PhD: Multi-scale time passive control of acoustic waves using chains of nonlinear resonators

Laboratories: LTDS – LAMCOS
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In acoustics, several solutions are usually used to perform passive attenuation of noise. They mainly consist of using porous materials (foams or multi-layered systems), viscoelastic materials and resonators. Porous materials are efficient for high frequencies, because they stay in viscous regimes for lower frequencies [1]. In order to obtain sound absorption at lower frequencies, resonators such as Helmholtz Resonators (HR) are often used [2]. However, they are only efficient for a specific frequency in a narrow frequency range. Studying nonlinear behaviors of a Helmholtz resonator (HR) in nonlinear regimes was carried out by Alamo Vargas et al [3] showing that these types of resonators with nonlinear behaviors can be exploited for control to enhance the frequency range of efficiency. Later on Gourdon et al [4] coupled the same resonator to an acoustical mode for having a targeted energy transfer phenomenon from the acoustical mode to the resonator. The idea of the PhD thesis is to create an array of such resonators in series for controlling acoustical mode(s) in the nonlinear domain. The coupling between several resonators will be carried out via an interaction potential while each can be subject to global potentials as well.
The overall goal of the PhD subject is analytical developments for tracing behaviors of a chain of acoustical resonators with local or interaction potentials using multiple scale method and stability analysis. Analytical developments should be validated by numerical tools and potential experimental results.

Such direction of research is original. Existing works consider similar problems with different approaches: see for example [11],[12]. The focus is on analysis and benefits of nonlinear effects, but not clearly design. Or the focus is to analyze transition from discrete nonlinear oscillators to continuous modeling and nonlinear waves analysis.

Analytical developments:
The existence of different types of responses (nonlinear modes, breathers, traveling waves) and their stability will be studied. Derivation using a multiscale expansion of an amplitude equation describing the nonlinear modulation of unidirectional wavetrains will be carried out to interpret simulations.
The system can be treated in discrete domain [5] ending to evaluations of a continuous system [6] and its behaviors.

Numerical developments:
Developed [7-8] or adopted [9] numerical tools such as continuation or shooting techniques will be exploited. All equilibrium points and their stabilities including the detection of Neimark-Sacker bifurcations will be carried out. Such numerical developments have already been initiated by the supervisors of the proposed PhD subject in the framework of the PhD thesis of Grenat [10]. They need to be consolidated and adapted to large scale arrays of resonators.

Experimental developments.
An array of HR with nonlinear behaviors will be designed via tools developed in previous steps and will be fabricated with the 3D-printing facilities of the LTDS team in ENTPE (ProJet 3510SD of 3D Systems Europe Ltd.). The chain will be coupled to an acoustical mode to study experimentally the passive noise control of the mode.

Other aspects and remarks

a) Supervision of the PhD:
b) The PhD will be co-supervised by C.H. Lamarque and S. Baguet, with the support of E. Gourdon, A. Ture Savadkoohi and R. Dufour. Neither C.H. Lamarque (HDR) nor S. Baguet previously supervised a PhD student with financial support of CeLyA.

b) This PhD will permit to strengthen an ERC candidature (by a member of the LTDS) around a scientific breakthrough : the use of nonlinear dynamics to control noise via passive non linear absorbers and especially the role of Neimark-Sacker bifurcations in energy exchanges between multiple states of slow invariant manifolds for fast-slow time scales systems [5-6], and applications in vibro-acoustics.

c) The PhD topic is in the scientific scopes of CeLyA: the aim of the PhD is to design nonlinear absorbers to control the effect of noise sources; modeling, analytical and numerical studies will provide a general methodology for the design of energy exchanges. The aimed experimental development will provide a proof of concept of possible noise mitigation.

d) The PhD subject will consolidate the ongoing collaborations between LTDS and LAMCOS and facilitate the preparation of further collaborations between other members such as A. Ture Savadkoohi, E. Gourdon and S. Baguet.

e) We have potentially several good candidates interested by the PhD.

f) This PhD will be provide a fundamental support to a CIFRE PhD in the frame of OpenLab VAT@Lyon with Peugeot (PCA).

g) A PhD committee will be proposed: R. Dufour (LaMCoS), E. Gourdon and A. Ture Savadkoohi (LTDS).

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