Possibility of Positioning Mechanism for Superconductor Levitation System using Stick-slip Mechanism

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***Abstract*-- In this paper, a new type of positioning mechanism for superconductive magnetic levitation system is proposed. The proposed mechanism uses an impact driving energy against pinning force for positioning. When a permanent magnet levitates over a superconductor, the pinning force works tightly between a superconductor and a levitating permanent magnet. If the system has an impact driving energy against pinning force, the pinning force will be broken and the permanent magnet will move to next pinning points. To begin with, we propose a typical positioning mechanism. Next, we explain the principle of the positioning mechanism followed by the experimental method and system. Finally, some basic experimental examinations are introduced and the possibility of the proposed positioning mechanism is examined.**

***Index Terms*—Superconductor, Magnetic Levitation, Impact Drive, Stick-slip Mechanism**

I. Introduction

Magnetic levitation mechanisms have many advantages such as reducing friction, abrasion, and noise. In addition, they are easier to maintain, and can be operate at a faster speed.

In magnetic levitation mechanism thinking about practical use, there are two types: one is a normal conductive levitation system, the other is superconductive levitation system. Normal conductive levitation systems must have a feedback loop to keep levitation and tends to be a complicated system. On the other hand, superconductive magnetic levitation mechanism is able to sustain the levitation stability without active control and can levitate easily. Furthermore, a permanent magnet levitating over a high temperature superconductor has a pinning force which can position the levitated magnet.

In this paper, a new type of positioning mechanism for the permanent magnet levitation system over high temperature superconductor is proposed and tested upon its feasibility. We propose an impact driving technique for positioning.

II. Proposed Noncontact Positioning System

A. Type 2 Superconductor

In this experiment, objected for a defective meisner condition (levitation with pinning) with type 2 superconductor. We used YBa2Cu3Ox without pinning center, the quantum magnetic flux can goes through. YBa2Cu3Ox achieves a superconductive condition at -181 (℃). It is cooled down with liquid nitrogen (the boiling point – 196 (℃)). When a superconductive condition is realized, a permanent magnet is levitated directly on top of it. In this experiment, used YBCO d=48mm t=10 mm.

B. Pinning Force and Levitation with Pinning

Fig.1 shows an illustration of the type 2 superconductor levitation and its pinning points. Pinning points are the place where there exist defects, impurities, and where there is a small cohesion energy even under a superconductive condition.

Compared with the quantum magnetic flux in normal conductive part and it in superconductive part,the energy of the latter is higher than that of the former. Therefore, if the quantum magnetic flux moves from normal conductive part to superconductive part, the pull back power will work the flux. This is called a pinning effect and its power is known as a pinning force. This condition as shown in Fig.1 is called pinning levitation. In pinning levitation, magnetic fluxes are trapped in the pinning points.

Furthermore, the pinning levitation has self positioning function by itself. If the system can generate a large enough power to exceed the pinning force, it can have an active positioning function by slipping the pinning point. In this study, we generate the large power by impact mechanism and make the superconductive positioning mechanism to slip pinning points of trapping magnetic flux.

C. Principle of Positioning

When a magnet is levitating over a superconductor, impact forces may drive the magnet. Fig. 2 shows the principle of the driving mechanism. First, a permanent magnet is levitated (first diagram, Fig.2). Then a fast impact force is added to the superconductor by a piezoelectric actuator (second diagram, Fig.2). At the moment, the movements of the superconductor and the magnet are different, and the levitated magnet is slipped by impact force. The movement of the superconductor is larger than that of the magnet. When the superconductor returns to the original position by a slow movement (third and fourth diagram, Fig.2), the magnet position changes from the initial position. The position of the levitated magnet changes with the superconductor during this time. In other saying, the levitated magnet sticks to the high temperature superconductor. The repetition of the impact force and soft returning movement positions the levitated magnet. This repetition allows the magnet to move as a stick-slip mechanism.

III. MEASURING OF PINNING FORCE

A. Pinning Force Measurement System

This experimental system is shown as Fig.3. The system is mainly composed of X-Y stage to be able to move in highly precise manner, and of load cell to be able to measure a minute force. The X-Y stage put on the load cell draws a thread connecting to a levitated magnet that pinning force is working. On the other hand, the position of X-Y stage and the levitated magnet are measured by two laser sensors.

B. Experiment Result

At first, we cooled down a superconductor and levitate a permanent magnet at the middle of the center of superconductor. The levitated permanent magnet was drew with a thread connecting to X-Y stage, between right 1/4 and left 1/4 on both side of the diameter. We measured force with a load cell and the positions of X-Y stage and a levitated permanent magnet.

