Development of Multiple Small Linear Planar Motor System

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Abstract
A small linear planar motor based on Sawyer principle[(1)(2)] is developed to make an application as a moving tray. We constructed the planar motor system for performing coordinative operations with multiple planar motors. The construction of the planar motor is firstly introduced. We then investigated the static characteristics of the linear planar motor, such as the relationship between the current and the maximum thrust force (I-F curve), load characteristic and the positioning accuracy. The capability of movement of multiple planar motors synchronously was confirmed. Finally we gave an example of a 6-dof parallel mechanism loaded on three planar motors.

Introduction
With the rapid development in the field of precise industry, the performance of high speed and high accuracy operation in mechatronics apparatus is widely demanded. Recently the linear planar motor that can perform linear motions in XY directions of a plane is being used by more and more applications. Compared with traditional XY stage, the linear planar motor owns the advantages of long stroke, compact size, high speed, high precision, etc. Generally the applications in the semiconductor fabrication equipment and machining tool are well known. In this paper we consider using the linear planar motor to make an application as a moving tray which could convey goods in a line quickly and perform coordinative operations with multiple planar motors. Toward the target, the size about human's hand of the linear planar motor is expected, and it is important to control the multiple motors to perform operations synchronously.

A small linear planar motor is manufactured with a size of L80×W80×H28 (mm) and a weight of 750g. It includes two 3-phase linear stepping motors based Sawyer principle in X and Y directions respectively. The air bearing is used to float the motor (slider) on the toothed iron platen. By using a 3-phase stepping motor driver, the motor can move in micro-step method with high speed and high precision. We investigate the linear planar motor for studying all kinds of motor characteristics and evaluating some important characteristics in open loop mode, such as maximum thrust force, positioning accuracy, maximum speed, load, etc. In order to build the multiple planar motor system, three same linear planar motors are manufactured at the first. With controlling the mutual movements of the three planar motors synchronously, we performed the coordinative operations of a 6-dof parallel mechanism loaded on the three planar motors.

Construction of the Small Linear Planar Motor
The substance of the small planar motor is divided into a platen which is a stator part as a desktop and a slider which could move on the platen. The platen (Fig.1) is a thin flat iron plate with a pattern of convex teeth, the pitch of which is 2×2(mm). The grooves between the teeth are then filled with epoxies. The part of slider includes four same linear motor units, which are packaged into a frame at one surface. The diagonal two linear motor units are as a group of one motion direction. With two groups equipped vertically, the slider could move in XY directions. The structure of the slider without the frame is shown in Fig.2. The linear motor unit is mainly a three-phase linear stepping motor (Fig.3), which consists of multi-tooth poles, coils, permanent magnets and a yoke. The photos of the small linear planar motor are shown in Figs.4, 5 and 6. The slider owns the size of L80×W80×H28 (mm). To prevent influences from friction, compressed air (about 0.2MPa) is poured from the holes of the bottom of the slider (Fig.4) to keep a gap (about 15μm) floating the platen. By switching off the current value in the 3-phase coils appropriately, the slider can make a step movement quickly.

