Technology

Development and Application Examples of Magnetostrictive Vibrational Power Generation Technology

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Abstract

Many of the IoT sensors, which are expanding with the social penetration of digital transformation, use batteries. As the use of IoT sensors is expected to further expand in the future, there is a demand for power generation technology that uses environmental energy and does not require battery replacement, as well as stable power generation technology that is not affected by weather or location. In response to this need, Nippon Steel Chemical & Material Co., Ltd. has developed a magnetostrictive vibrational power generation module that uses Electrical steel sheet. We confirmed that various wireless communications can be operated using the power obtained by placing the magnetostrictive vibrational power generation module in various vibrational environments. We will continue to collaborate both inside and outside the company to create concrete examples in the future.

1. Introduction

In recent years, as the internet of things (IoT) spreads, an era where several trillion IoT sensors are required is approaching. Under such circumstances, IoT sensors having a wireless communication function are under development. However, many sensors use batteries as their power sources and thus there is concern about the increase in cost for manual periodic maintenance (e.g., battery replacement and charging) and about the environmental issues caused by frequent use of primary batteries. To resolve these problems, there is demand for the development of long-term maintenance-free energy harvesting modules that can continuously obtain electric power from environmental energy at the installed locations. To satisfy such needs, we are focusing on vibrational energy that exists even at dark places (e.g., indoors). The vibrational power generation market is expected to expand from now on (**Fig. 1**) and IoT sensors involving vibrational power generation technologies are the products that match the two main trends in society: Digital transformation (DX) and green transformation (GX). Consequently, Nippon Steel Chemical & Material Co., Ltd. has been developing, as a vibrational power generation technology, magnetostrictive vibrational power generation that uses steel. This paper reports on an outline of the developed magnetostrictive vibrational power generation technology along with its application examples.

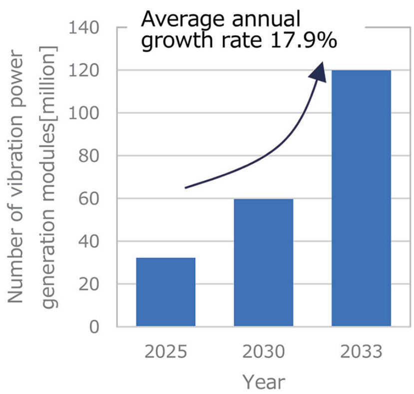

Fig. 1 Growth outlook for vibration power generation market (Created from the Japan Management Association report)

2. Main Subject

2.1 Outline of the magnetostrictive vibrational power generation technology

The magnetostrictive vibrational power generation technology

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uses an effect where when strain is applied to a magnetic material (e.g., Electrical steel sheet), the magnetic susceptibility changes, i.e., the inverse magnetostrictive effect (Villari effect). Specifically, by using changes in the magnetization occurring when a magnetic material arranged in a coil is subjected to stress, electromotive force is obtained at both ends of the coil according to the law of electromagnetic induction. In this paper, magnetic materials for magnetostrictive vibrational power generation are referred to as magnetostrictive materials. The magnetostriction coefficient is used to indicate the degree of a change in the magnetization against strain. A magnetostrictive material having a large coefficient can cause a change in the magnetization sensitively to strain, so such material has a high power generation efficiency. Accordingly, as magnetostrictive materials, iron-gallium (FeGa) and iron-cobalt (FeCo) have been studied so far because their magnetostrictive coefficients are large. However, there are problems with these materials: They use rare elements; although resin is used to bond a magnetostrictive material to a frame that transmits vibration, such resin peels off due to vibration. Meanwhile, Nippon Steel Chemical & Material found that Grain-oriented electrical steel sheets (GO), which had not been considered as a power generation material because their magnetostriction was small, would, by controlling the residual stress, cause a large change in the magnetization against strain. By combining GO of Nippon Steel Corporation, which is widely used as a transformer core material, with metal joining technologies cultivated by Nippon Steel Chemical & Material, we have succeeded in strongly integrating GO and a frame to develop a high-durability power generation material. A magnetostrictive vibrational power generation module consists of four components of a magnetostrictive material, frame that transmits vibration, magnet, and detection coil (**Fig. 2**). For the developed power generation material, the magnetostrictive material has been integrated with the frame, so it can be stamped or bent.

2.2 Application examples

To introduce the developed material, this paper uses two types of vibration modes as shown in **Fig. 3**.: Snapping vibration and continuous vibration. In the snapping vibration mode, low-cycle high strain is applied to a magnetostrictive material and vibration caused when a door is opened and closed by hand and caused by actions of pushing and stepping is applicable. On the other hand, in the continuous vibration mode, high-cycle low strain is applied to a magnetostrictive material and vibration caused by cyclic operations of motors, etc., is applicable.

