http://dx.doi.org/10.11142/jicems.2014.3.3.312

Journal of International Conference on Electrical Machines and Systems vol. 3, no. 3, pp. 312~316, 2014

A Turnout without Movable Parts for Magnetically Levitated Vehicles with Hybrid Magnets

Toshio Kakinoki*, Hitoshi Yamaguchi*, Naoya Yoshinaga, Eiichi Mukai* and Hiroyuki Nishi***

Abstract – This paper describes a turnout without movable parts for magnetically levitated vehicles with hybrid magnets, which have been studied by the authors in place of streetcars. Their low construction cost and low maintenance is key to their practical use. Magnetic levitation systems using forces of attraction can generate guidance force automatically, but the damping force against lateral motion is negligible. However, the lateral damping characteristic was improved by using divided iron type magnets and rails. Using this turnout without movable parts will facilitate smooth direction switching.

Keywords: **Magnetically Levitated Vehicle, Without Movable Parts, Low Maintenance Cost, Noiseless and Dustless.**

1. Introduction

An experimental truck was magnetically levitated using dry-cell battery power. The truck had 4 hybrid magnets, equipped with divided iron cores in two rows.

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

The controller was applied to the current integral control to reduce excitation loss and the experimental results were shown.

2. Trial Design

2.1 A Turnout without Movable Parts

An experimental track switching system without movable parts for magnetically levitated vehicles was established, the outline of which is shown in. Fig .1. A set of plane iron slabs as iron rails is located on the upper part of the track, while the under surface is mounted on the same level as that of the dividing iron rails of the straight tracks. The magnetically levitated truck can travel under the iron rails and branch out to the selected line. When the truck reaches the turnout, the electromagnet for switching is excited to branch the selected track. Fig. 2 shows the outline of a turnout without movable parts.

.

2.2 Magnetically Levitated Vehicle

Fig. 3 shows hybrid magnets [1~ 4], including divided iron cores and permanent magnets. Thin and broad permanent magnets were placed at the bottom of the divided iron cores and arranged in two rows to reduce magnetic resistance against the magneto-motive force of levitation coils. Moreover, the energy consumption for levitation can be significantly reduced by adopting divided iron type hybrid magnets [5~ 7].

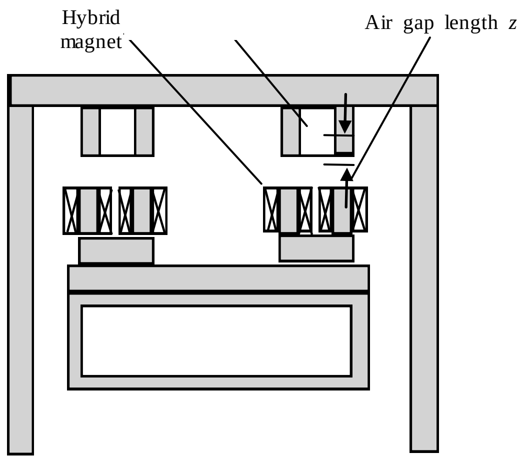

Fig .1 Equipment Outline (Front view).

* Dept. of Computer and Information Science, Sojo University, Japan. (kakinoki@cis.sojo-u.ac.jp)
** KYOWA LIMITED, Japan

Received 15 April 2013; Accepted 15 June 2013

This system operates using AA size dry-cell batteries. The application of pull-up type magnetically levitated vehicles will be useful for free path track design and smooth running.

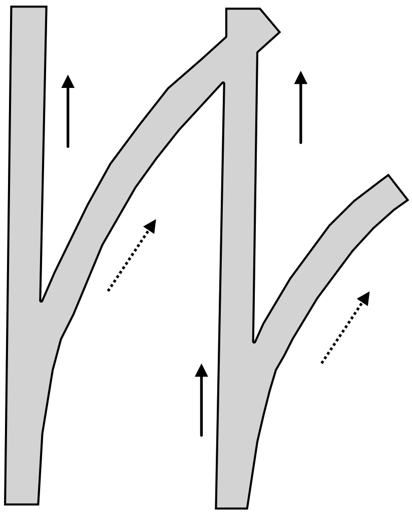

Fig. 2 Outline of a turnout without movable parts (Top view).

