Pendulum base 3D printed electromagnetic energy harvester

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Abstract. In this paper we present for the first time results of works on pendulum base energy harvester fabricated by inkjet 3D printing technology. 3D printing is recognising as a technology that can change the word. First results of harvester operation shows that it is possible to harvest energy in this device with maximal generated voltage near 1.8 V. Printing of this harvester take 12 h and material costs are near 15 USD. It seem that it is possible to utilise this device to power supply a wearable sensors network. Also proposed energy harvester can be used as a simple pedometer.

1. Introduction

Pendulum for spring tension is widely use in watches from centuries. Also it is used for electromagnetic (EM) energy generation for watch powering. This kind of energy harvester is based on inertial move of pendulum and electromagnetic energy conversion. Pendulum microgenerators are patented and produced by at least 3 companies (i.e. Seiko, Eta, Kinetron) but theirs solutions are indirect, based on one inductor coil and microgear system. This approach is expensive (involved precision micromechanics processes) and harvested power is low (only for quartz clock powering). Here we propose direct power generation where the pendulum is integrated with magnets. Inductor coils are below pendulum in the generator housing. This kind of generator is simpler, easier to fabricate and power generated is higher.

2. Fabrication

Energy harvesteer is designed in Autodesk Inventor Pro (Autodesk inc, USA) and printed by Projet 3510 printer (3D System, USA) with Visijet M3 Crystal build material and S300 support material. Utilized 3D printing technique can produce microstructures with details dimensions down to 200 um [1]. Printing direction and conditions are optimized to achieve surface roughness of 0.41 um [1]. In previous work we have shown that it is possible to fabricate microfluidics devices [2], lab-on-a-chip [3] and integrated polymer-silicon-glass structures [4]. Recently we presented water turbine with EM harvester with integrated elements fabricated with this method [5].

Presented here device is designed as three parts. First is a disk with mounted inductors coils, second is a pendulum with installed neodymium magnets and the third is a housing. Thanks to 3D printing technology housing can be specially, designed for desired application, in our case as a watch-like devices (fig.1).
Figure 1. Pendulum base energy harvester with described main components: a) computer design, b) physical realization, c) wearable device for smart watch powering.

Presented energy harvester consists of 8 small neodymium magnets (1x3x5 mm$^3$, magnets.eu, Poland), SMD 10 mH small (5x5x4 mm$^3$) inductor coils (Viking NL20JT103, Taiwan) and precision bearings (Grw, Germany). Each output of the inductor is connected to striating bias. Next all of them are connected to a storage capacitor. In the experiment CS20D Gratz bias (Diotec semiconductors, Germany) was used.

External dimensions of the energy harvester are 44 mm in diameter and 11 mm thick (fig 1.). Printed pendulum is moved by centrifugal force related with harvester movement. In the next phase, oscillations are going down until full stop. Schematic movement of the pendulum in relation to coils matrix is shown at fig. 2.

Figure 2. Principle of operation of the harvester
Developed energy harvester is only first part of the wearable system. Typical they consist more elements like: microprocessors, sensors, communication module.

![Scheme of electrical connection of the harvester.](image)

**Figure 3.** Scheme of electrical connection of the harvester.

Presented system with energy harvester can be used in every life aspect were inertial move is present. For example: power source for smart watches, animal monitoring unit, forest monitoring system etc. (fig.4). Thanks to application of 3D printing we have opportunity to fast develop a device and personalized case for it. First results shows that is possible to harvest energy by proposed idea and we suppose that is possible to use this solution as simple pedometer.

![Possible application fields of the developed harvester.](image)

**Figure 4.** Possible application fields of the developed harvester.
3. Results

Power generator was installed in watch-like housing and tested. It was noticed that the pendulum was moving (oscillating) during each step (fig. 4) generating oscillating output voltage. Maximal peak-to-peak voltage amplitude was near 1.8 V. Voltage expired in time. Charging of capacitor was also provided. It was possible to distinguish individual human steps on the base of electric signal.

![Figure 5](image)

Figure 5. Generated voltage: a) for next 3 steps in time function, b) charging voltage of storage capacitor

4. Conclusion

3D printing is a powerful tool for fabrication of presented energy harvester. Described here energy harvester is based on EM energy conversion with rotating pendulum as EM field generator. Standard pendulum base generator are indirect and complicated. Described here configuration is much simpler and utilised additive manufacturing technique. 3D printing is a powerful tool for mechanical components fabrication. Proper work of the harvester was archived. Maximal P-P voltage seems to be high enough to powered small sensors system with wireless communication module.

5. References

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