3phase Linear Actuator in Magnetically Lavitated Linear Slider with Non-Contact Power Supply

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***Abstract*—This paper presents a linear actuator which magnetically levitatated a linear motor using non-contact power supply. A prototype of the system is designed and implemented. The simulation results confirm the validity of the proposed system**

I. INTRODUCTION

In recent years, manufacturing processes are required to use a clean room in various field of research and development., e.g., pharmaceutical items, semiconductor, etc. In addition, magnetic levitation slider system, without mechanical contact, has been utilized in many places in the clean room by taking advantages of dust generation prevention, easy maintenance and lubricant cost reduction. In order to construct such a transportation system, we consider a system that has a mechanism for floating and driving control on the slider part. For this system, it is able to supply electric power to the slider part for floating with noncontact to the driving part. There are two methods for supplying power to the slider, that is, onboard battery installation and contactless power supply. On the one hand, by installing a large battery to the system, there is a limitation of battery operational time as well as additional weight of the system. On the other hand, contactless power supply is considered as an alternative potential method for supplying power to the system.

This research focuses on the driving mechanism for moving slider without any mechanical contacts. This paper is organized as follows, Section II gives a brief overview of a design of magnetic levitation linear actuator system. Section III demonstrate a production of linear actuator. Section IV gives a demonstration of a driving experiment. Section V shows a simulation results of the proposed system. Finally, conclusion is given.

II. DESIGN OF MAGNETIC LEVITATION LINEAR ACTUATOR SYSTEM

A. *Magnetic levitation linear slider*

Fig. 1 shows the basic design of the magnetic levitation linear slider. The slider system consists of three mechanisms: magnetic levitation mechanism, contactless power supply mechanism, and linear actuator mechanism.

B. *Stator*

Two guide rails are used to guide magnetic flux paths of the HEMs are mounted on the stationary support structure as shown in Fig 1. The supported linear moving distance of the prototype platform is 30 [cm]. The support structure is made from A6061 Aluminum and SS400 steel. The rotor is mounted on the stationary support structure. The rotor is driven by using an electric motor which is mounted on the stationary support structure. The motor and the rotor are coupled using a belt drive. It is expected to use magnetic bearings and direct coupling between rotor and motor to avoid mechanical contacts between moving and stationary components.

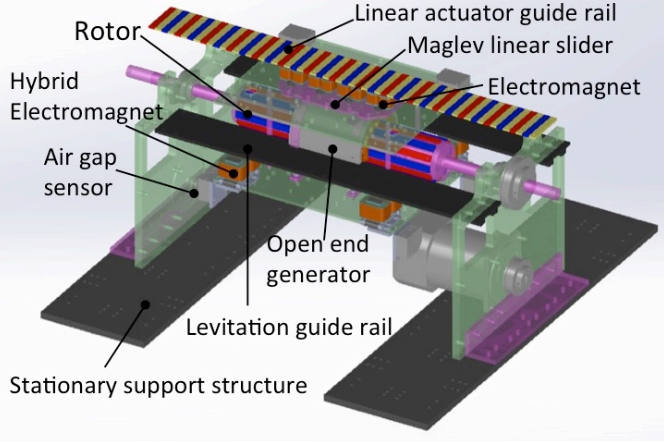

Figure 1. Overall image of magnetic levitation linear slider

C. *Magnetically levitated linear moving platform*

The levitated platform contains four major elements of the system, which includes HEMs, air gap sensors, the stator of the open-end generator and the linear motor. The HEMs, the open-end generator, and the linear motor are custom designed to the MagLevLS platform. The top plate of the levitated platform is made from A6061 Aluminum, and the bottom plate of the platform is made from SUS304 stainless steel. Stainless steel was used to increase the strength of the platform and Aluminum is used to reduce overall levitated weight. The top and the bottom plates are connected using rods. The mover of the linear motor is mounted on the top plate. The four HEMs used as actuators for the levitation which are mounted at four corners of the platform as shown in Fig. 1. A laser distance sensor is mounted close to each

HEM to measure the air gap between HEM and the guide rail. The stator of the open-end generator was mounted between the top and the bottom plates.

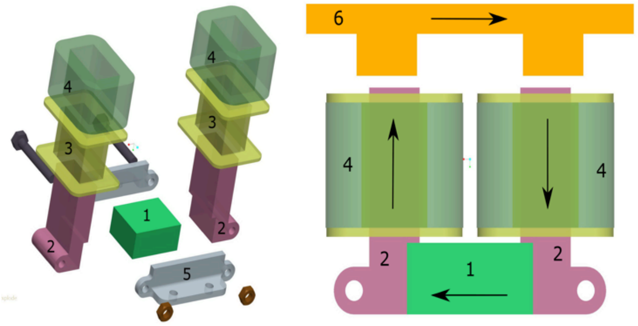

Figure 2. Guide rail for levitaion and HEM (1. N50 permanent magnet, 2. 23ZH100 soft magnetic steel core, 3. Plastic bobbin, 4. Copper coil, 5. Mounting plate, 6. Guide rail.)

