Research project (Postdoc)

Project title: Design and experimental implementation of a periodic nonlinear vibration energy harvester

Project team

Noureddine BOUHADDI, Full Professor, University Bourgogne Franche-Comté

Najib KACEM, Associate Professor, University Bourgogne Franche-Comté

Laboratory: FEMTO-ST Institut – Department of Applied Mechanics, 25000 Besançon
Salary: About 2 350 € /month (subject to funding availability)
Duration: 12 months
Contract start date: September 2017

Description of the project

The mechanical structures are subjected to ambient and internal vibrations, which could be exploited to produce energy by using suitable transducers, which convert the mechanical energy into electrical energy. The energy produced in these cases can be stored and used in low-energy consuming applications for which autonomy is a priority regardless of the external conditions in which these structures are located. This energy harvesting approach is suitable to small-scale smart systems such as wireless sensor networks or portable embedded systems for various applications such as monitoring, diagnosis and control in the fields of urban transport, aeronautics, biomedical, environment…

Vibration Energy Harvesters (VEHs) are generally designed and optimized for frequencies that correspond to those of the excitation. These resonators possess low damping, which causes a great loss of the harvested electrical power as soon as a slight deviation of the excitation frequency from the resonant one occurs. To overcome this issue, it has been shown in the literature [1-3] and in the research activities of the Department of Applied Mechanics (DAM) [4] that the introduction of nonlinearities significantly improves the frequency bandwidth and the harvested power.

On the other hand, the collective dynamics of periodic structures offer interesting properties in terms of modal interactions, multi-stability and energy localization, and this has been theoretically demonstrated in recent studies carried out in DAM [5]. These properties induce a substantial widening of the useful frequency bandwidth and increase the harvested power.

As part of an engineering project [6], a prototype laboratory was set up to verify the physical phenomena involved and to reinforce the knowledge of the outstanding characteristics of a 1-Dof and 2-Dofs VEHs based on magnetic levitation, namely: resonance frequencies, mechanical and electrical modal damping, frequency responses, critical resistance limiting the linear and non-linear domains, optimal load resistance which maximizes the harvested power, the frequency matching of the two eigenmodes which increases the bandwidth. Also, a numerical model has been developed, which is useful for the design phase of the prototype. From a functionalization point of view, the equivalent stiffnesses created by the magnetic forces are linear and nonlinear. These stiffnesses can be identified experimentally and introduced into the nonlinear dynamic behavior prediction model.

The experimental work carried out has mainly shown the feasibility of the vibration energy harvesting approach using an array of levitated magnets. It has also demonstrated the role of the magnetic coupling and frequency matching in improving the VEH performances in terms of frequency bandwidth and harvested energy.

At this stage of the project and in order to achieve successfully a broadband vibration energy harvester prototype, the following tasks will be accomplished:

- Experimental implementation of an array of coupled levitated magnets (AA battery size) under harmonic base excitation.
- Design and implementation of the transduction circuit of the VEH.
- Model validation/calibration.
- Optimization of the VEH performances (harvested power, frequency bandwidth, prototype size).
- Modeling and characterization of the VEH under random excitation.

References

[1] B. Mann, N. Sims, Energy harvesting from the nonlinear oscillations of magnetic levitation, Journal of Sound and Vibration, 319 (12) 515 – 530, 2009.

[2] M. H. Arafa, "Multi-modal vibration energy harvesting using a trapezoidal plate. Journal of Vibration and Acoustics, 134(4):041010, 2012.

[3] G. Sebald, H. Kuwano, D. Guyomar and B. Ducharne, Simulation of a Duffing oscillator for broad band piezoelectric energy harvesting. Smart Materials and Structures, 20(7):075022, 2011.

[4] S. Mahmoudi S., N. Kacem and N. Bouhaddi, Enhancement of the performance of a hybrid nonlinear vibration energy harvester based on piezoelectric and electromagnetic transductions. Smart Materials and Structures, 23(7):075024, 2014.

[5] I. Abed, N. Kacem, M. L. Bouazizi and N. Bouhaddi, Multi-modal vibration energy harvesting approach based on nonlinear oscillator arrays under magnetic levitation. Smart Materials and Structures, 25(2):025018, 2016.

[6] Mise en œuvre expérimentale d'un récupérateur d'énergie multimodale basé sur un réseau d'aimant en lévitation, projet de fin d'études, Ecole Polytechnique de Tunisie, Septembre 2016.

Candidate profile

The candidate should have a PhD degree in applied mechanics, physics or engineering sciences. He/she has to prove his/her relevant skills in the following disciplines: energy harvesting, nonlinear dynamics, Instrumentation and vibration experiments. A disposition for experimental work is required. Proficiency in English is important.

Application

The application consists of ONE pdf-file comprising:

- Curriculum Vitae with list of publications
- Short summary of the PhD thesis
- Suggestion of two referees with contact details
- Provide detailed explanation justifying your choice for this project

Contacts

Noureddine BOUHADDI, phone: (+33)381666056, E-mail: noureddine.bouhaddi@univ-fcomte.fr

Najib KACEM, phone: (+33)381666702, E-mail: najib.kacem@univ-fcomte.fr