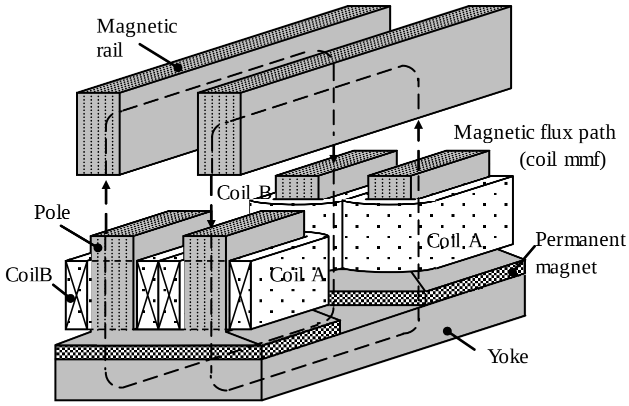

Fig. 3 Hybrid Magnets.

Table. 1 Equipment Parameters

Items	Units	Value
Residual magnetic flux density of PM	T	1.384
Number of turns per pole		160
Resistance of a single side coil R	Ω	1.2
Shunt resistance r_s	Ω	1
Single side coil inductance L	H	0.012
Number of poles		2
Mass of truck M *(levitated part)*	Kg	19.3
Amplitude of triangle voltage E_Δ	V	5
Voltage drop of IGBT E_{ce}	V	2
Target current for integral control I_0	A	0.1

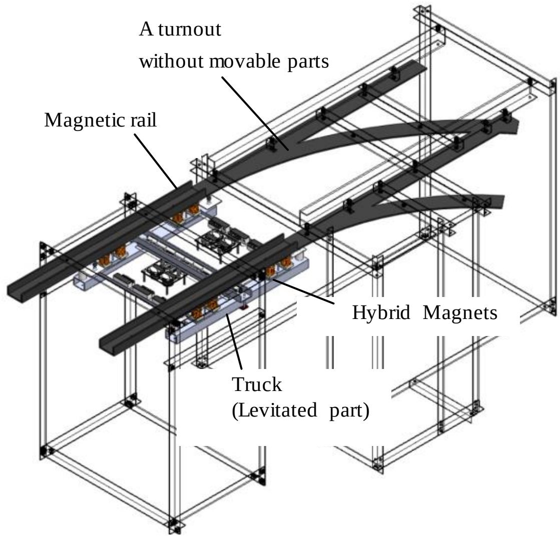

Fig. 4 Solid figure of the Equipment.

Fig. 5 Equipment (Photo).

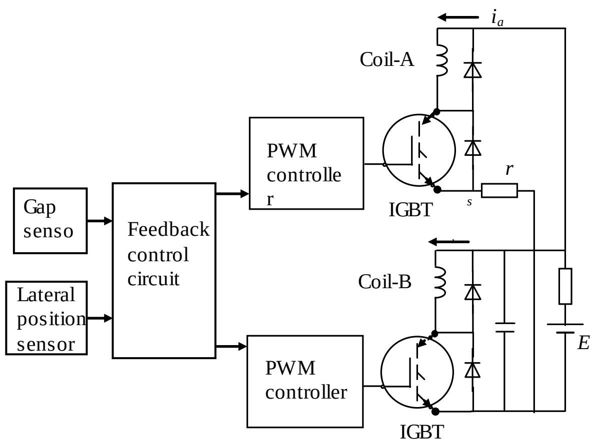

Fig. 6. Schematic circuit diagram for levitation

3. Experiments

Table 1 shows the parameters of the experimental equipment. The magnetically levitated part must be cordless and the power source must involve ten Ni-MH AA size rechargeable batteries connected in series, equating to a normal voltage of DC 12V. The battery capacity is 1900mAh.

Fig. 4 shows a solid figure of the equipment, which can easily be operated using a experimental table under the system at Fig. 5. The radius of curvature is 1250 mm. A turnout without movable parts is not a divided iron core, because that facilitates construction and smooth switching. The authors presume the truck runs through a turnout without movable parts and at low speed.