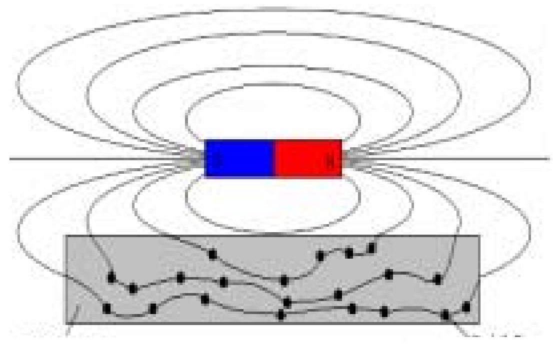

Fig.1. Pinning point and normal conduct positioning

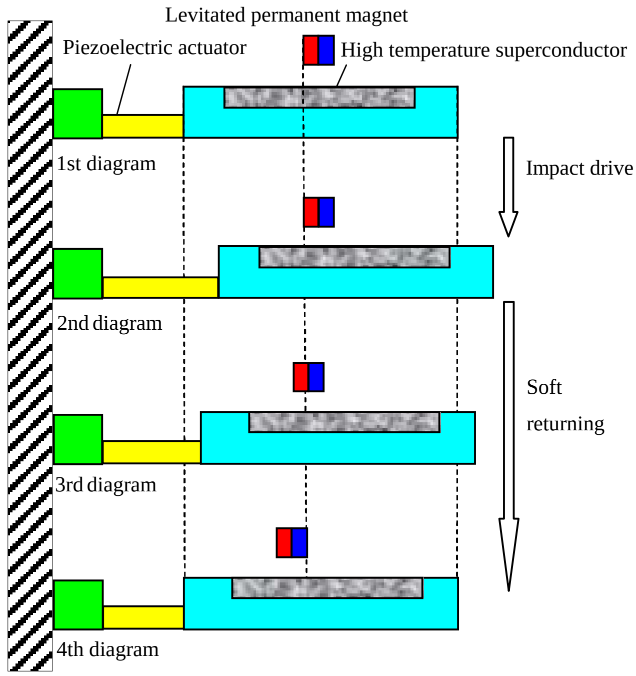

Fig.2. Proposed principle

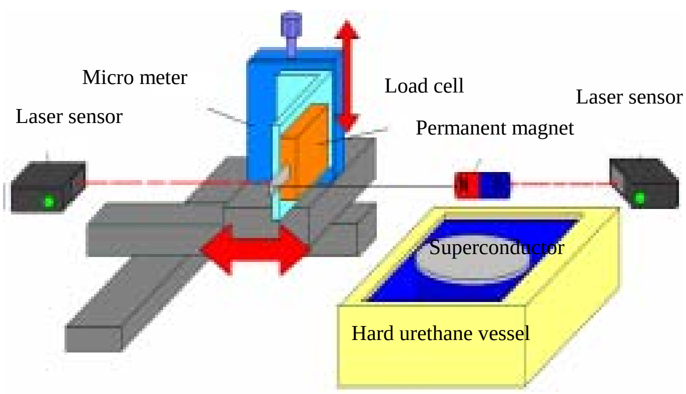

Fig.3. Pinning force measurement system

In 2 kinds of magnets at same size, a ferrite(d=10mm, l=10mm) and a neodymium(d=10mm, l=10mm), drew the X -Y stage at velocity of 0.5mm/s. The pinning force is measured as shown in TABLE.1. Compared with a ferrite and a neodymium's pinning force, a ferrite's value is less than that of a neodymium's value that its pinning force is divided by mass as shown in TABLE. Ⅰ. From this fact, the ferrite has advantage for the movement by the impact energy.

So, in this experiment, we will use the ferrite to check the principle of positioning.

TABLE Ⅰ

RELATION BETWEEN PINNING FORCE AND MASS

	ferrite d=10 l=10	neodymium d=10 l=10
Max. pinning force(gf)	1.61	2.71
mass(g)	3.77	5.85
pinning force(gf) / mass(g)	0.43	0.46

Ⅳ. EXPERIMENT OF POSITIONING

A. Experimental System

We used a piezoelectric element the reason why it has many advantages, especially, high-speed response less than 100 μs at extension and shrinkage

Furthermore, it has a displacement expansion function that can generate higher impact energy to amplify the produced impact power by a piezoelectric element as shown in Fig.5.

