Noncontact Positioning Mechanism Using Pinning Effect and Electromagnets

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This paper describes a proposal of noncontact positioning system using pinning effect of superconductor. The proposed system consists of a superconductor, electromagnets, and actuators. The levitation force is obtained from the pinning force between a superconductor and an electromagnet and is controlled by a current switch. The pinning of electromagnet is not used for only levitation, but hold the position of the levitated object. The positioning system is moving like an inchworm system. A prototype of proposed system is introduced and some experimental results are shown. These results verify the feasibility of the proposed noncontact positioning system.

Key Words: noncontact positioning system, pinning effect, inchworm mechanism

1. Introduction

There are many kinds of noncontact levitation mechanism [1 and 2]. Noncontact levitation mechanism is effective for reducing friction, abrasion, maintenance, vibration, noise, and so on. To realize noncontact levitation electromagnetic suspension system (EMS system) is a major method because of its easy generation and control of force. However, usual magnetic levitation systems need closed loop control, and its device becomes larger and complicated. Superconductive magnetic levitation mechanism can get the levitation stability without active control and can easily realize levitating. Furthermore, a permanent magnet levitating over high temperature superconductor has a pinning force and has a self positioning function by itself. Levitation system using pinning effect is very simple and useful system because of no need of the feedback control and enough levitation force. Some positioning systems with pinning effect have been proposed [3-5]. However systems proposed in [3 and 4] need additional driving or positioning mechanism, and the system proposed in [5] has not enough performance.

This paper is a proposal of noncontact positioning system using pinning effect of superconductor. The proposed system consists of a superconductor, electromagnets, permanent magnets and actuators. This mechanism is an improved device of the system proposed in [5]. The levitation force is obtained from the pinning force between a superconductor and an electromagnet and is controlled by a current switch. The pinning of electromagnet is not used for only levitation, but keeping the position of the levitated object. The positioning system is moving like an inchworm system.

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2. Preparation of Manuscript

Three types of experimental device were made. They use electromagnets for their levitation mechanism. For their positioning mechanism, one of them uses a piezoelectric actuator, and other two devices uses electromagnets and permanent magnets.

2.1 Experimental Device I

The A photograph of the experimental device I is shown in Fig. 1. As shown in the figure, two electromagnets are connected by an actuator of piezoelectric which changes the length between left and right magnets. Two superconductors are used for levitation and positioning because of its size. Two electromagnets are controlled by on-off switch and so is the actuator.

An electromagnet has an E shaped ferrite core and a coil of 150 turns. Its size is about 10mm cubic. The flux under the core is 60mT at the current of 2A. The piezoelectric actuator is made by NEC Tokin and the length of 45mm. Maximum displacement is 28 μm at the voltage of 150V.

The principle of the positioning mechanism is shown in Fig. 2. These illustrations are views from the top of the device and indicate the procedure when the device is moving to the right. Each illustration explains the procedure as follows.

1. The device is in the initial state which means the device is stably levitated by pinning effect. Two magnets are on and the actuator is expanded.
2. The right magnet current is changed to turn off.

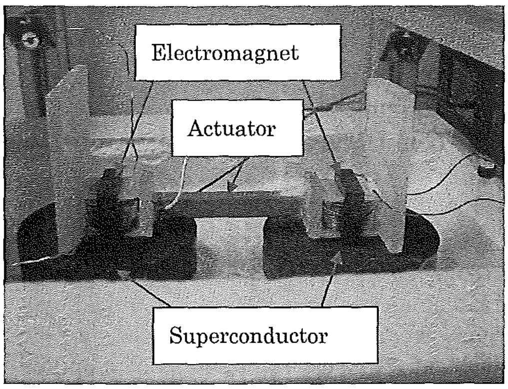

Fig. 1 Photograph of device I (using piezoelectric)