The Magnetically Levitated Vehicle comprises Hybrid Magnets and a permanent magnet. The magnetically levitated vehicle with hybrid magnets can levitate via both large and small air gap lengths. The Hybrid Magnets are controlled to maintain the air gap length between the Hybrid Magnets and magnetic rail so that the forces of attraction from the Hybrid Magnets are balanced out by the levitated weight of the vehicle. Each of the Hybrid Magnets is independently controlled.

The target air gap length at steady state levitation is 10.5mm. At steady state levitation, each hybrid magnet is a controlled current at 0.1A due to the balanced mass between a levitation part and the force of attraction. The total current is 0.4A, but this does not include the power of the control circuit.

Fig. 6 shows a schematic circuit diagram for levitation, which operates, when coils A and B have air gaps larger and smaller than the target air gap length respectively. Coils A and B cannot be operated simultaneously.

Each hybrid magnet has a rotation axis and can rotate along a magnetic rail.

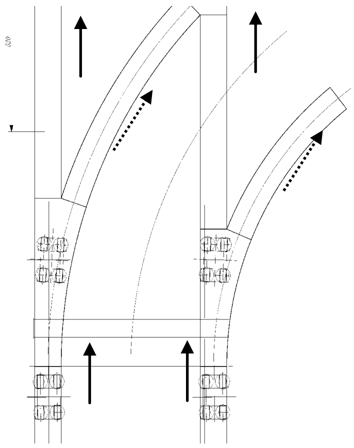

Fig. 7. Perspective of the equipment (just on the curve).

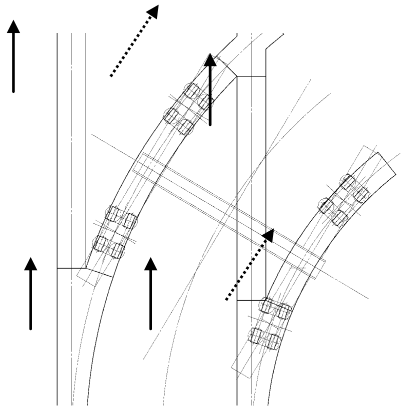

Fig. 8. Perspective of the equipment (on the curve).

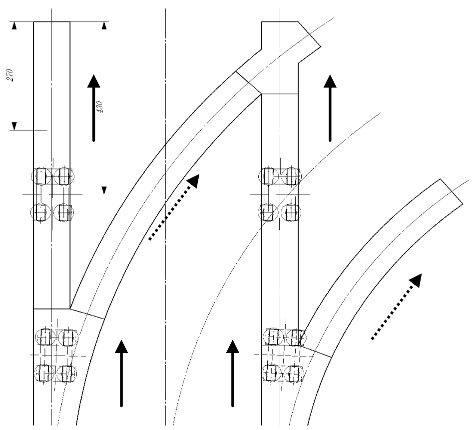

Fig. 9. Perspective of the equipment (on the straightsection).

4. Experimental Results

A turnout without movable parts consisted of a plane with iron slabs and a magnetic rail for changing the orbit. Conversely, a liner part of a magnetic rail with divided iron cores has a large guidance force that does not run off the magnetic rail, making it easy to switch the direction of the magnetic levitated part and change the orbit.

When the air gap length z has a range of mm, transfer for steady state levitation will be possible. No guide force was needed to levitate parts run straight above a magnetic rail. Conversely, the guide force required to change the orbit at turnout without movable parts exceeded 0.2kgf.

The hybrid magnets moved along the magnetic rail on a turnout without movable parts automatically

Fig. 7 shows the perspective of equipment with a view solely of the curve rail. The front hybrid magnets passed away a max angle of 3.8 degrees of axis and smoothly ran along the magnetic rail.

Fig. 8 shows the perspective of the equipment with a view on a curve rail. All hybrid magnets passed away on a turnout without movable parts. The max angle of each of the hybrid magnets was 2.5 degrees in terms of the axis on the curve rail.

Fig. 9 shows the perspective of equipment with a view on a straight rail. The front hybrid magnets passed away and smoothly on a turnout without movable parts. The hybrid magnets moved alongside the magnetic rail on a turnout without movable parts, with automatic confluence.

5. Conclusions

We will construct a cage for changing the weight test and also establish and run the same with a linear motor.