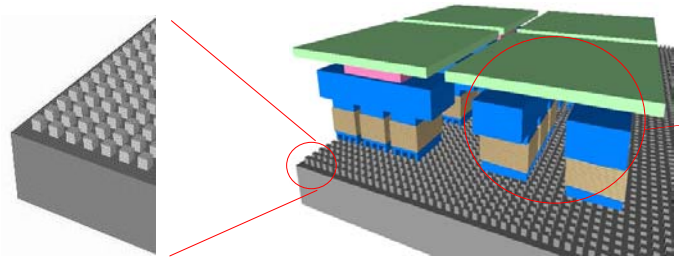

Fig.1 Structure of the platen

Fig.2 Structure of the small linear planar motor

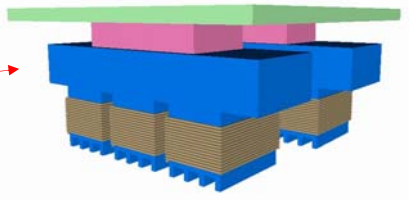

Fig.3 Structure of the 3-phase linear stepping motor

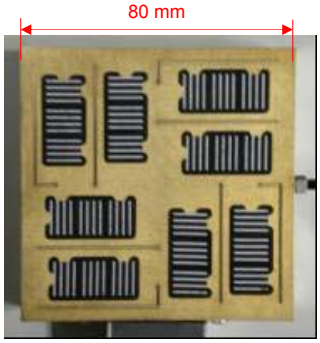

Fig.4 Photo of the bottom of the slider

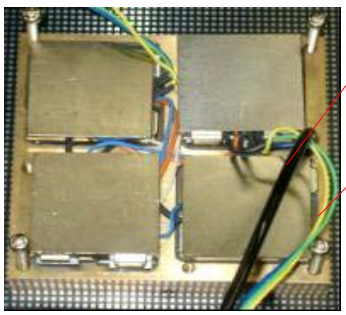

Fig.5 Photo of the top of the slider (without the top cover)

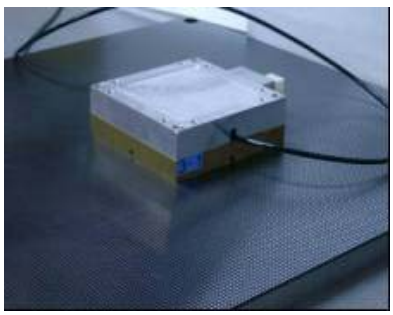

Fig.6 Photo of the small linear planar motor slider

The schematic of the multiple planar motor system is shown in Fig.7. A set of air compressor system is used to offer suitable compressed air to every slider. To drive the planar motors, we use a special control board to generate a series of pulse sets, which is input to three-phase linear motor drivers belonging to every slider. The special board could not only generate the pulse sets we commanded but also generate several series of pulse sets toward multiple planar motors at the same time. It is important for the system to perform coordinative operations with multiple planar motors.

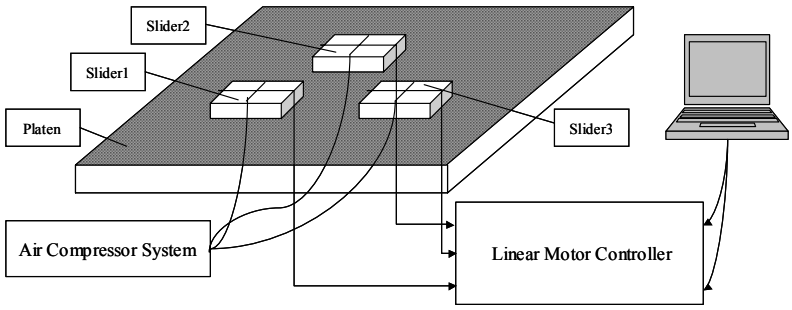

Fig.7 Schematic of the multiple planar motors system

Characteristic Evaluation

We evaluated open-loop characteristics of the small planar motor, such as floating gap, maximum static thrust force, positioning accuracy, maximum speed, load characteristics and stiffness. The relationship between the current and the maximum thrust force is shown in Fig.8. We can get a maximum thrust force of above 12N while the excited current is above 2A. It seems that the I-F curve is linear approximately. Fig.9 shows the relationship between the load and the floating gap/stiffness. The floating gap is 19μm in the no-load status. We confirmed the load capability until 18kg, but if we assume that the floating gap of above 10μm is needed, we can get the maximum load of 9kg and stiffness of above 7N/μm. The specifications of the small linear planar motor are shown in Table.1.

