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Comparison of electrostatic and electromagnetic induction type generators for muscle-driven implantable energy harvesting system

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We have proposed an implantable energy harvesting system (IEHS), which uses electrically stimulated muscle as driving source. In this paper, in order to realize a simple, compact and high efficient generator for the IEHS, an electrostatic induction type generator utilizing electret sheets was investigated and the output power was compared with that of the electromagnetic one having the same diameter of the rotor, the same number of poles. Experimental results showed that the output power of the electromagnetic type generator is superior to that of the electrostatic one at the same rotational speed.

Keywords: *Implantable energy harvesting system, Active implantable medical devices, Electromagnetic, Electrostatic, Electret, Muscle*

1. Introduction

Active implantable medical devices (AIMDs) such as pacemakers usually consume electricity in a range of several μW to several hundred μW. Implanted batteries and percutaneous wireless power supplies are currently used for powering the AIMDs. However, the implanted battery requires the replacement by surgical operation every several years. The wireless power supply requires carrying external batteries and devices.

Recently, some implantable energy harvesting systems (IEHSs) have been studied. Some of them use heartbeat, respiration and body motion which generated several ten μW [1]. However, IEHSs utilizing heartbeat are not desired because they are directly related to life-sustaining activities. IEHSs utilizing body motion cannot supply the stable power in the case of bedridden patients. Therefore, we have proposed an IEHS utilizing contraction of skeletal muscle excited by an electrical stimulation. The advantage is that the output power can be controlled by the stimulus signal. The IEHS utilizing the skeletal muscle is safer than that utilizing blood circulation.

In this proposed system, the motion of muscle contraction with a large displacement is converted into electrical energy by a generator. In the previous study, we have developed the electromagnetic induction type generator for the proposed IEHS. In order to achieve high output power, the generator includes a speed increasing gear and a one-way clutch. Such mechanism, however, results in growing the size and complication of the generator. If the number of the magnetic poles of the rotor can be increased, high output power is expected even without the mechanism. Therefore, we focus on an electrostatic induction type generator using electrets which can easily increase the number of poles. In this study, the electrostatic induction type generator is fabricated and the generation performance is compared with that of the electromagnetic one.

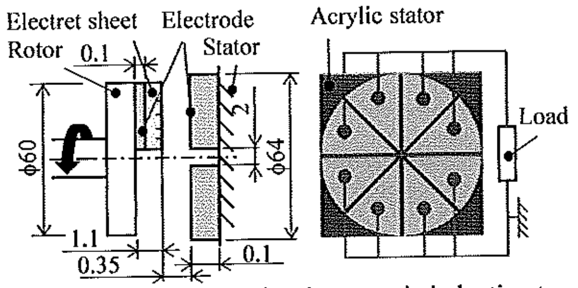

Fig. 1 Configuration of the electrostatic induction type generation with electret sheets

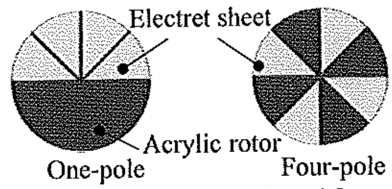

Fig. 2 Top views of the one-pole and four-pole type rotors

2. Evaluation of the electrostatic induction generator with electret sheets

Basic characteristics of the electrostatic induction type generator with electret sheets are experimentally evaluated. According to the reference [2], the structure of electrostatic induction type generator is advantageous for miniaturization. Moreover, the output power is theoretically proportional to the number of poles. Figure 1 shows the experimental setup. A stator has eight electrodes of cupper and a rotor has four electret sheets. The electret sheets made of PTFE were polarized by corona charging and the measured surface potential was

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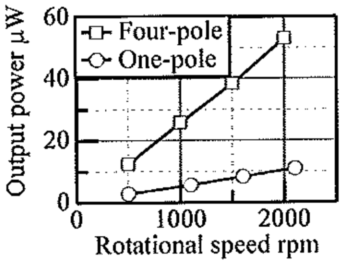

