A Study on Linear Actuators with Dual-Halbach Arrays (Fundamental Consideration on Effect of Magnet Geometry on Thrust Characteristics)

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Abstract

There are many situations in the operation of mechanical products that require linear motion. In most cases, the conversion from rotational to linear motion is performed through various mechanisms. However, there is concern that such a method may be subject to the mechanical effects of each mechanism. Although there are some cases in which the motion pattern can be varied by installing a variable mechanism, such mechanisms are rarely used in general products because they complicate the system. Therefore, our laboratory has been continuously studying linear actuators that enable high-speed and high-precision linear motion. In this report, a linear actuator with a dual Halbach array of permanent magnets in the stator was designed to further improve the thrust of the linear actuator. The effect of the geometry of the permanent magnets on the thrust characteristics was investigated using electromagnetic field analysis based on the finite element method.

1 Introduction

Reciprocating motion is used in various places in the operation of mechanical products. Generally, to generate a reciprocating motion, the rotational motion of a motor or engine is often converted to a linear motion by means of a cam mechanism, piston crank mechanism, or rack and pinion. In such cases, however, there is a problem that the output is affected by the characteristics

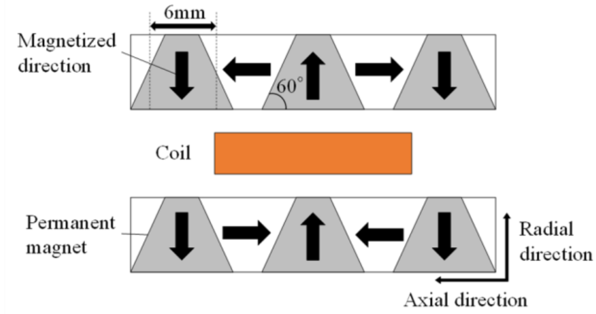
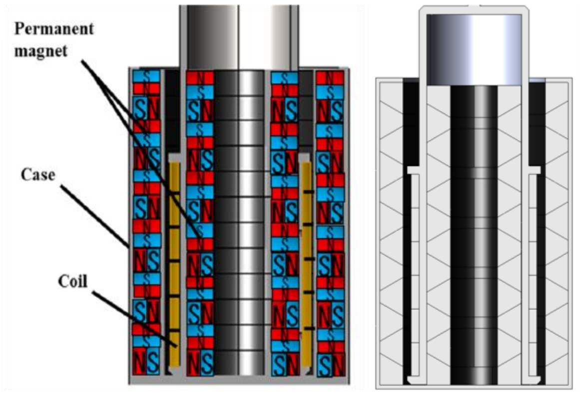


Fig. 1. Schematic of dual Halbach array



(a) Schematic of the actuator (b) Shape of the array
Fig. 2. Analysis model of liner actuators
With dual Halbach arrays.

of each mechanism. Performance improvement can be expected by changing the motion pattern, etc., but such variable mechanisms make the system multiple, so they are employed only in some high-performance products and rarely in general-purpose products. Therefore, a direct-drive linear actuator that can generate a high-precision reciprocating motion with a simple mechanism is being investigated. The authors have proposed and studied a linear actuator with a dual Halbach array of permanent magnets in the stator to realize a linear actuator capable of high-speed reciprocating motion.[1] In this report, the effect of changing the shape of the permanent magnets on the thrust characteristics is investigated.

2 Thrust Characteristics of Actuator Using Dual Halbach Array

A linear actuator was designed using a dual Halbach array for the stator permanent magnet array and a coil for the mover. A diagram of the Halbach array arrangement is shown in Figure 1, and a finite element model of the linear actuator is shown in Figure 2. In previous studies, the shape of the permanent magnet was set as a rectangle, but in this study, it was changed to a trapezoidal shape to investigate thrust characteristics. The coils in the actuator are assumed to be six; the six coils are connected to a three-phase inverter, with the first and fourth coils from the top connected to the U phase, the second and fifth to the V phase, and the third and sixth to the W phase. The number of turns in each coil is 33 turns. The current amplitude was set to 20 A. For the magnetic field analysis, the electromagnetic analysis software JMAG was used to analyze 25 steps with a valve lift of 24 mm and a movement of 1 mm every 0.1 second per step.

3 Conclusion

The results of the analysis confirmed that thrust could be generated even when the cross-sectional shape of the permanent magnets was changed from rectangular to trapezoidal in a model with a dual Halbach array of permanent magnets and three-phase AC as the current condition. The average thrust in this model was 53.8 N. The trapezoidal model had 1 N greater maximum thrust than the rectangular model. In the future, we will conduct a detailed study of the effect of the permanent magnet arrangement of the stator on the thrust characteristics.

References

[1] Y. Sato, H. Kato and T. Narita, Dynamic Valve Mechanism for Spark Ignition Engine Using Linear Motor (Fundamental Study on Shape Modification): Proceedings of the Japan Society of Mechanical Engineers Kanto Branch General Meeting 2019.25. Japan Society of Mechanical Engineers, 2019. p. 19G10.