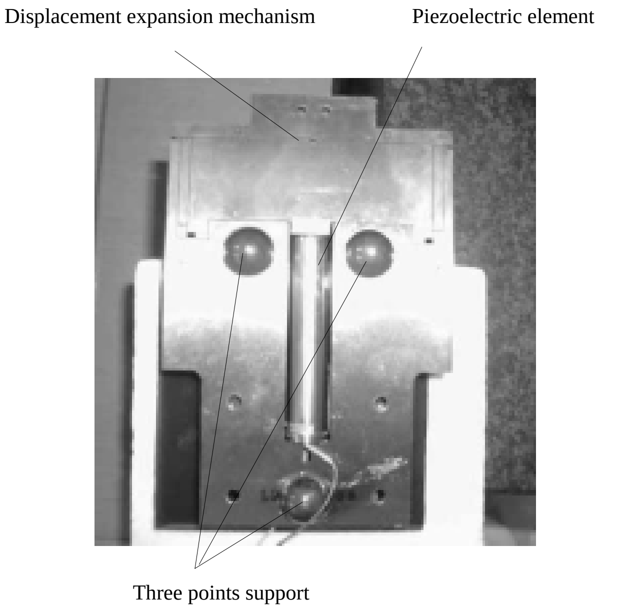

Fig.5. Piezoelectric actuator with displacement expansion mechanism

Fig.5 shows the backside view of the stage. There is the piezoelectric element as a shape of a cylinder among the three points support at the center of stage. A displacement expansion mechanism exists in upper part of both the piezoelectric element and three points support of stage as shown in Fig.5. The piezoelectric actuator is composed of all items with the stage. The appearance of the experimental system is shown in Fig.6. The system is composed of a superconductor, a permanent magnet and piezoelectric actuator. All items are installed on a stage, so we call this stage a piezoelectric actuator. Superconductor and refrigerant are to be stored in a hard urethane vessel.

Position of both the levitated magnet and the superconductor are to be measured by two laser sensors.

An output edge of a piezoelectric actuator connect to a fixed edge. A piezoelectric actuator expands rapidly in adding the step voltage to it, and a superconductor is driven by impact.

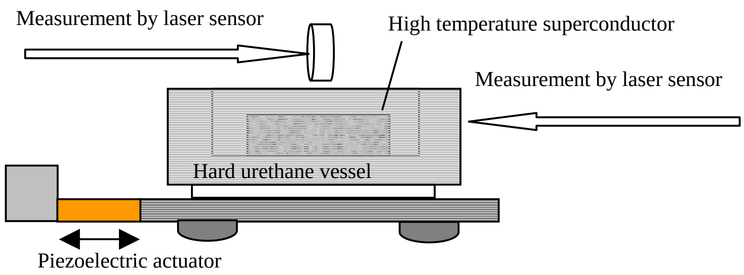

Fig.6. Impact driving experimental system

B. Performance of Actuator

The developed impact driving system produced and its displacement is shown in Fig.7. The piezoelectric element for impact energy source, by itself, stretches about 20 μ m at 100V. In this experiment, a stretch in static condition at 100V is 0.275mm, and that of in impact condition is 0.267mm in mean. From this result, in both condition, the piezoelectric actuator almost equal performed.

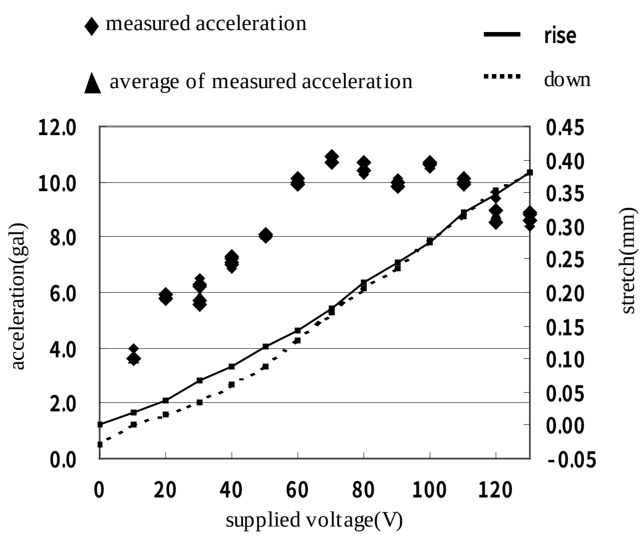

Fig.7. Performance of piezoelectric actuator

The displacement expansion function produced is about 13.8 times in length.

On the other hand, in this experiment, we can see that this system could produce maximum acceleration of 10.8(gal) at 70V and the acceleration from 0V to 70V increased in proportion to voltage rising.

Thus, the development of a displacement expansion system has been verified by a sufficient performance.

C. *Experimental Result*

Defined that E value is equal to acceleration (gal) multiplied by stretch(mm). Fig.8 shows the supplied voltage, displacement of one impact to permanent magnet, and E value.

