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Extended Abstract

Design, Simulation, Construction and Characterization of a Vibrant Magnetic Structure for its Use in Magnetostrictive Energy Harvesters

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I. Introduction

Most industrial processes often generate vibrations at relatively low frequencies, around 100 Hz [1]. These vibrations can be harnessed to generate green electrical energy through vibration harvesters, being piezoelectric ones the most commonly used. However, at this frequency interval, these devices display the disadvantage of requiring a larger size as the vibration frequency reduces. This study aims to design and optimize, based upon mechanical criteria, a U-shaped vibrant magnetic structure to be employed as the core of a magnetostrictive harvester, offering an alternative to substitute piezoelectric ones in low-frequency industrial applications.

The importance of the analysis relies on the fact that the performance of the harvester highly depends on the mechanical properties of the vibrant structure and on the design parameters, fundamentally: the resonance frequency, the stresses, and the displacement amplitudes under vibration. Their enhancement enables the design of a low resonance frequency, compact, long-lasting and cheap device whose features will permit the massive application to industrial processes and even at remote locations.

II. Harvester Design and Simulation

In a magnetostrictive vibration energy harvester electrical energy is obtained when the ambient vibrations from the source are transmitted to the magnetostrictive material (Galfenol in this case). This active material undergoes variable mechanical stresses, generating a varying magnetic flux through the collecting coil due to the coupling of stresses and the magnetic field governed by the Villari effect. Device losses, in the form of heat, occur due to damping, hysteresis, eddy currents and wiring resistance.

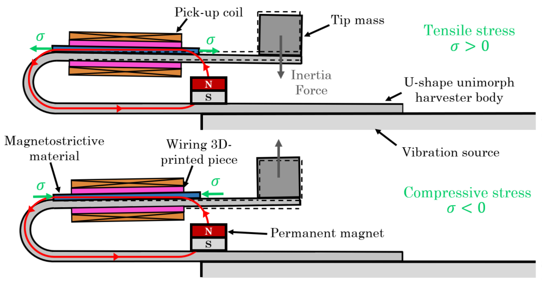

Figure 1. U-shaped harvester configuration proposed by Ueno in [2].

Among the different configurations, the bending-type U-shaped harvester proposed by Ueno in [2] was chosen for its low cost and high performance. The designed structure is built from a 0.5 mm thickness gray cast iron plate with dimensions 4×88.4 mm, bent in such a way that the length of the device is 5 cm. These dimensions were obtained from an iterative static and dynamic simulation process in MATLAB® to obtain the first frequency mode at around 100 Hz, while maximizing the stresses where the 20×4×0.5 mm as-cast Galfenol sheet is located.

III. Results and Discussion

A first prototype was built and characterized by measuring resonance frequency, ω_0, and amplitude of vibration, X_0, controlling the source of ambient vibrations.

Table I shows the results obtained for different configurations, by adding elements of the harvester to the magnetic structure. It is observed that the resonance frequency can be easily modified by changing the tip mass.

TABLE I. Comparison at 0.1 mm Constant Shaker Amplitude

Setup	No Galfenol sheet and 3D-printed piece	With Galfenol sheet and 3D-printed piece	With extra 2.1972 g tip mass
ω_0 (Hz)	113	111.5	56
X_0 (mm)	3.48	5.02	0.71

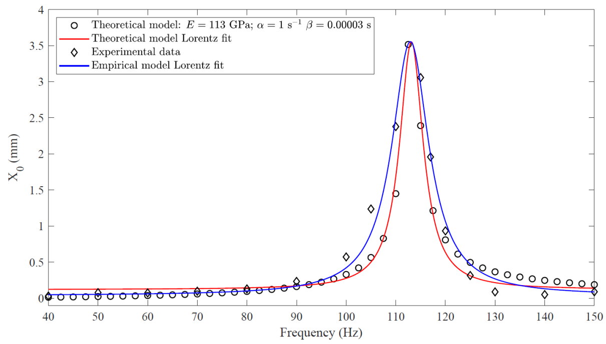

Figure 2. Comparison of simulation and empirical results.

IV. Conclusions

In conclusion, a low-cost, compact, and durable magnetic vibrant structure was designed from the initial proposal of Ueno in [2]. Through MATLAB® static and dynamic simulations, the design was optimized and validated in terms of resonance frequency, stresses, and displacements. Experimental characterization of the prototype confirmed its excellent resonance frequency tuning capabilities, which could enhance the harvester's performance in various applications. Finally, theoretical predictions aligned well with empirical data, providing an accurate estimation model of the harvester's features prior to construction.

References

[1] L. Tang, Y. Yang, and C. K. Soh, "Toward Broadband Vibration-based Energy Harvesting," *Journal of Intelligent Material Systems and Structures*, vol. 21, pp. 1867–1897, Dec. 2010.

[2] T. Ueno, "Magnetostrictive low-cost high-performance vibration power generator," *Journal of Physics Conference Series*, vol. 1052, no.1, p. 012075, Jul. 2018.