2021 16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

# Modelling of an Electromechanical Coupling in Magnetic Levitation Energy Harvester

KRZYSZTOF KECIK[1*], ANDRZEJ MITURA[2]

1. Department of Applied Mechanics, Lublin University of Technology, Poland [0000-0001-8293-6977]
2. Department of Applied Mechanics, Lublin University of Technology, Poland [0000-0002-6749-8232]
* Presenting Author

**Abstract:** This paper concerns the research of electromagnetic energy harvesting consisting of a moving magnet in a specially designed coil consisting of four modules. The electromechanical coupling is modelled by different configurations of the coil. The voltage induced from the interaction between the coil modules differs from the case of a classic single coil. First, the electromechanical coupling models are validated by a free fall test. Then, performances of the harvester are simulated and tested. The obtained results show that the proper configuration of each coil module allows modifying the shape of the electromechanical coupling and the increase of energy harvesting efficiency.

**Keywords:** electromechanical coupling, energy harvesting, magnetic levitation, multi-segments coil

## 1. Introduction

Vibration energy harvesters have been expected to be a promising way to solve the energy supply problem for small sensors and MEMS devices. The vibration harvester can convert mechanical energy into electrical energy and has gained much attention in recent years because of the rapid development of systems with low power consumption. The electromagnetic harvester generates electrical power through Faraday's law of induction and induced electromotive force [1]. This force is produced in the coil when it cuts through the magnetic field generated by the moving magnets.

The power density of electromagnetic harvesters can vary depending on the size and coupling (called electromechanical) between the mechanical and electrical components. Therefore, the amount of electricity depends upon the strength of the magnetic field, the velocity of the relative motion between the magnet and coil, and the number of turns of the coil. These harvesters are usually designed for micro and macro scales and the operating frequency range can vary from a few hertz to a couple of hundred hertz.

Electromechanical coupling is defined as the ability to convert mechanical energy into electrical energy. It is mainly studied using the analytical approach and assumed as the constant value due to the small magnet's oscillations leading to the fixed electrical damping [2]. However, as shown in [3] the electromechanical coupling is a strongly nonlinear function. For this, the electromechanical coupling coefficient can be modelled as a function of the magnet position of the coil at any instant.

A promising solution for low-frequency energy harvesting is the development of magnetic levitation systems. This paper presents an analysis of a prototype magnetic levitation harvester with a specially designed coil that consists of four independent coil segments. This is to control the profile of magnetic field variation in the region of the coil movement. Finally, an increase in energy recovery effectiveness is expected.

## 2. Results and Discussion

Fig. 1(a) shows the design of a vibration-based energy harvester consisting of a single moving permanent cylindrical magnet placing it in a repelling configuration between two stationary ring magnets in a tube. On the tube, a specially designed solenoid coil consisting of four connected in series coil segments is wrapped. Each of the modules can be activated separately or together.

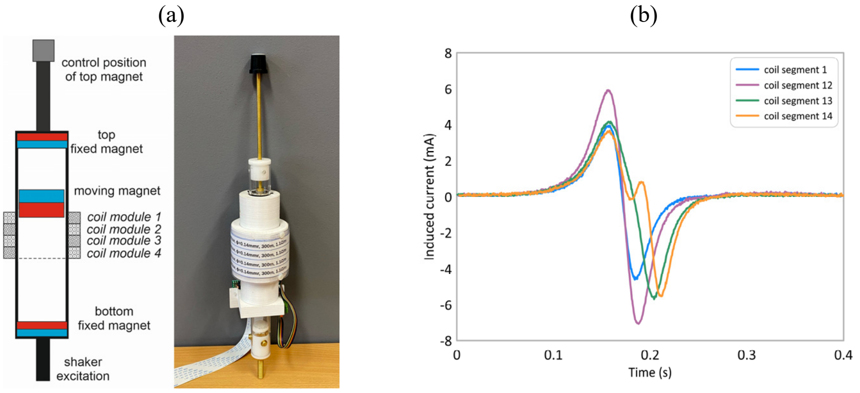


**Fig. 1.** Scheme and photo of the electromagnetic harvester with modular coil (a) and induced current across versus time for the free fall test and different configuration of coils (b).

Fig. 1(b) shows the result of a free fall test. A simple way to do this is to drop a magnet through a coil. A magnet was released from an initial distance of 0.06m for different combinations of active coil modules. The measured voltage has been obtained from the module combinations: 1, 1:2, 1:3 and 1:4. As we can see, the voltage induced from the interaction between the magnet and coils differs significantly from the case of a single active coil.

## 3. Concluding Remarks

The obtained results show that the proper configuration of the coil allows to modify of the induced current as well as the electromechanical coupling function. This electromechanical coupling function can be moving, expanded and significantly modified. Interestingly, for some configurations additional peaks close to the coil centre are observed.

## Acknowledgment:
The research was financed in the framework of the project: *Theoretical–experimental analysis possibility of electromechanical couplings shaping in energy harvesting systems*'', no. DEC-2019/35/B/ST8/01068, funded by the National Science Centre, Poland.

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