Axial-gap Generator Using Sintered Fe Nano-polycrystalline Body

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Abstract

Reduced iron (Fe) nanoparticles and sintered Fe nano-polycrystalline were used for core inductor of axial-gap generator. Property on magnetization of core inductor at low frequency was investigated. Reduced Fe nanoparticles were produced from iron oxide fine particles by high voltage pulse or laser ablation in liquids. Core inductors with these materials were fabricated. It was clarified from the measurement for magnetization of core inductor that the relative permeability of the sintered Fe nano-polycrystalline was 1 million. These experiments show that core inductor can be thinner and lighter than those using conventional core materials. Using Fe nano-polycrystalline should make axial-gap generator more compact with keeping high efficiency.

1. Introduction

Research on the utilize of the natural energy such as wind power and hydroelectric power generation has conducted until now. Generators are used to convert motive power into electrical energy. Axial-gap generators, which is one of generators, has a thicker core than that of conventional radial-gap generator using a permanent magnet. Axial-gap generators have low iron loss, and are considered to be light weight. Researches for the generators has been continued.

On the other hand, research on the magnetism of fine sub-nanoparticles such as gold and platinum has been conducted. It was predicted that the magnetism would increase when the metal was made into nanoparticles. In accordance with Hunt's law, it has been shown that fine particles such as metal nanoparticles are strongly influenced by the orbital magnetic moment due to electrons and develop new magnetism [1]. Our group has shown that aluminum nano-polycrystalline and silicon nano-polycrystalline have ferromagnetism [2,3,4].

In this time, we developed a power generator using reduced Fe nanoparticles and sintered Fe nano-polycrystalline as core materials. The magnetization characteristics and electromotive force characteristics of the core inductor were investigated.

2. Experimental setup

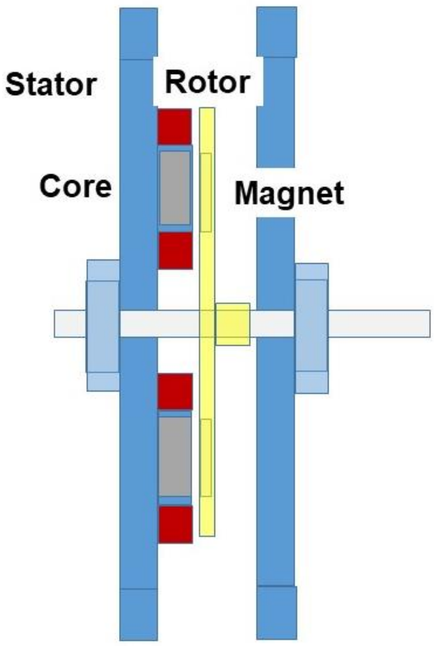

Fig.1. Axial-gap generator for an example.

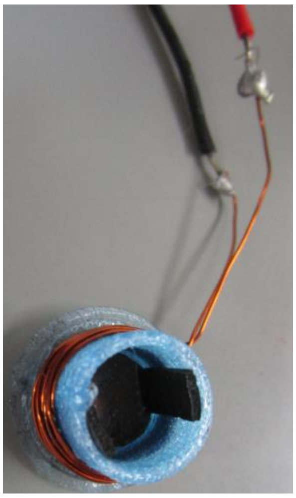

Fig.2. Core inductor with coil and Fe nano-polycrystalline.

An example of axial gap generator is shown in Fig.1. Firstly, a method for producing iron nanoparticles will be described. Reduced Fe nanoparticles were prepared by laser ablation in liquids [4] and high voltage repetitive pulse method. Reduced Fe nanoparticles were produced from iron oxide (Fe_3O_4) particles by two methods. Reduced Fe nanoparticles were prepared by each method by injecting several g of the iron oxide particles with mean diameter of several μm in a glass bottle with pure water. The prepared Fe nanoparticles were pasted and sintered. A DC current was adapted through the coil to generate DC magnetic field in the coil, and the magnetic field was measured by a gauss meter, and the magnetization characteristics of the core inductor were evaluated. As a generated core material, commercially available iron plate was used for comparison. The size of both the sintered Fe nano-polycrystalline body and the iron plate was 5 mm x 1 mm x 10 mm. The thickness of the sintered Fe nano-polycrystalline used for the electromotive force measurement (shown in the photograph of Fig. 2.) was 0.5 mm. The core was circular, and the diameter was 10 mm.