Fig. 3 Measured output power using one-pole and four-pole generators

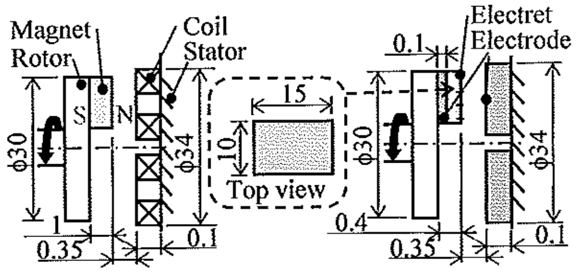

Fig. 4 Configuration of electromagnetic and electrostatic induction type generators

-0.92 kV. Output power was measured in the cases of one-pole and four-pole as shown in Fig. 2. A load resistance connected to the stator was set to make the load consume the maximum electric power. The number of pole was changed by repositioning the four electret sheets in order to use the same electret sheets.

As show in Fig. 3, the measured output power of four-pole was five times as large as that of one-pole. The expected difference is four times. This error might be caused by the gap of 2 mm between each electret sheet in the one-pole shown in Fig. 2.

3. Comparison of electromagnetic and electrostatic induction type generators

The output power of the electrostatic and the electromagnetic induction type generators is compared in order to choose a more suitable generator type for IEHS. Figure 4 shows the experimental setup. Surface areas of a square-shaped permanent magnet made of NdFeB and a square-shaped electret sheet made of PTFE are the same. Thicknesses and surface areas of coils and electrodes are the same. The output powers of both types were measured at rotational speeds from 50 to 250 rpm. It is assumed that the proposed IEHS will be operated at this range of rotational speeds.

The output power of the electromagnetic type was measured with an optimal load resistance of 13 Ω and other resistances of 4 and 75 Ω. Since the optimal resistance is largely dependent on the rotational speed in the case of electrostatic induction type generator, the load resistances were set to 400, 500 and 650 MΩ, those were optimal value at the rotational speed of 100, 150 and 200 rpm, respectively.

Table 1 Properties of electret and permanent magnet

Electret	Dimensions	10×15×t0.3
	Surface potential	-0.44 kV
Permanent magnet	Dimensions	10×15×t1
	Surface magnetic flux density	86 mT

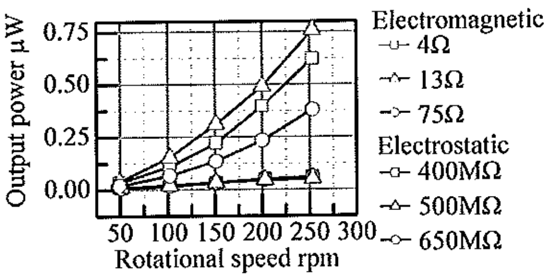

Fig. 5 Measured output power of electromagnetic and electrostatic induction type generators

Table 1 shows properties of an electret sheet and a permanent magnet used in the experiment. The stator of the electromagnetic induction type generator has two coils with 30 turns for each, which is made of enamel wire of 0.1 mm in diameter.

Figure 5 shows the measurement results. The output power of the electromagnetic induction type generator was larger than that of the electrostatic one. Hence in these diameters of the rotors and rotational speed, the electromagnetic type generator has a potential to realize higher output power.

4. Conclusion

In order to realize a simple and compact mechanism for the IEHS, we investigated the output power of the electrostatic induction type generator using electret sheets and compared with the electromagnetic one. The experimental results showed that the output power of the electrostatic induction type generator is increased proportional to the number of poles and the electromagnetic induction type generator had higher output power than electrostatic one in the case of the same number of pole, diameter of the rotor and rotational speed. However, electrostatic induction type generator has advantages that the number of pole can be easily increased and also the rotor and stator can be laminated in multi-layer. Hence, further investigation will be conducted in future work.

References

[1] C. Y. Sue and N. C. Tsai, Human powered MEMS-based energy harvest devices, Applied Energy, Vol. 93, pp. 390-403, 2012.

[2] J. Boland, Y. H. Chao, Y. Suzuki and Y.C. Tai, Micro electret power generator, Proceedings of the IEEE 16th Annual International Conference, MEMS, pp.538 -541 2003.