Because the turnout we propose does not involve mechanical movement, smooth, ductless and noiseless switching is possible. Furthermore, it incorporates a simple structure, which can be economically produced. For subways and city trains running along the streets, the turnout without movable parts for magnetically levitated vehicles with hybrid magnets will be optimal.

The merits of this system will be as follows:

The hybrid magnets will automatically move alongside the magnetic rail on a turnout without movable parts.

The cost of constructing the vehicle system will be lower due to the lack of movable parts.

Maintenance cost will be reduced due to the lack of failure from wear and tear.

No noise and dust pollution will be generated.

References

[1] T. Kakinoki, H. Yamaguchi, et al, ”A Study on Lightweight Hybrid Magnet Using Divided Iron Cores and Permanent Magnets for Magnetically Levitated Vehicle”, The Fifth International Symposium on Linear Drives for Industry Applications,(LDIA2005), The Institute of Electrical Engineers of Japan (IEEJ) 2005, P.445-448.

[2] T. Mochizuki, Y. Jifuku, et al, ”Magnetic Characteristic of Electromagnetic Levitation System using Electromagnet and Rail with Divided Iron Rail”. T The 4th International Symposium on LinearDrives for Industry Applications (LDIA2003), The Institute of Electrical Engineers of Japan (IEEJ) 2003, P.199-202 .

[3] [3] T. Nomiyama, , T. Kakinoki, H. Yamaguchi, Y. Jifuku, T. Mochizuki,”Magnetic Characteristics of Electromagnetic Levitation System for Short Radius Curve Track”, IEEJ Trans. IA, Vol.125, No.7,pp.691-697(2005)

[4] M. Morishita, M. Akashi, ”Guide-effective Levitation Control for Electromagnetic Suspension Systems”, IEEJ Trans. IA, Vol.119, No.10, 1999, pp.1259-1268.

[5] T. Kakinoki, H. Yamaguchi, Y. Jifuku, T. Nomiyama ,K. Shinohara, ” A Study on Lightweight Hybrid Magnet Using Divided Iron Cores and Permanent Magnets for Magnetically Levitated Vehicle”, Proc. of Linear Drives for Industry Applications (LDIA2005), pp.445-448.

[6] T. Kakinoki, H. Yamaguchi, K. Shinohara ”Energy-saving Coil Excitation of Electromagnetic Levitation System Using Divided 1 Iron Core Type Hybrid Magnet”, IEEJ Trans. IA, Vol.127, 2007, No.9,pp.935-941.

[7] T. Kakinoki, H. Yamaguchi ”Reduction in Exciting Energy of Divided Iron Core Type Hybrid Magnet Used for Magnetically Levitated Vehicles”, IEE-J Meeting for Linear Drives, LD-08-86, 2008, pp. 57-62.

Toshio Kakinoki received his Master’s degree from Kagoshima University in 1996 and became an assistant lecturer at Kumamoto Institute of Technology (Now, Sojo University). He become an Associate Professor in 2013 at Sojo University. He is primarily pursuing research on magnetic levitation system. He holds a D.Eng. degree.

Hitoshi Yamaguchi graduated from the Department of Electrical Engineering at the University of Kyushu in1963 and joined Fiji Denki. He was involved in research on linear motors, rope-less elevators, and magnetic levitation railways. In 1996, he become an instructor at Sojo University, and has been a professor there since 1998. He is primarily pursuing research related to constant conductance-type magnetic levitation railways. He holds a D.Eng. degree.

Naoya Yoshinaga received his Master’s degree from Sojo University in 2013 and joined KYOWA LIMITED. He is primarily pursuing research on magnetic levitation system.

Eiichi Mukai received his B. E. degree from Saga University in 1972. Later, he received his Doctor Eng. degree from Kyoto University. He joined Hitachi Electronics Ltd. in 1972. In 1974 he became a research associate at Saga University, and in 1993, an associate professor. In the same year he became an associate professor at Kumamoto Institute of Technology (Now, Sojo University), and in 1997, a professor. Since then he has been engaged in research related mainly to electrical machinery and apparatus. He is the members of IEEJ, SICEJ and CSSJ.

Hiroyuki Nishi received B. E. and M. E. degrees in electronic engineering from Kyushu University, and PhD from Tsukuba University. He is currently a professor and a dean of Sojo University. He has worked mainly on the research of spoken dialog systems.