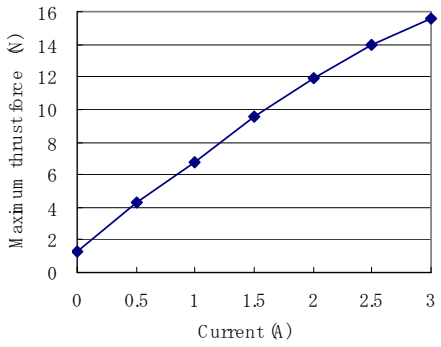

Fig.8 Relationship between the current and max thrust force

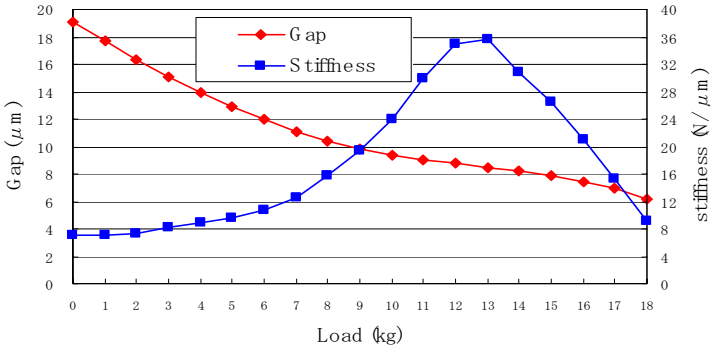

Fig.9 Relationship between the load and floating gap/stiffness

Table 1 The specifications of the small linear planar motor

Item	*Value*	*Item*	*Value*	*Item*	*Value*
Size of platen (mm)	1000×1000	Floating gap	19μm	Maximum velocity	0.25m/s
Pitch of platen (mm)	2×2	Excited current	2A	Instruction resolution	42μm
Size of slider (mm)	L80×W80×H28	Maximum thrust force	12N	Repeatability	20μm
Mass of slider	750g	Load capacity	88N	Positioning accuracy	50μm

Coordinative operation with multiple planar motors

The conception drawing of the complicated coordinative operation using multiple small planar motors is shown in Fig.10. With three small planar motors combined a parallel mechanism, a multiple-dof equipment can be produced. Toward an object on another planar motor, the multiple-dof equipment can perform the operation of machining or measurement precisely. The actual example we made is shown in Fig.11. A 6-dof parallel mechanism using three planar motors can be performed.

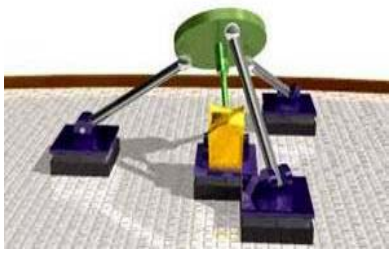

Fig.10 The conception drawing of the coordinative operation using multiple small planar motors

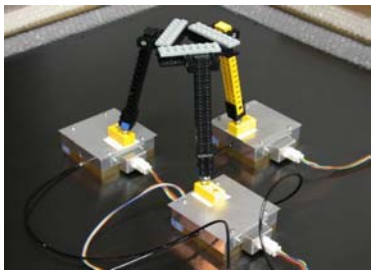

Fig.11 The example of a 6-dof parallel mechanism

Conclusions

A small linear planar motor with the size of L80×W80×H28 (mm) is developed. By evaluating the open-loop characteristics of the planar motor, it can be confirmed that the small planar motor could be used as a moving tray. As a result, we got the maximum thrust force of 12N, the positioning accuracy of 50μm and the maximum speed of 0.25m/s. We also confirmed the movement of multiple planar motors synchronously, which is a very important feature for an application of coordinative operations.

Acknowledgement

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References

(1) B.A. Sawyer. (1969) ‘Magnetic positioning device’ US Patent 3,457,482.
(2) W. Hinds. Et al. (1973) ‘The sawyer linear motor’ Proceedings of The Second Symposium on Incremental Motion Control Systems and Devices. W-1.W-10