The characteristics of the developed magnetostrictive power generation material were examined in the snapping vibration and continuous vibration modes. In the snapping vibration mode, the power generation output obtained in the experiment was approximately 59 Vp-p[*1] and when converted to electric energy, it was 6.2 mWs at maximum (**Fig. 4**). It has been confirmed that with this power generation output, Zigbee™[*2] and Bluetooth™[*3] wireless communications are possible. In the continuous vibration experiment, a magnetostrictive vibrational power generation module was placed in a continuous vibrational environment (above a vacuum pump); a wireless communication module (ABLIC Inc./power source with an electric storage function and private LoRa communication module) combined with a storage circuit was used to verify whether wireless communications were possible (**Fig. 5**). The experiment showed that when the acceleration above the motor was approximately 15 m/s^2 and the frequency was 100 Hz, the private LoRa communication module could make wireless communications after being charged for 30 minutes with power generated by the magnetostrictive vibrational power generation module.

[*1] Difference between the maximum and minimum AC voltage values
[*2] "Zigbee" is a registered trademark of the Connectivity Standards Alliance.
[*3] "Bluetooth" is a registered trademark of Bluetooth SIG, Inc.

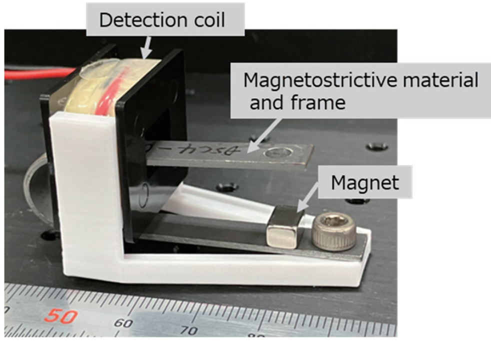

Fig. 2 Example of magnetostrictive vibration power generation module

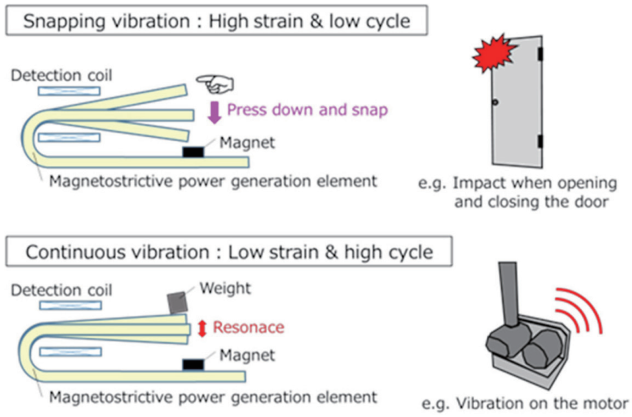

Fig. 3 Snapping vibration and continuous vibration

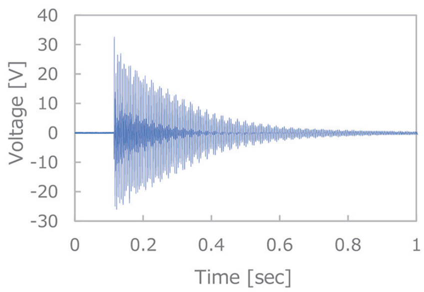

Fig. 4 Waveform of power generated by snapping vibration

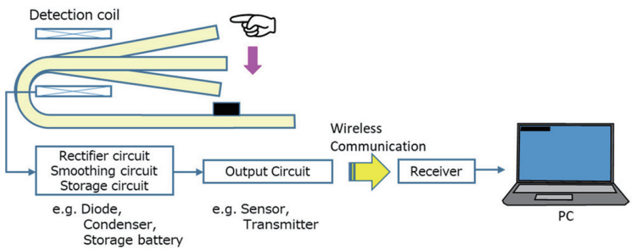

Fig. 5 Wireless communication using magnetostrictive vibration power generation

3. Conclusion

As an environmental power generation technology that is expected to grow in the future market, Nippon Steel Chemical & Material has developed vibrational magnetostrictive power generation technology using steel. We succeeded in operating wireless communication devices (Zigbee™, Bluetooth Low Energy™[*4], and private LoRa) with power generated by the prototype vibrational power generation module. Based on this result, we will propose the magnetostrictive vibrational power generation module in many fields in and outside the company from now on so as to contribute to realizing a society where access to affordable, reliable, sustainable, and modern energy is ensured for all as stated as one of the SDGs.

[*4] "Bluetooth Low Energy" is a registered trademark of Bluetooth SIG, Inc.


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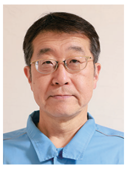
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