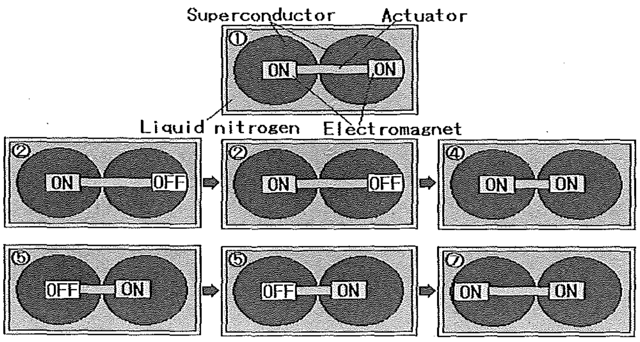

Fig. 2 Positioning mechanism for device I

3. The actuator is contracted and the right magnet moves to the left, because the left magnet is held at same place by pinning effect.

4. The right magnet is turned to on, and is held by pinning effect.

5. The left magnet is turned to off.

6. The actuator is expanded and the left magnet moves to the left.

7. The right magnet turned to on.

When the device is made to move to the right the inverse procedure may be adopted. This device has the problem that the piezoelectric actuator is weak in low temperature and easy to break.

2.2 Experimental Device II

A photograph of the experimental device II is shown in Fig. 2. As shown in the figure, the device II consists of three electromagnets, two permanent magnets, and springs. Three electromagnets are all used for levitation. All coils are wound about the horizontal axis. The magnets A and C are only used for levitation. Spring force and the attractive force between the magnet B and two permanent magnets are used for the positioning of the device. Two permanent magnets are attached to the electromagnet A and C, and their direction of the magnetic pole is set as the same poles are inside. This device uses the electromagnet B shown in the figure as the actuator for positioning.

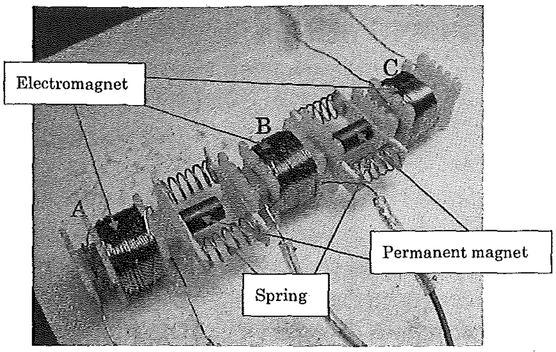

Fig. 3 Photograph of device II (using electromagnet)

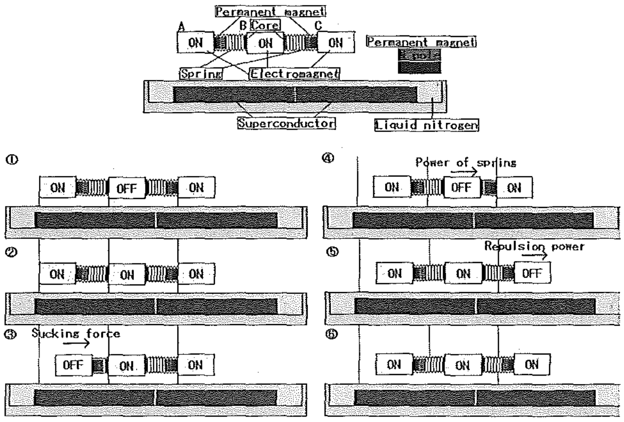

Fig. 4 Positioning procedure for device II

The principle of the positioning mechanism of the device II is shown in Fig. 4. When the permanent magnets face the N pole to the inside, the rightward moving procedure is as follows

1. After cooling the superconductor, the device is set over the superconductor as is levitated. The magnet A and C is on, B is off. The springs are set to the natural length.

2. The electromagnet B is excited as the flux passes from the left to the right.

3. The A is turned to off. As pinning effect is removed and the attractive force between the B and the left permanent magnet is acted to the A, the A moves to the right.

4. The A is turned to on and the B is turned to off. As the pinning effect of the B is removed, the B is positioned as the center between the A and B.

5. The B is turned to on and the C is turned to off. As pinning effect of the C is removed and the repulsive force between the B and the right permanent magnet is acted, the C moves to the right.

