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Development of New Propulsion System for Magnetically Levitated Vehicles

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Abstract
This paper describes a new propulsion system for magnetically levitated vehicles with hybrid magnets, which were studied in place of streetcars and transportation systems in semiconductor production. The new propulsion system for magnetically levitated vehicles proposed here is low cost and easy to make. We obtained static experiment results of the linear switched reluctance motor (LSRM) as a new propulsion system, and obtained the basic characteristics.

Keywords: Magnetically Levitated Vehicle, Non contact, Propulsion Force, Streetcars and Transportation Systems, Hybrid Magnets, Linear Switched Reluctance Motor, Low Cost

1. Introduction

This paper describes a new propulsion system for magnetically levitated vehicles with hybrid magnets, which were studied in place of streetcars and transportation systems in semiconductor production. The new propulsion linear switched reluctance motors (LSRM) we made are light weight, low cost, and easy to make as compared with a general linear motor. We have developed a magnetic levitation transport system for overhead traveling vehicles (OTV). One advantage of the OTV is the effective use of space.

Magnetically levitated systems have the following advantages: no bearings, wheels, noise, or air pollution and requires only low maintenance. We also propose new constructive electromagnets and magnetic rails. The magnetically levitated part is cordless and the power source involves Ni-MH AA size rechargeable batteries.

The reduction of dust and noise is essential. Linear drives have been widely developed and utilized because of their direct drive features. Their low construction cost and low maintenance is key to their practical use.

The new propulsion system for magnetically levitated vehicles proposed here is low cost and easy to make. We obtained static experiment results of the linear switched reluctance motor (LSRM) as a new propulsion system, and the basic characteristics. The new propulsion system LSRM and the experimental results are presented.

2. Levitation system

Figure 1 shows a diagram of the equipment. Luggage is put under the levitated part. An experimental truck (levitation part) is magnetically levitated using AA size dry-cell battery power. Ten batteries are connected in series, which presents a large energy saving. The levitated vehicle had 4 hybrid magnets, equipped with divided iron cores in two rows [1~4]. The hybrid magnets were composed of iron cores, coils and permanent magnets. The hybrid magnets are composed of divided iron cores, permanent magnets (PM) and coils.

The use of hybrid magnets contributed to large energy savings, and their practical use is facilitated by their low construction cost and low maintenance. The gap between magnetic rails and hybrid magnets is measured by a gap sensor. Coils are excited by a negative feedback circuit, which has a PWM control circuit. The current is controlled when coils are excited to maintain the gap due to a constant gap or load variation.

The coils of one side of the divided core are excited with a direct current controller to produce polarity equivalent to a permanent magnet, while the others are excited with the opposite polarity. The magnets control both levitation and lateral damping forces. The controller is applied to the current integral control to reduce excitation loss.

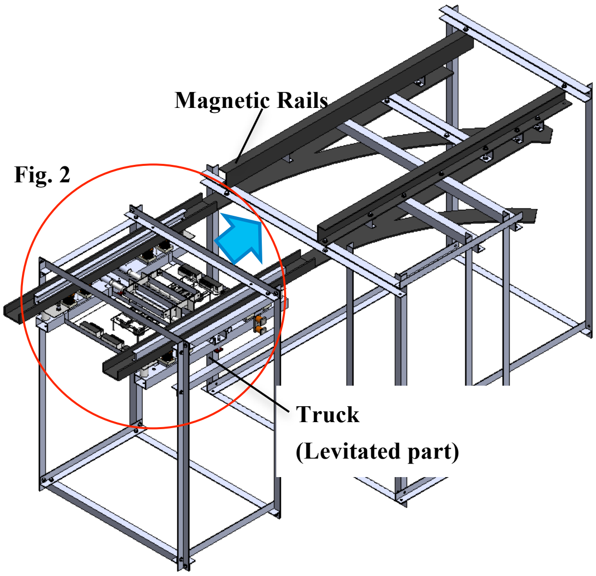

Fig. 1 Diagram of the equipment.