D. *Magnetic levitation mechanism*

The HEM used for the magnetic levitation mechanism is a combination of a permanent magnet and an electromagnet. By adjusting the gap of the permanent magnet by the magnetic force of the electromagnet in the steady state, it plays the role of enabling the zero power control to float only by the attractive force of the permanent magnet. The shapes of HEM and guide rails and magnetic flux paths are shown in Fig. 2.

E. Long rotating permanent magnet array

A long rotating permanent magnet array is shown in the Fig. 3. The rotor uses six magnetic pole pairs which are mounted on the surface of the rotor. The base material of the rotor is made from SS400 soft magnetic steel. The rotor is rotated using an AC electric motor. The permanent magnets for the rotor are the N35 type. Each of them has dimensions of 3×10×60 [mm]. These permanent magnets are magnetized in 3[mm] direction. The red color and the blue color faces shown in Fig. 3 which represents the north and the south poles of the permanent magnets. The design of the rotor was influenced by the availability of suitable permanent magnets for the design.

F. Non-contact power supply mechanism

An open-end generator is used to achieve non-contact power transfer to the levitated platform. The non-contact power transfer system includes the stator core of the open-end generator mounted on the levitated platform as shown in Fig. 1. A permanent magnet rotor mounted on the stationary structure of the MagLevLS system. It was used to generate electrical power in the coils of the open-end generator. The length in the x-direction of the generator core is 100 [mm]. The open-end generator winding consists of two phases arranged in 180-degree phase angle. Each phase has 120 turns wound using 0.5mm copper wire. The core of the open-end generator was manufactured using ABS for the final prototype. Fig. 3 shows a basic 3D design of the open-end generator as well as stator mountings.

III. PRODUCTION OF LINEAR ACTUATOR

A switched reluctance linear motor is used to move the levitated platform in a direction. The motor design consists of 3 individually controlled electromagnets as a mover and an array of permanent magnets as a stator. The mover is mounted on top of the levitated platform. Each electromagnet consists of two coils connected in series. The stator consists of permanent magnets, and SS400 strips is mounted as shown in Fig. 4. Type N35 permanent magnets are used in the system. It has dimensions of 3×10×60 [mm] and magnetized in 3[mm] direction. The voltage of the evaluation board (NUCLEO-F401RE), the DC motor driver IC (TA 7291 P) and the NAND circuit IC (SN 74 HC 00 N) as shown in the Fig. 5.

