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Study on Energy Harvesting from Living Environment Using Dynamo with Rotating Vibrator
回転振動体発電を利用した住環境からのエネルギー回生の基礎研究

Toru Haremaki and Mitsutaka Hikita (Kogakuin Univ.)
晴柀　亨、疋田光孝　（工学院大学）

1. Introduction

Electric trains and hybrid vehicles use their motors as dynamos when reducing velocities or braking, which provides high total-energy performances. Besides such large-scale industrial energy saving trends, energy harvesting from our living environment has also been a remarkable movement in recent years. Main stream for the latter is electric power generation from vibrations of objects and temperature differences of human bodies or others. However today's power levels are not so high, that is those from 100 μW to several tens mW, which cannot be widely used in consumer products. On the other hand, unplugged battery charge for electric handy gadgets such as watches, cellular phones, digital cameras, etc. has become a realistic requirement nowadays.

In this paper, we study an energy harvesting device which might provide such high voltage that it can be used as power supply for electric handy gadgets. In our configuration, we exploit both vibration and rotation phenomena of a fan-shape weight whose center is fixed with bearing. Along the fringe of weight several small Neodymium magnets are buried. Two sheets of polyimide multi-layer film where many coils are formed are used to generate electric power. Our proposed small dynamo can be mainly divided into three portions, top high magnetic-permeability (μ) steel plate, middle rotary fan-shape weight and also bottom high magnetic-permeability steel plate. One sheet of polyimide film is arranged between top steel pale and middle weight, while the other is between the weight and bottom steel. We also investigate voltage up-conversion method. In general, power density of magnetic dynamos is larger than other piezoelectric generators, such as PZT, PVDF, etc. But, their generated voltages are rather low due to the lower internal impedances. We examine two up-conversion methods: (1) combining Schottky diodes with capacitors, (2) introducing switches synchronizing with rotating weight.

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am13057@ns.kogakuin.ac.jp

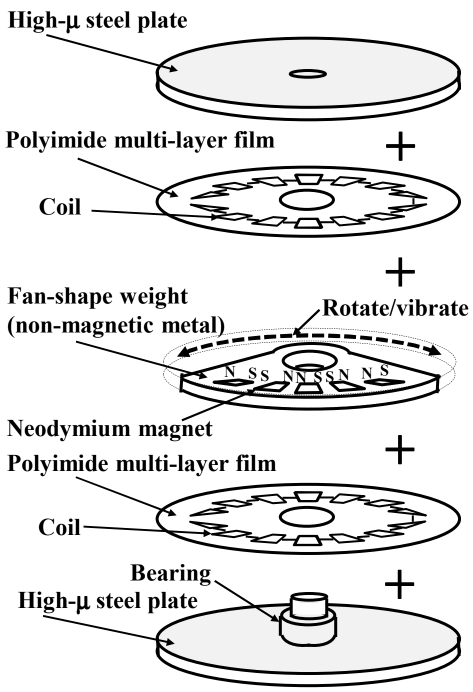
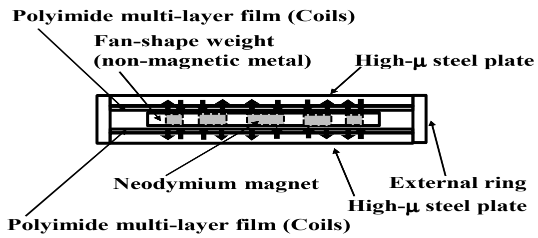
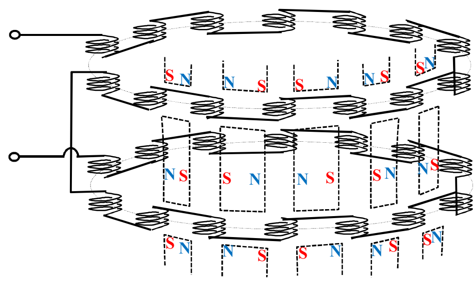


Fig. 1 Each section of proposed small dynamo.



(a) Cross sectional view of dynamo.



(b) Equivalent circuit of dynamo.
Fig. 2 Assembled small dynamo.