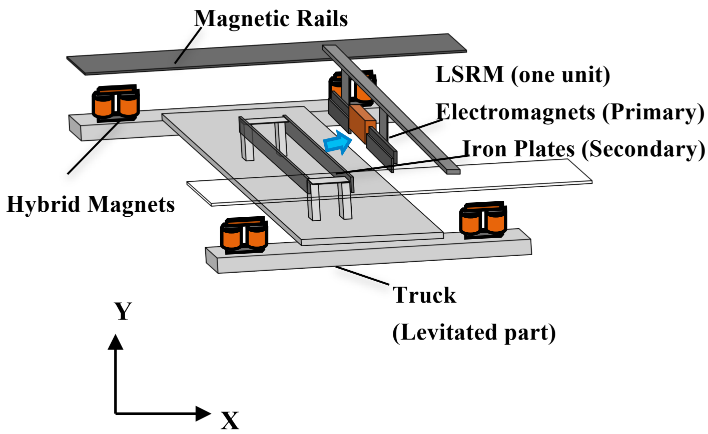

Fig. 2 Structure of the LSRM and levitation part.

3. Propulsion system

Figure 2 shows the structure of the linear switched reluctance motor and levitation part. Figure 2 shows a diagram of one unit of the LSRM.

The propulsion force uses the attraction force of the iron plate (Secondary) and the electromagnet (Primary). The propulsion system is supplied with energy from a DC power supply. We experimented with changing the thickness of the iron core of the electromagnet.

LSRM was created using a coil and iron plate, and has a simple structure. Therefore, LSRM is low cost, light weight and easy to process. The greater the thickness of the iron core of the electromagnet, the greater the resistance value of the coil and the weight. The iron plate is 3-mm thick. The number of turns of the coil is 800. The iron is SS400.

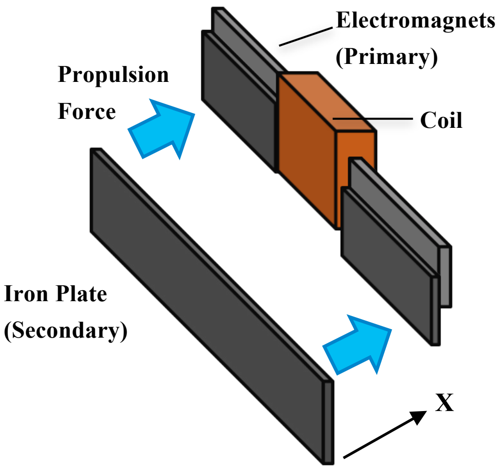

Fig. 3 Diagram of one unit of the LSRM.

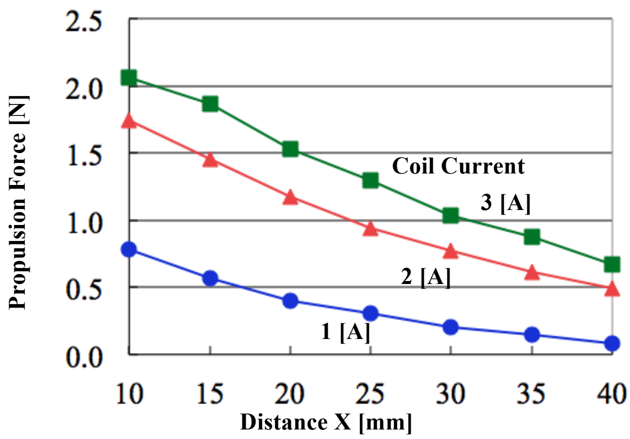

Fig. 4 Static experiment results of LSRM with 9-mm thick iron core.

(Distance Y: 5 mm, Coil: 800 turns, 0.6 mmϕ, 3-mm thick iron plate)

4. Static experiment apparatus

In order to remove the influence of the levitation force of the magnetic levitated part, the propulsion force at the static experimental apparatus is measured. The static experimental apparatus is shown in Fig.5.

The electromagnet (Primary) and the iron plate (Secondary) are placed upside-down to make it easier to measure the propulsion force in the static experimental apparatus. The iron plate is hung by three wires attached vertically from the ceiling. The iron plate is mounted vertically to the aluminum plate. The propulsion force is measured with a distortion sensor connected with the wire attached horizontally. The electromagnet is fixed at the base.