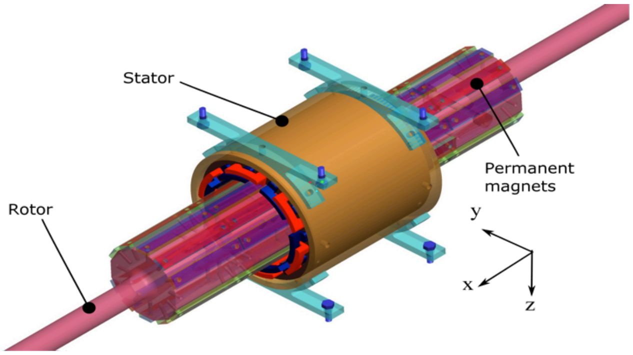

Figure 3. Open-end generator

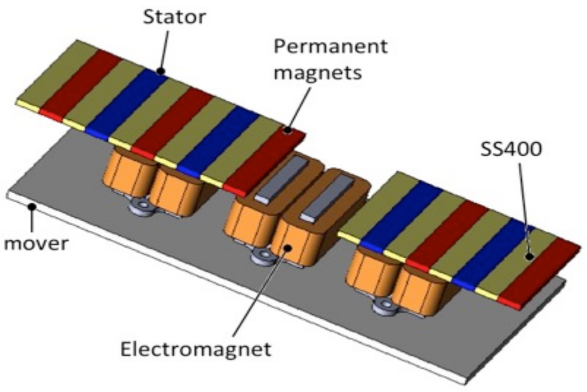

Figure 4. Linear actuator

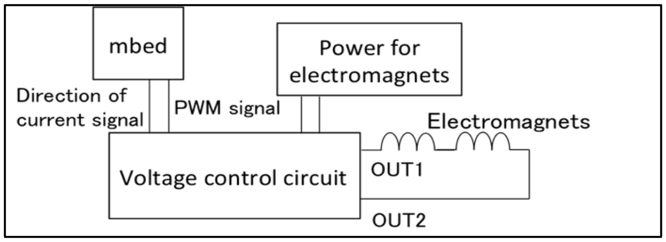

Figure 5. Voltage control circuit

IV.DRIVING EXPERIMENT

The current in Fig. 6 was supplied to each coil. Next, the displacement of the linear actuator was measured. The measurement result is shown in Fig. 7, it is seen that the ideal value and the measured value were almost the same. Hence, the experimental result confirms that our proposed linear actuator can be operated.

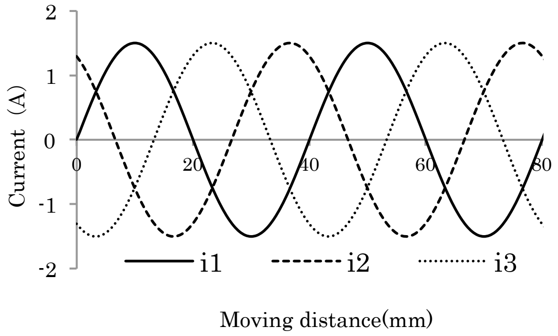

Figure 6. Each current pattern of the electromagnet

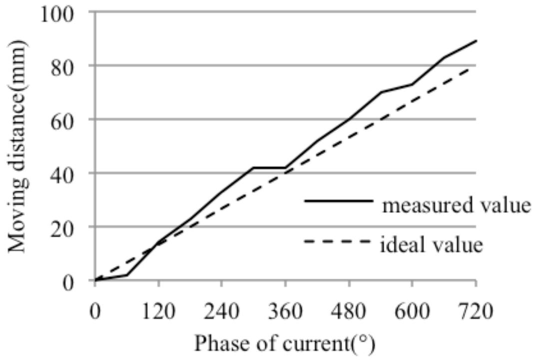

Figure 7. Driving experimental result

V. MAGNETIC ATTRACTION FORCE SIMULATION

In order to move the slider more smoothly, FEM analysis was performed with the omanko magnetic field analysis software JMAG using a model to investigate the relationship between the current phase and the stable point. Two materials of SS400 and ABS were used for the core material. Fig. 8 and Fig. 9 show the analysis results when the current, as shown in Fig.6, was applied .

VI. CONCLUSION

From the simulation results, it is necessary to change the material as well as the shape of the iron core in order to smoothen the operation of the linear actuator. In this experiment, only the linear actuator was used without being installed on the levitation. This is because the attractive force of the linear actuator inclines the entire slider. From this fact, it is considered that a floating method changes the attractive force generated by the linear actuator.

ACKNOWLEGEMENT

I am deeply grateful to Chiramathe Nami.

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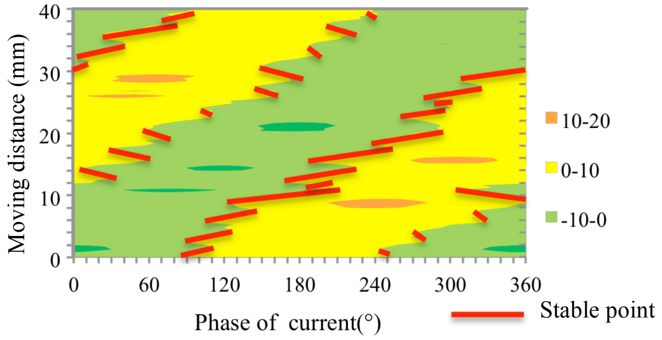

Figure8. Relationship between stable point and phase of current (Core:SS400)

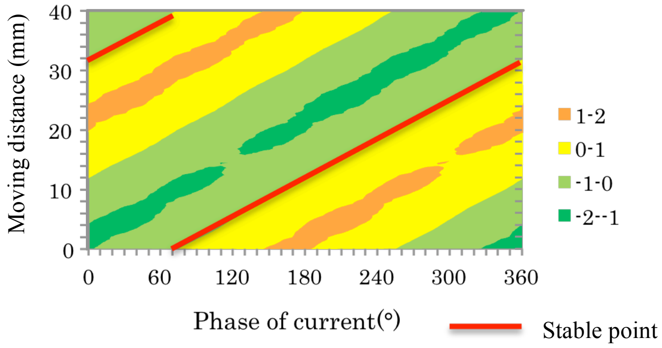

Figure9. Relationship between stable point and phase of current (Core:ABS)