Influences of System Parameters on Energy Harvesting from Autoparametric Absorber. Experimental Research

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Abstract

In the paper an experimental analysis of an autoparametric system dedicated to vibration suppression and energy recovery is presented. The main part is an electromagnetic energy harvester. Its properties were defined by quasi static and dynamic tests. The obtained results show influence of selected parameters on energy recovery level. The experimentally identification of electromechanical coupling coefficient which couples mechanical and electrical systems is done.

Keywords: Non-linear autoparametric system, Energy harvester, Experimental research, Magnetic levitation

1. Introduction

In practice application of magnet and coil systems are often used in harvester construction. For example, Malaji and Ali [1] propose a concept in which the magnet is attached to the pendulum end. Both elements move together relative to the coil, which is mounted as the separated part. The similar concept is presented in the paper [2], where author presents a solution of the coil mounted on the pendulum tube. A movable magnet moves inside the tube and the coil and induced energy. This efficiency of the harvester device was studies numerically and experimentally in papers [2, 3]. The harvester application has fewer restrictions and can be used in the real object, for example mounted on existing nonlinear vibration absorbers in high buildings.

The paper presents preliminary experimental results of the magnetic levitation (maglev) harvester. The work is divided into two parts: the static (quasi-static) and the dynamic tests. The obtained results show, that coupling coefficient strongly depends on the magnet's position in the coil. In literature this coefficient usually assumed as a constant [2, 4].

2. Experimental setup

The experimental study has been made on a laboratory rig at the Lublin University of Technology (LUT) in the Department of Applied Mechanics. A scheme and general view of the real apparatuses in Fig. 1(a) and 1(b) is shown. This laboratory system consists of three main subsystems:

- the nonlinear oscillator (damped mass),
- the pendulum (vibration absorber),
- the energy harvester (maglev system) with the electrical circuit.

The system has three mechanical degree (x, φ and r) and one electrical (i) degrees of freedom. In this section more information about construction of energy harvester is presented (Fig. 1(c)).

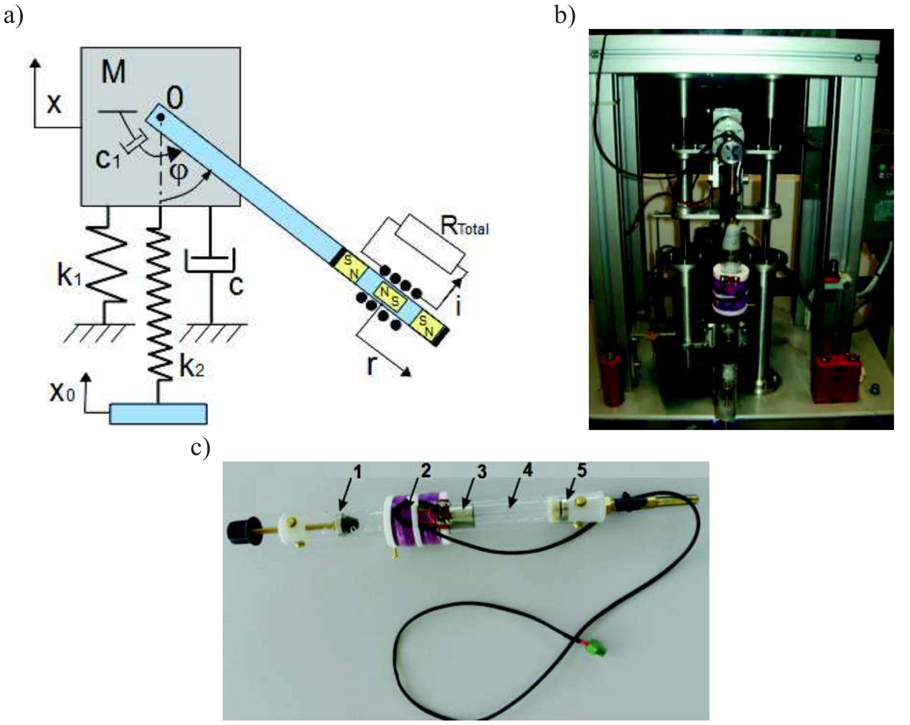


Figure 1. An autoparametric vibration absorber: scheme (a), a photo of the laboratory rig (b), and maglev harvester (c). The elements of harvester are: 1- lower fixed magnet, 2- coil, 3- movable magnet, 4- neutral magnetic tube, 5- top fixed magnet

The energy maglev harvester consists of the movable levitating magnet (3), which moves inside the coil (2). The motion of this magnet generate current flow i in the coil electrical circuit with the resistor (R_{Total}). The initial position of the movable magnet is determined by magnetic levitation suspension. It levitates between two fixed magnets (no. 1 and no. 5). The electrical circuit is provided with a receiver (resistor) and measurement system to recorder current, voltage and power of generated electrical signal. The tube of the pendulum (4) is made of non-magnetic material. The all parameters of electromagnetic harvester are listened in Table 1.

