and doors can be designed as NES in order to reduce the sound transmission of these components at low frequencies. In fact, the vibration energy can be transferred from the panel to the supporting frame, acting as a NES, and dissipated therein.

Methodology

Two port methodology with respect to scattering matrix theory is used for different experimental measurements, furthermore the X-Parameters technique is studied in nonlinear acoustics network. Sound pressure, waveform photographs, particle velocity profiles, and spectra would be obtained at a number of locations in the duct for several different configurations. The interest parameters to evaluate the NES occurrence would be the pressure along the duct with respect to reference signal of loudspeaker and the phase shift in velocity profile at a certain point. Possible theoretical explanations for the effect will be presented along with the experimental data and conclusion such as, in order to observe membrane as a NES, it is necessary that the membrane is exited with sufficient "Energy", will be discussed. The studies performed will be both experimental and analytical, with a certain prevalence of the experiments. It will consist of fundamentals of theoretical and applied acoustics, with emphasis on wave decomposition methods and multi-port systems. Beside it deals with non-linear oscillation and, in general, with non-linear dynamical systems [4].

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