For measuring the electromotive force, two rotating plates with the diameter of 20 cm were prepared. One was fixed, and the other has Nd magnets with the diameter of 15 mm and a thickness of 1 mm, which ware attached to one side at a position 5 cm from the center. The other plate was rotated by a motor. The electromotive force of the core, which is proportional to the rotational speed of rotor disk, was measured by an oscilloscope. The thickness of core made of Fe nanoparticles for measuring the electromotive force was 10 mm and a diameter of 10 mm.

An 8-pole axial-gap generator using reduced Fe nanoparticles as a core of coil was fabricated. The diameters of rotor and stator was 9cm and 10cm, respectively. The core was circular, and the diameter was 15 mm, which is the same as the diameter of the Nd magnet. The single coil has 100 turns. The disk and core holder to hold the coils and Nd magnet were made by a 3D printer.

3. Results

Measured magnetic field generated by DC current flowing through an inductor (coil has 20 turns) with reduced Fe nanoparticles as the core is shown in Fig.3. The magnetization characteristic of the core was equivalent to that using ordinary soft iron. Measured magnetic field at the end of the core coil (coil has 10 turns) with commercial iron and sintered Fe nano-polycrystalline shown in Fig.4. When the sintered Fe nano-polycrystalline was used as a core, it showed unique characteristics, and it was found that the rise of the magnetic field using the sintered Fe polycrystalline as a core at low current was extremely large.

This data means that the low-frequency relative permeability of the sintered Fe nano-polycrystalline is the order of 1000000. Conventional soft iron bulk has low relative permeability of several 1000.

Electromotive force of the coils with each material measured by the oscilloscope are shown Fig. 5. The experiment showed that (coil has 50 turns) the electromotive force of the coil using sintered Fe nano-polycrystalline was two times as large as that using reduced Fe nanoparticles, even though the thickness of the sintered iron polycrystalline body was thin.

Output voltage of the 8-pole axial gap generator is shown in Fig.6. An output of 5.6 V was obtained when the rotational speed of the rotor was 1300 rpm.

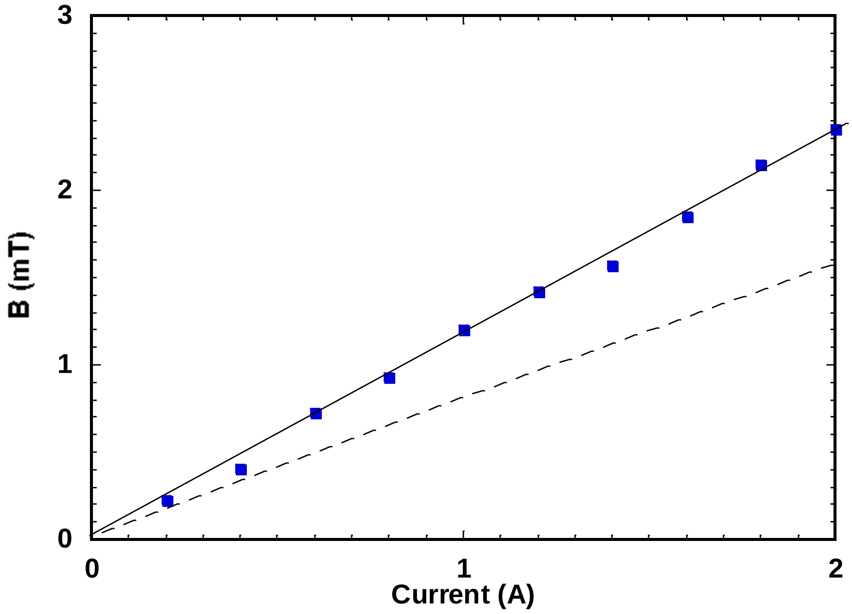

Fig. 3. Measured Magnetic field on cored coils. Dash line: Air core.