We can see that the movement starts from 50V at supplied voltage, and near 1.0 at E value. At 70V in supplied voltage, the displacement of permanent magnet by 1 impact is 5.22 μm, and E value is 1.91.

From this experimental result, the movement of the levitated permanent magnet is concerned more deeply with not acceleration but E value as shown in Fig.8.

We can see that the experimental result is to be the proof of the proposed principle in 3 columns as shown in Fig9, the most upper column shows the supplied voltage, the second column shows the movement of the high temperature superconductor and the third column shows the movement of the levitated permanent magnet in the condition of supplied voltage being 100V, impact period being 5 seconds.

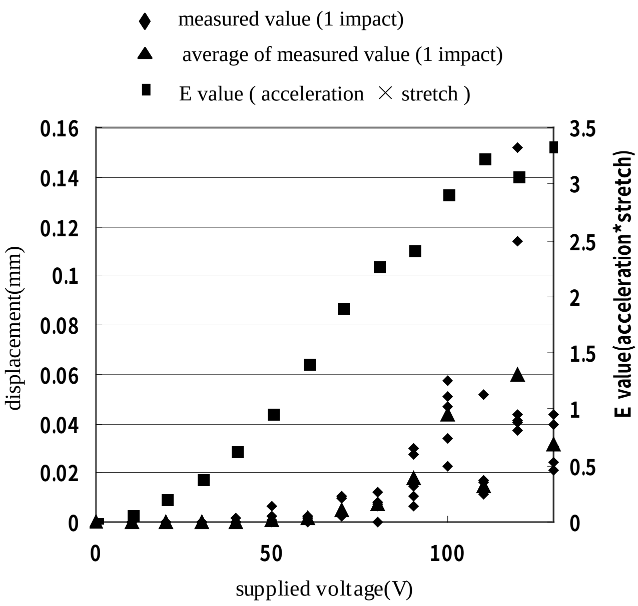

Fig.8. Relation with supplied voltage, permanent magnet's displacement and E value

V. CONCLUSION

A new prototype of the system was developed and some experimental examinations were carried out on the system. An experimental result shows the possibility of positioning mechanism for superconductor levitation system using our proposed principle, a stick-slip mechanism.

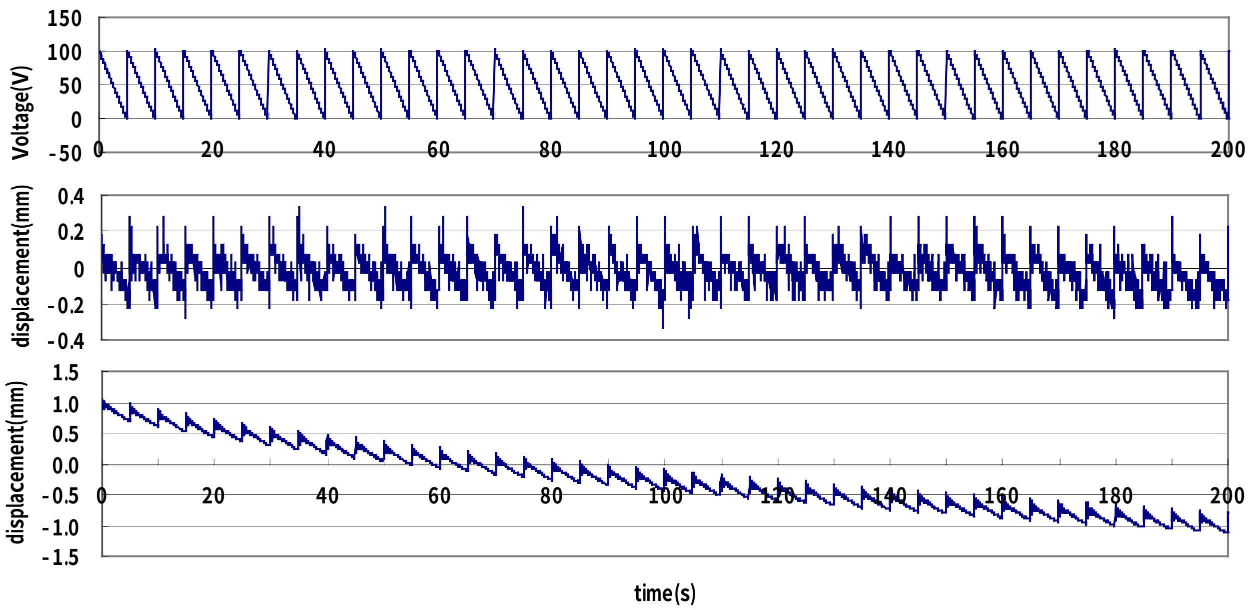

Fig.9. Supplied voltage
displacement of superconductor,
displacement of permanent magnet