6. The C is turned to on. And after that the B is turned to off and the state returns to the initial.

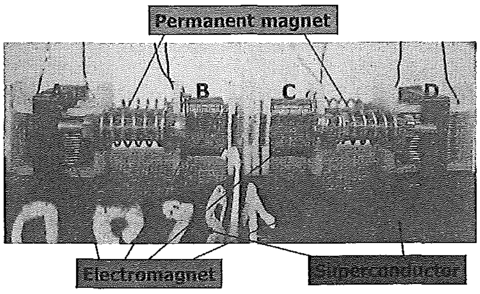

Fig. 5 Photograph of device III

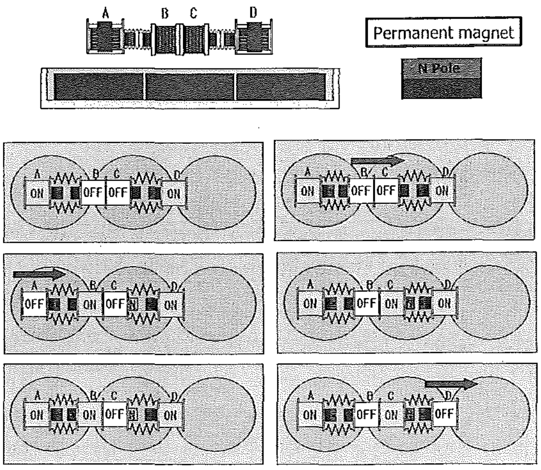

Fig. 6 Positioning procedure for device III

The device can be moved to the leftward by the inverse current adoption to the magnet B.

2.3 Experimental Device III

The device III is an improved version of the device II. The photograph of the device III is shown in Fig. 5. The differences are the number of the coil and the core and the direction of the coils in both side of the electromagnets. The device III has the structure that is easy to generate the levitation force by both sides of the magnets.

The procedure for positioning is shown in Fig. 6. It is almost same as the device II. The device III can be controlled more delicately than device II. The centre magnet divided into two coil and they can be excited individually.

3. Experiments

3.1 Experiment of Levitation

First, levitation performance of the electromagnet has been examined. The experimental setup is shown in Fig. 7. An electromagnet is set on the superconductor after cooling it. The vertical movement of the magnet has been measured by a laser displacement sensor located upper the magnet during the switch of the magnet has been turned to off and on repeatedly.

3.2 Experiment of Device I

First, The positioning examination was carried out using the device I. The result is shown in Fig. 9. The inputs of the magnet and the actuator and the output of laser displacement sensor which measures the movement of the right magnet are recorded.

As shown in the figure, we can see that the right magnet is driven to the left direction. The feasibility of the proposed positioning system was verified. The movement, however, is different from considered. The movement does not caused by the voltage of the actuator, but the on-off signal of the right magnet coil. The reason is considered as the pinning force is still acted when the current is zero. Also we may consider that as levitation was not realized, nonlinear friction force between the magnet and the superconductor might apply.

3.3 Experiment of Device II

A result of positioning experiment of the device II is shown in Fig. 10. The graph shows three input signals of the magnets and the displacement of the right magnet. As the input signals are pulse wave, the displacement is pulse form. And it vibrates when the signal of the magnet C is on. It is caused by the spring which connects the magnets. However it is clearly confirmed that the device moves step by step.

The actuator which made of electromagnets, permanent magnets, and springs is useful for this positioning device because of light weight, simple structure, and endurance for cold circumstance.

3.4 Experiment of Device III

An experimental result of the device III is shown in Fig. 11. Recorded signals are four switch signals of the magnets and the displacements of both side magnets as shown in the upper figure.

Compare with the result of device II, there is no vibration during the positioning process. The device III has rods in the center of the springs as shown in Fig. 5. This rod may generate the friction force and suppress the vibration.

As shown in Fig. 11 we can seen that the displacement of the left and the right magnet is different. The reason is that the left and the right attractive forces between the electromagnets and the permanent magnets may be different. However it is clearly confirmed that the device moves step by step.

