

Planar Coils Made in the Thick-Film and LTCC Technology For the Electromagnetic Microgenerator

Miroslaw Gierczak, Andrzej Dzedzic
 Wrocław University of Science and Technology,
 27 Wybrzeże Stanisława Wyspiańskiego st.
 50-370 Wrocław

Summary:

This study presents the structure of silver planar coils made by thick-film and LTCC technology. These coils were used along with magnets as the basic elements included in a rotary electromagnetic micro-generator. The fabricated microgenerator has been fully characterized. Results and conclusions will be presented in the paper, along with the further research direction.

Keywords: coils, thick-film, LTCC, electromagnetic microgenerator, 3D printing

Background, Motivation and Objective

Developments in electronics are driving electronic devices into more areas of our lives. In recent years, for example, rapidly developing industrial automation (Industry 4.0), wearable electronics, or the Internet of Things (IoT) are generating increased demand for electricity for mobile devices. With the miniaturization of circuits, there is a need to miniaturize their power sources while deviating from conventional solutions. Typical means of power supply, such as commonly used batteries, have finite energy resources, limited lifespans and contain environmentally dangerous chemicals. In addition, they are characterized by their significant size relative to currently manufactured devices. Conventional batteries are being replaced by autonomous, miniature systems that enable the extraction of electricity from the environment [1], such as from wind, hydropower, solar energy, electromagnetic waves, vibration or heat.

Technological progress has reduced the power consumption of sensors, actuators and other components of microcircuits and microsystems. As a result, such low-power systems have become potential consumers of energy recovered from the environment. Therefore, the devices become maintenance-free, which benefits the environment due to the reduction of chemical waste from batteries. Various methods of energy harvesting have been studied for many years [2, 3]. The research focuses on reducing size and weight, increasing the surface or volume power density, and reducing environmental harm.

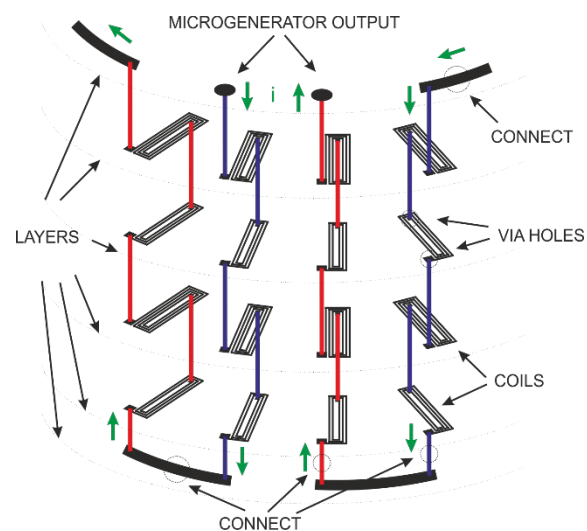


Fig. 1. Connection method.

Description of the Methodology

Electromagnetic microgenerators consisting of a disc with magnets and a coil structure with an outer diameter of 50 mm were designed and fabricated. The magnets disc that was placed on the rotating element and the disc was realized using 3D printing technology. This made it possible to place magnets with different geometric dimensions in it. The coil structure was made using Low-Temperature Co-Fired Ceramic technology. As a result, miniaturization of the spatially connected planar coil system was carried out. Twelve 2-, 8-, 10- and 12-layer structures were fabricated using two different sets of coil patterns. The first coil patterns were rectangular in shape, with external dimensions matching those of the magnets. The second designs were more

trapezoidal, allowing for better space management on the substrate. There were 28 coils on each layer, the same number as the magnets on the rotor disc. Thus, the total number of coils in each structure was 56, 224, 280 and 336, respectively. To determine the properties of single coils, single layers with printed inductors were also realized.

A series of calculations, simulations and measurements of electrical properties and parameters were carried out. The geometric properties of the single coils were investigated. The obtained results were then compared with calculated values as well as with the results of computer simulations. Electrical measurements were carried out using a self-designed and partly fabricated measuring system.

Results

The measurement system for the characterization of electromagnetic microgenerators made it possible to generate an alternating magnetic field and to measure the rotational speed of the disc with magnets that generate it. Using an electronic system, electrical measurements of coil structures were carried out. For an 8-layer structure with this particular pattern of coils, printed with DuPont silver paste, the best output performance was obtained: for 11620 rpm, the microgenerator generated 589.91 mW (for a load resistance of 167 Ω). The best solution was found to be a configuration with trapezoidal magnets. The maximum value of the obtained volume power density is 23.13 mW/cm³.

Conclusions

Based on the study, it can be concluded that the optimization of electromagnetic microgenerators should first include the design of a miniature coil structure due to geometric constraints. In the design, special attention should be given to the number of turns of individual coils and their total number in the planned structure. Equally important is their arrangement, i.e. choosing their shape in such a way that they cover as much as possible of the substrate that will be under the influence of an alternating magnetic field. The next element of the microgenerator, the disc with magnets, should be designed with regard to the geometry of the coils so that the surface of the magnets covers as much as possible of a single coil. The last very important parameter is the distance between the two elements - the disc with magnets and the structure of the integrated coils.

With LTCC technology, rotary electromagnetic microgenerators were made, the output parameters of which depend most on the rotational speed of the element generating the alternating magnetic field.

References

- [1] J. Pei, F. Guo, J. Zhang, B. Zhou, Y. Bi, R. Li; Review and analysis of energy harvesting technologies in roadway transportation, *Journal of Cleaner Production*, vol. 288 (2021), art. 125338, 17 s.
- [2] K.V. Selvan, M.S.M. Ali; Micro-scale energy harvesting devices: Review of methodological performances in the last decade, *Renewable and Sustainable Energy Reviews*, vol. 54 (2016), s. 1035-1047.
- [3] H. Pan, L. Qi, Z. Zhang, J. Yan; Kinetic energy harvesting technologies for applications in land transportation: A comprehensive review, *Applied Energy*, vol. 286 (2021), art. 116518, 22 s.

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