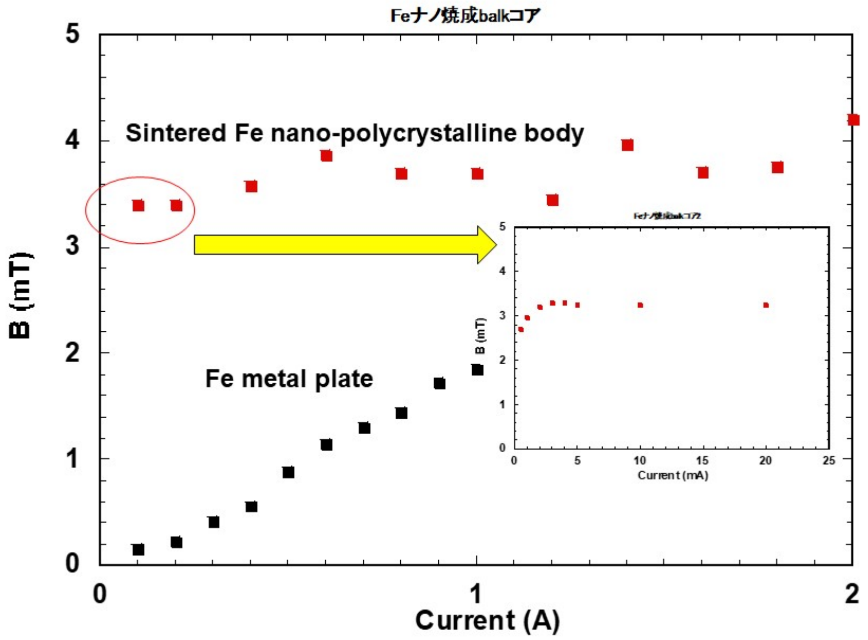

Fig. 4. Magnetic field on core inductors.

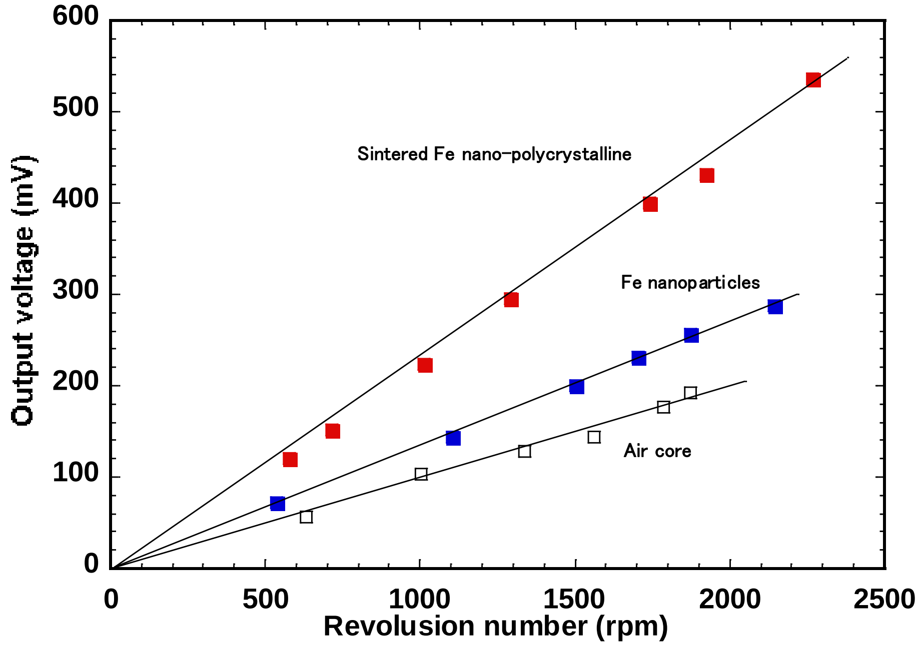

Fig. 5. Output voltage.