2. Proposed configuration using rotating vibrator

Illustrations of assembly for our proposed energy harvesting dynamo using rotating vibrator are shown in Figs. 1. Non-magnetic metals such as aluminum, etc. are used as fan-shape weight. Several Neodymium magnets are buried in the weight, which can rotate and vibrate because of being fixed by a bearing. One sheet of polyimide film including many coils is glued to the top high-μ steel plate, while the other to the bottom plate.

Cross sectional view of an assembled dynamo is illustrated in Fig. 2(a). The top and bottom plates are connected by an external ring. A magnetic flux density, B, from N poles of the Neodymium magnets go through coils to the steel plate and come back to S poles of the Neodymium magnets through coils again. Magnetic flux passing through the coils alternates increasing and decreasing to synchronize with rotation and vibration of the weight. As the equivalent circuit of Fig. 2(a)'s dynamo is shown in Fig. 2(b), upper coils (glued to the top plate) and lower coils (glued the bottom plate) are connected in series. Thus if total magnetic flux is denoted by Φ, twice of its derivative can be obtained as generated voltage.

$$V(\text{generate}) \sim -2\, d\Phi/dt \qquad (1)$$

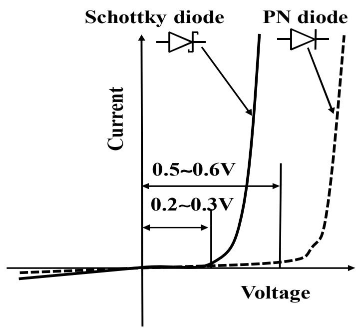
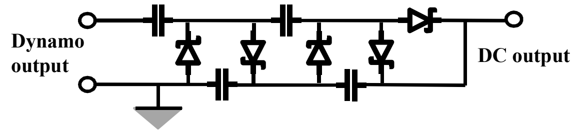


Fig. 3 Forward rectification characteristics of diodes.

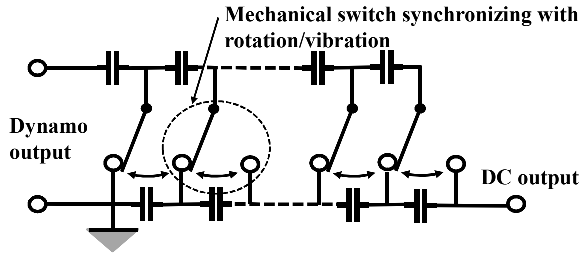
3. Characteristics of diodes

As shown in Fig. 2(b), a magnetic dynamo has only inductive coils whose resistive parts are very small. So, the dynamo acts as a low impedance voltage generator. The voltage level depends on the rotation or vibration speed, which is given by Eq. (1). Assuming that the dynamo is installed in a cellular phone for example and the phone is used on a palm or stored in a pocket or a handbag. In this case, the dynamo receives not so high-speed rotation or vibration which generates very low voltage. So up-conversion is an essential function for our energy harvesting device.

In general, diodes are used to rectify AC voltage to DC voltage. There are two kinds of diodes, i.e. Schottky diode and PN junction diode. Rectification characteristics of these diodes are shown in Fig. 3. Schottky diode cannot handle high power, but its threshold voltage is 0.2 ~ 0.3V, which is about half of the conventional PN diode.



(a) Cockcroft Walton voltage up-converter.



(b) Up-converter using mechanical switches.
Fig. 4 Investigated voltage up-converter circuits.

4. Voltage up-conversion circuits

In order to obtain high DC voltage from the dynamo, we study a well-known four times multiplier called "Cockcroft Walton circuit" using Schottky diodes. As shown in Fig. 4(a), this circuit provides four times of input peak-to-peak voltage. However, this circuit requires amplitude of input AC voltage larger than threshold of Schottky diode. We also investigate a new up-conversion circuit using synchronizing mechanical switches with rotation and vibration of the weight as shown in Fig. 4(b). This circuit requires almost zero volts for input AC voltage.

5. Conclusion

We propose a new energy harvesting device which uses a concept of magnetic dynamo aiming at handy electric gadget. Two types of up-conversion circuit are investigated, one of which requires almost zero-volt amplitude for dynamo output. Experiment and simulation using COMSOL will be conducted.

Reference

1. T. Shimizu and M. Hikita, in Proc. of Symp. on Ultrason. Electron. Vol.32, pp.375-376, 2011.