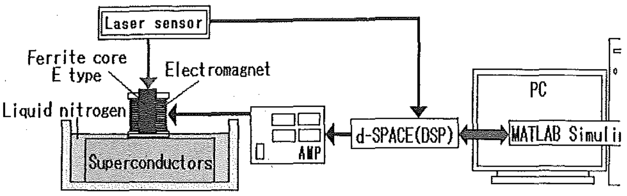

Fig. 7 Experimental setup for levitation

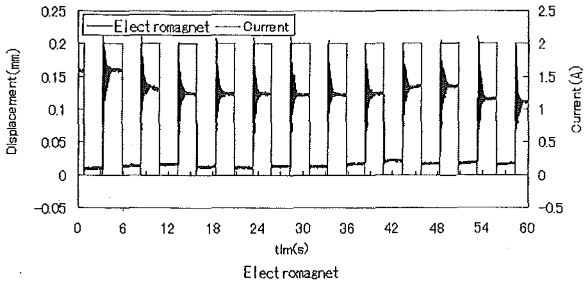

Fig. 8 Experimental result for vertical levitation

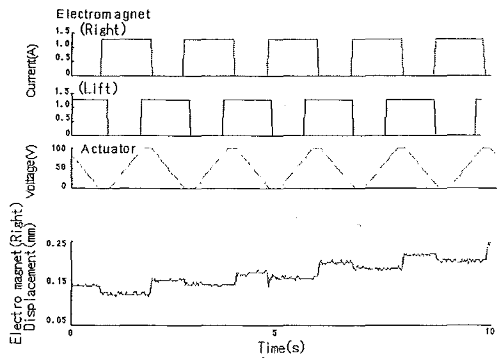

Fig. 9 Experimental result of device I

3. Conclusion

Three new types of noncontact positioning systems using pinning effect of superconductor have been proposed and the feasibility of the proposed system was verified by experiments. The followings are conclusion of this work.

A device using piezoelectric has been made and succeeded about positioning examination. However we cannot confirm that the device maintains noncontact state and the motion is difference from predicted.

Devices using actuators of electromagnets and permanent magnets have been made and also succeeded about positioning. The actuator may be effective for the positioning and levitation, however the vibration remains because of using springs.

Precise and smooth noncontact positioning system using superconductor is the goal of this work. They will be a further study.

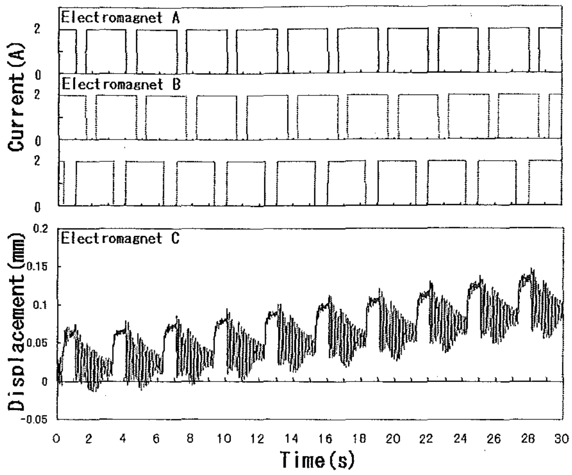

Fig. 10 Experimental result of device II

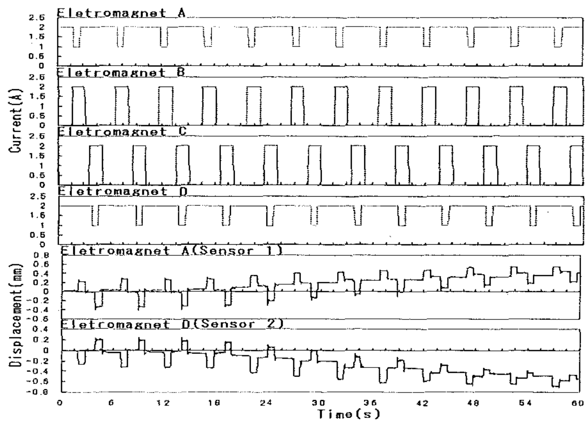

Fig. 11 Experimental result of device III

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