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Nonlinear Dynamics of a 2DOF Magneto-Mechanical Harvester

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Abstract: The nonlinear dynamics of a two-degree-of-freedom (2DOF) magneto-mechanical harvester based on magnetic levitation is modelled and investigated. The equations of motions have been derived while taking into account the magnetic nonlinearity. The experimental relationship of magnetic forces versus the distance between the magnets was determined. Based on these dependencies a strongly nonlinear model of a system with two degrees of freedom was proposed. Finally, the obtained results allowed the determination of nonlinear effects in the investigated system.

Keywords: energy harvesting, magnetic suspension, nonlinearity,

1. Introduction

Magnetic levitation systems have practical importance in many engineering systems. In our previous research, the investigations of a system with one degree of freedom for energy harvesting were presented. Inspiring by [1,2] where the model with one movable magnet between two fixed magnets and inside the coil was presented. Properties of this model were determined from analytical analysis and they were experimentally verified. The obtained results confirmed the existence of nonlinear effects such as bifurcations, amplitude jumps, multistability. Whereas, in the article [3], the interaction between mechanical and electrical was analysed. The obtained results show that the nonlinear resonance and recovered energy can be controlled by the simple configuration of the magnet coil position.

The presented research is a continuation of our previous works. An extension of magnetic levitation for a multi-degree of freedom vibration harvester is proposed. The new concept composed of two levitating magnets is proposed. An additional magnet is introduced to investigate the possibility of increasing the level of energy recovery.

2. Results and Discussion

Fig. 1(a) shows a photo and scheme of the prototype 2DOF harvester. The two identical cylindrical magnets denote A_1 and A_2 are mounted in the tube and experience magnetic levitation. All magnets are placed vertically and have the same magnet orientation (repulsion). Outside the tube, two identical coils are connected. When the harvester is subjected to external excitation, the moving magnets oscillate around their equilibrium state, and the current is induced in both electrical circuits.

The restoring forces were determined from the experiment tests. Top Fig. 1(b) shows the nonlinear relation between the magnets moving magnet A_1 and the fixed magnets B_1-B_2. Because the moving magnets are identical, the same characteristic is obtained for the second moving magnet A_2. As we can see this characteristic is strongly nonlinear and similar to the Duffing model. The restoring force between the two moving magnets at the bottom of Fig. 1(b) is shown. This relation is also strongly nonlinear.

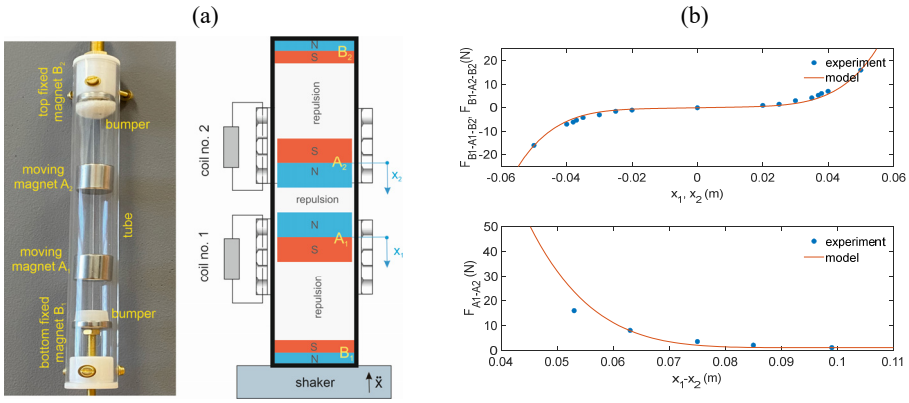

Fig. 1. Photo and scheme of 2DOF magnetic levitation harvester (a) and exemplary induced current during the moving magnet with constant velocity (b).

The experimental measured repulsion force-displacement relations were approximated by the polynomial functions using a least-squares regression method. Polynomial fit is often used due to its simplicity and easy numerical application. The analytical models for magnetic interaction were developed and integrated into the equations of motion directly to simulate the dynamic behaviour of energy harvester configurations.

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