PhD position - Univ. Lyon - LabEx CeLyA

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

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1 Global objective and hypotheses

In acoustics, several solutions are usually used to perform passive attenuation of noise. They mainly consist in 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 in order to have 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 resonator can be subject to global potentials as well. The overall goal of the PhD subject consists in analytical developments for tracking 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 a direction of research is original. Existing works consider similar problems with different approaches: see for example [11-12]. In these works, the focus is on analysis and benefits of nonlinear effects but not clearly design, or on the transition from discrete nonlinear oscillators to continuous modeling and nonlinear waves analysis.

2 Different steps of the project

2.1 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.

2.2 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.

2.3 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.

3 References

[1] Allard, J. et N. Atalla. 2009, «Propagation of sound in porous media :Modelling sound absorbing materials»,Wiley, New York.

[2] Helmholtz H.V.: Die Lehre von den Tonempfindungen als physiologische Grundlagefur die Theorie der Musik. Braunschweig, Druck und Verlag von Friedrich Vieweg und Sons, Germany (1863).

[3] Allard, J. et N. Atalla. 2009, «Propagation of sound in porous media :Modelling sound absorbing materials»,Wiley, New York.

[4] Helmholtz H.V.: Die Lehre von den Tonempfindungen als physiologische Grundlagefur die Theorie der Musik. Braunschweig, Druck und Verlag von Friedrich Vieweg und Sons, Germany (1863).

[5] Alamo Vargas, V., Gourdon, E., Ture Savadkoohi, A., Nonlinear softening and hardening behavior in Helmholtz resonators for nonlinear regimes, Nonlinear Dynamics 91(1), pp. 217-231, 2018.

[6] Gourdon, E., Ture Savadkoohi, A., Alamo Vargas, V., Targeted energy transfer from one acoustical mode to an helmholtz resonator with nonlinear behavior, Journal of Vibration and Acoustics, 140(6), 061005, 2018.

[7] Charlemagne, S., Lamarque, C.-H., Ture Savadkoohi, A., Vibratory control of a linear system by addition of a chain of nonlinear oscillators, Acta Mechanica 228(9), pp. 3111-3133, 2017.

[8] Charlemagne, S., Ture Savadkoohi, A., Lamarque, C.-H., Dynamics of a linear system coupled to a chain of light nonlinear oscillators analyzed through a continuous approximation, Physica D: Nonlinear Phenomena 374-375, pp. 10-20, 2018

[9] Xie, L., Baguet, S., Prabel, B., Dufour, R., Bifurcation tracking by Harmonic Balance Method for performance tuning of nonlinear dynamical systems, Mechanical Systems and Signal Processing 88, pp. 445-461, 2017

[10] Baguet, S., Cochelin, B., On the behaviour of the ANM continuation in the presence of bifurcations, Communications in Numerical Methods in Engineering 19(6), pp. 459-471, 2003

[11] MANLAB, An interactive path-following and bifurcation analysis software, MANLAB v4.0, 2018.

[12] C. Grenat, Nonlinear Normal Modes and multi-parametric continuation of bifurcations: application to vibration absorbers and architectured MEMS sensors for mass detection, PhD thesis, Directors: R. Dufour , S. Baguet, C.-H. Lamarque, October 2018. INSA Lyon.

[13] Stéphane Griffiths, Benoit Nennig, Stéphane Job. Porogranular materials composed of elastic Helmholtz resonators for acoustic wave absorption. Journal of the Acoustical Society of America, Acoustical Society of America, 2017, 141 (1), pp.254-264.

[14] N. Sugimoto, Propagation of nonlinear acoustic waves in a tunnel with an array of Helmholtz resonators, J . Fluid Mech. (1992), vol. 244, p5 55-78.

4 Key Responsibilities

Main responsibilities of the PhD student are to

- Conduct literature searches and reviews.
- Plan and carry out research in accordance with the project aims.
- Generate and display the results and interpret their physical implications.
- Develop efficient reduced order modelling methods for nonlinear dynamics.
- Investigate reduced order modelling for nonlinear oscillations and bifurcation analysis
- Develop appropriate numerical codes to study exact models and track Neimark-Sacker bifurcations
- Apply the previous developments to a physical model (acoustical model). Prepare and realize experiments.
- Present research findings to colleagues and at conferences.
- Any other duties commensurate with the post as directed by the line manager.
- Observe and comply with all University of Lyon policies and regulations, including the key policies and procedures on Confidentiality, Conflict of Interest, Data Protection, Equal Opportunities, Financial Regulations, Health and Safety, Information Technology.

Job descriptions cannot be exhaustive and the post-holder may be required to undertake other duties, which are broadly in line with the above key responsibilities.

5 Requirement

- Master degree in mechanics (Mechanical or aerospace or civil engineering) or in Applied Mathematics in the domain of nonlinear dynamics or acoustics.
- Programming skills in Matlab® and Mathematica® or Maple®
- Good level in English.
- Background on experimental testing techniques are appreciated.

6 Work place

Université de Lyon, ENTPE, Laboratoire de Tribologie et Dynamique des Systèmes (LTDS), UMR CNRS 5513, rue Maurice Audin, F-69518 Vaulx en Velin, France

7 Approximate remuneration

Net remuneration: 1415 euro net /month

8 DEADLINE for applying:

November, 30th, 2018.

9 Contact and Supervisors

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