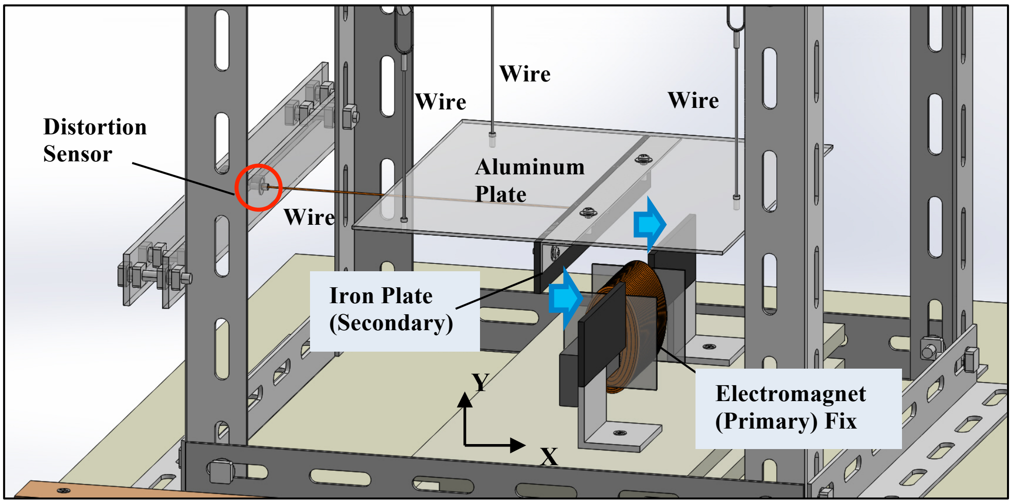

Fig. 5 Diagram of the static experimental apparatus.

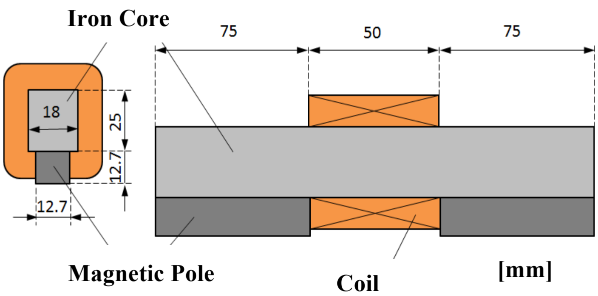

Fig. 6 Design drawings of the electromagnet.

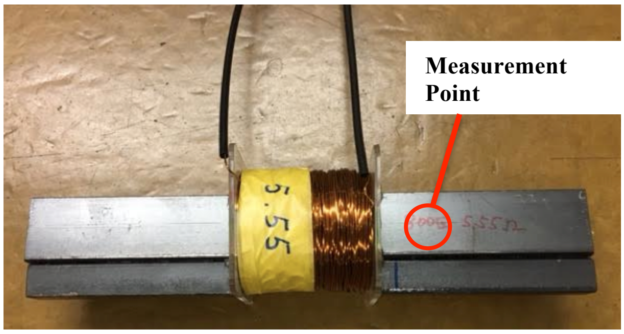

Fig. 7 Photo of the electromagnet.
(18-mm thick iron core.)
(Coil: 800 turns, 5.55 ohm, 0.6 mmϕ)

4.1. Magnetic saturation experiment

Figure 6 shows design drawings of the electromagnet. Figure 7 shows a photo of the electromagnet that we made. In order to investigate the magnetic saturation of the electromagnet, we measured the magnetic flux density of the electromagnet by changing the exciting current of the coil. We previously experimented with changing the thickness of the iron core of the electromagnet (9 mm, 18 mm). Figure 8 shows the experimental results of the electromagnet.

We measured the magnetic flux on the surface of the iron core close to the coil. The magnetic flux density was measured using a Teslameter. At a coil current of 2 A, the 9-mm thick iron core was saturated.

4.2. Static experiment

Figure 9 shows the static experiment results of the LSRM with an 18-mm thick iron core. Figure 9 shows the results of using an iron core of double the thickness of an electromagnet to that shown in Fig.4.

The static experimental apparatus can change the distance in the horizontal (X-axis) and vertical (Y-axis) directions. As the distance of the X-axis and Y-axis distance is small, you can see that the magnetic attraction force becomes stronger. However, in order to operate efficiently, an actual LSRM must attach to the magnetically levitated transport system required with an optimal air gap.