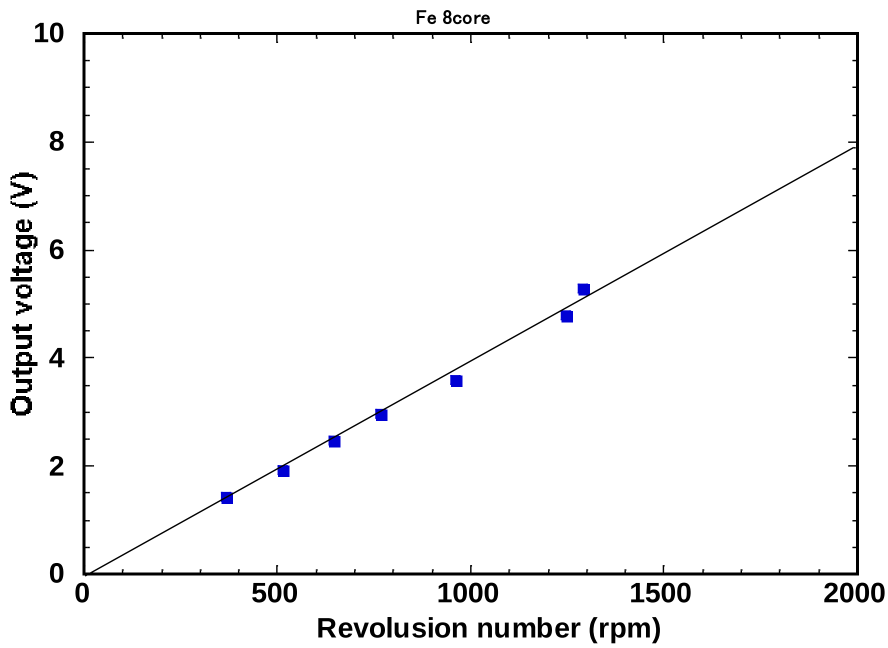

Fig. 6. Output voltage of axial-gap generator

4. Conclusion

We studied for an axial-gap generator using reduced iron nanoparticles and sintered metal. When the sintered Fe nano-polycrystalline is used as the core, the magnetic permeability is higher than common soft iron. It has been clarified in these experiments that the weight and the thickness of axial-gap generator could be reduced.

References

[1] Function Investigation Committee of Nanoscale Magnetic Material, “Nanostructured magnetic materials - physics, function, design-“, (Kyoritsu Publishing, Tokyo, JAPAN, 2010), Chapter 1 and 2.

[2] M. Inada, Y. Iida, T. Saiki, S. Masuda, “Aluminum Nano-polycrystalline Substance with Ferromagnetics and Application to High-Frequency Core Inductor”, J. of Electrical and Electronic Engineering, Vol. 5(3), June (2017) pp.98-103.

[3] T. Saiki, Y. Iida, M. Inada, “Appearance of Ferro-magnetic Property for Si Nano-polycrystalline Body and Vanishing of Electrical Resistances at Local High Frequencies”, J. of Nanomaterials, vol. 2018 (2018), ID9260280, pp.1-12.

[4] T. Saiki, Y. Iida, M. Inada, “Magnetic Property and Vanishing Resistance in Local High Frequency for Sintered Fe Nanopaste with Fe Nano-polycrystalline”, IEEJ Transactions on Fundamentals and Materials, Vol.138 No.10 pp.512-520 (2018) (in Japanese)