Table 1. Parameters of energy harvester.

Description of parameter	Unit	Value
Height of movable magnet	mm	35
Diameter of movable magnet	mm	20
Mass of movable magnet	g	98
Length of coil	mm	50
Coil resistance	Ω	1150
Coil inductance	H	1460e-3
Wire diameter	mm	0.14
Turn of winding	-	12740
Total length of tube	mm	340
Mass of tube with two fixed magnets	g	350

2. Experimental results. Static test

The first stage of experimental analysis was the quasi-static test. During this analysis, the tube, the coil with electrical equipment and the movable magnet mounted in the machine SHIMADZU (Fig. 2(a)) were used. The magnet was connected by a wooden rod with the upper handle, which is moved to a triangular signal (Fig. 2(b)). The handle moves with constant velocity ±500mm/min. The resistance of the receiver can be changed, set on a desired level.

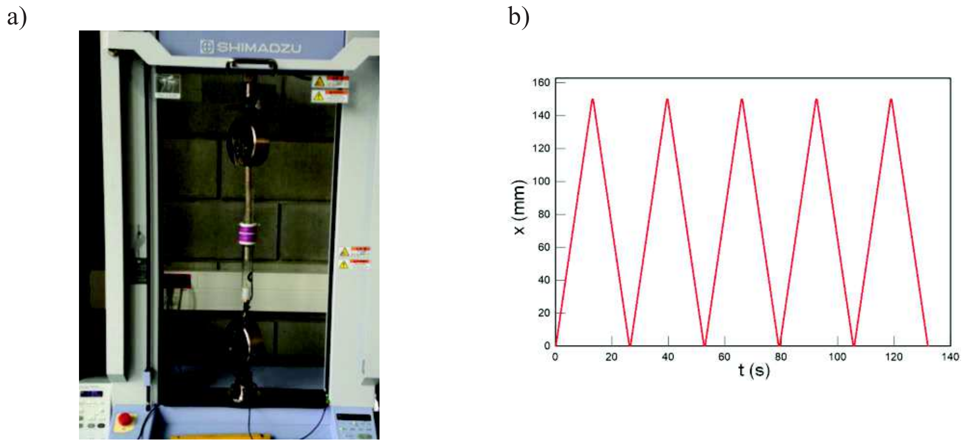


Figure 2. The system view for static tests (a), a displacement of an upper handle (b)

Tests were made for the three different values of receiver resistance (R=1.15kΩ, R=4kΩ and R=6kΩ). The obtained in Fig. 3 are shown. The coordinate r describes the distance from the coil center to center of the movable magnet. We can see, that the maximum current is generated when a center of the magnet is located on the end of the coil (r=±25mm). Generally, with increased resistance the values of the current flowing in the electrical circuit decreases.

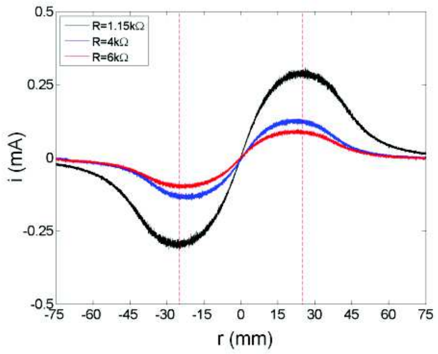
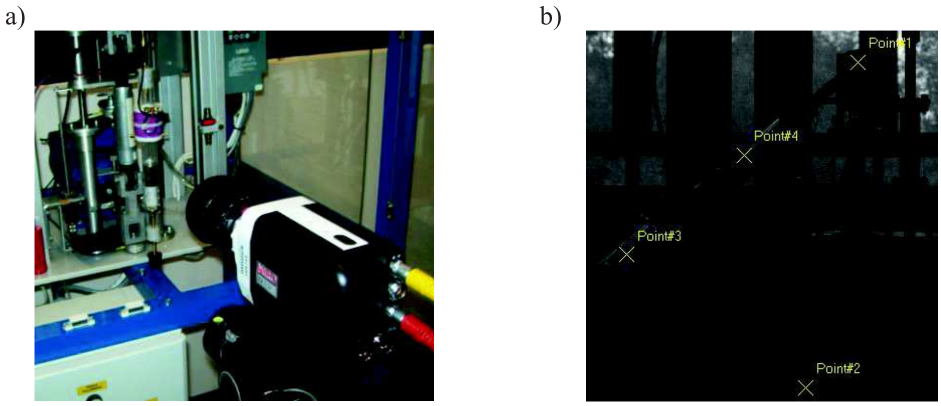


Figure 3. Experimental results: current versus magnet position from the static tests