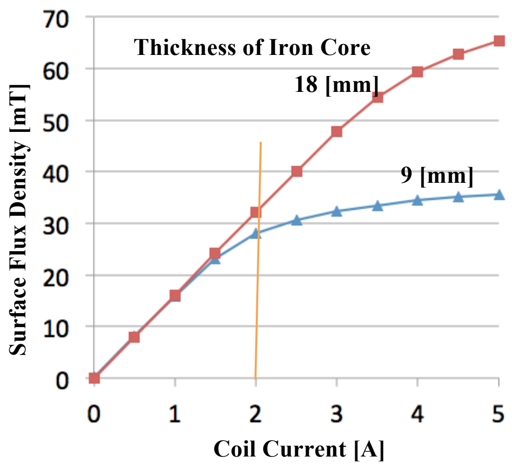

Fig. 8 Experimental results of the electromagnet.
(Distance Y: 5 mm, Coil: 800 turns, 0.6 mmϕ)

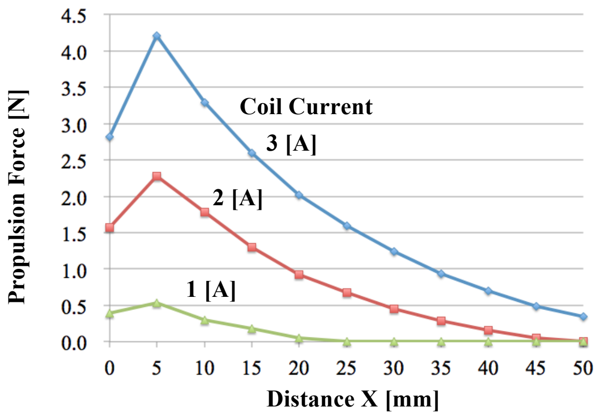

Fig. 9 Static experiment results of LSRM at thickness of iron core 18 mm.
(Distance Y: 5 mm, Coil: 800 turns, 0.6 mmϕ, 3-mm thick iron plate)

5. Experimental results

Other experimental results revealed that the levitation part moved 0.39N. Figure 4 shows the static experiment results of the LSRM with a 9-mm thick iron core. The distance of Y was 5 mm. When the exciting coil current was increased, the propulsion force also increased. For example, in the Y-distance of 5 mm, when the X-distance was less than 20 mm at an exciting coil current of 1 A, it was found that the levitated part moved.

Figure 4 shows the exciting coil current was increased from 1 A to 2 A, showing a large variation. In contrast, when the exciting coil current was increased from 2 A to 3 A, there was only a small variation. This was due to the occurrence of magnetic saturation in the electromagnet.

Since the iron core of the electromagnet was found to be saturated, an experiment was conducted again with double the thickness of the iron core of the electromagnet.

Figure 8 shows the experimental results of the coil current and the magnetic surface flux density. When the thickness of the iron core of the electromagnet was increased, it was not magnetically saturated at a coil current of 2 A. The 9-mm iron core was saturated at a coil current of 2 A. However, the 18-mm iron core was not saturated at the same value.

Figure 8 shows the static experiment results of the LSRM with a 9-mm thick iron core. The propulsion force was reduced over the distance of 5 mm in the X-direction, since the attraction force in the Y-direction increased. The distance in the X-direction at 5 mm was the maximum propulsion force. For example, at the Y-distance of 5 mm, when the X-distance was less than 45 mm at an exciting coil current of 3 A, it was found that the levitated part moved.

In Fig. 8 at the X distance of 10 mm, the exiting coil current of 3 A was 1.5 times larger than that shown in Fig.4.

To increase the propulsion force of the levitated part, it is necessary to increase the exciting current of the coil, which requires a design that prevents magnetic saturation by increasing the thickness of the iron core of the electromagnet. If the propulsion force is large, by spreading the installation interval of the electromagnets, it is possible to reduce the number of electromagnets.

6. Conclusions

We created magnetically levitated vehicles and the new propulsion system LSRM. Basic LSRM experiments revealed that the maintenance cost would be reduced due to the lack of failure from wear and tear. Furthermore, no noise or dust pollution would be generated. The new propulsion linear switched reluctance motors we made are light weight, low cost, and easy to make as compared with general linear motors. If the propulsion force is large, by spreading the installation interval of the electromagnets, it is possible to reduce the number of electromagnets.

We plan to experiment by changing the thickness of the secondary iron plate. We will attach the iron plates (secondary) on the upper magnetically levitated part. Furthermore, a running test has been scheduled with a plurality of electromagnets (primary) on top of magnetic rails. The magnetically levitated vehicle with LSRM will automatically move alongside the magnetic rail.

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