3. Experimental results. Dynamic test

The second stage of experimental study was the dynamic tests. Research was made on the complete experimental rig. The relative motion of movable magnet was measured by the high speed camera MIRO 120 (Fig. 4(a)). The mechanical responses r and $\dot{r}$ were determined from the video information using TEMA software (Fig. 4(b)). The exemplary results are shown in Fig. 5. These signals were compared with the measured current i (Fig. 6).


a)

b)

Figure 4. Photo during experiment test (a) and single picture with traced points from TEMA software (b)

Generally in literature [2, 4], the electromechanical coupling coefficient α can be assumed as the constant parameter. Their value depends on the construction of energy harvester. The electrical properties of the tested system can be written in the standard simple Kirchhoff law

$$L_{Coil}\dot{i} + R_{Total}i = a(r,\dot{r})\dot{r} \tag{1}$$

Based on the obtained results it is possible to determine values of the coupling coefficient α. Equation (1) was transformed to following form

$$a(r,\dot{r}) = (L_{Coil}\dot{i} + R_{Total}i)/\dot{r} \tag{2}$$

After a simple numerical calculations, the curve α=*f(r)* was prepared (Fig. 7).

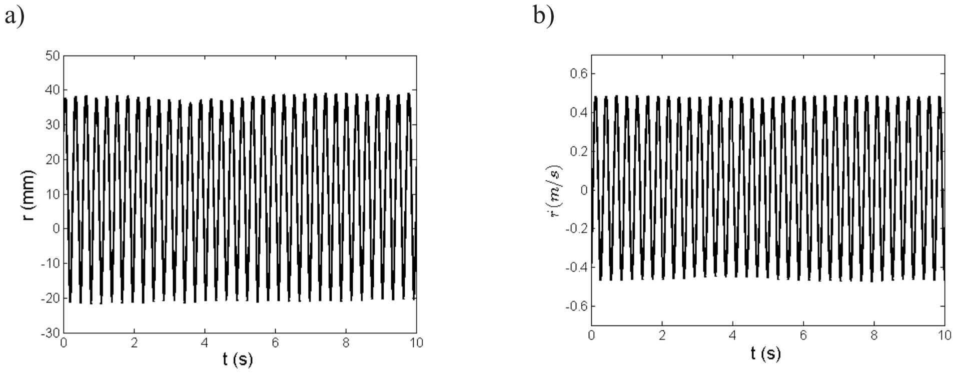


Figure 5. Experimental time series of the relative displacement r (a) and velocity $\dot{r}$ (b)

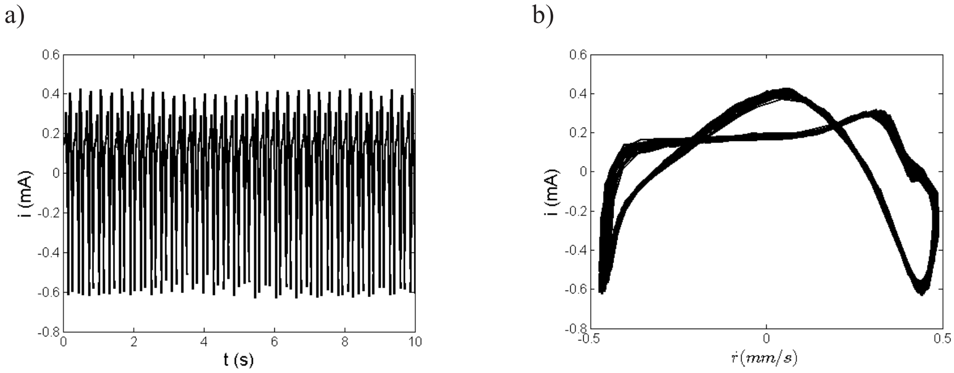


Figure 6. Time series of current *i* (a) and the phase portrait current - relative velocity (b)

The obtained experimental coupling coefficient results show that α value is not constant. The value depends on the distance from the coil center to center of the movable magnet, it is function of the coordinate *r*.

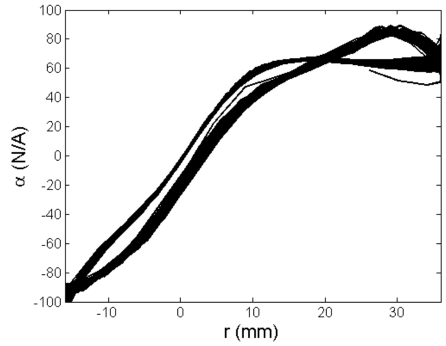


Figure 7. The experimental coupling coefficient characteristics

3. Conclusions

The paper presents experimental analysis of the selected electrical parameters in recovered current. The most important observation from the static and the dynamic tests is to detect a relationship between the electromechanical coupling $L_{Coil}\dot{i} + R_{Total}i$ coefficients α and the coordinate r. In future research will be planned to determine an empirical form of a new model of the coupling coefficient.

Acknowledgments

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