Design and Control of Versatile Micro Robot for Microscopic Manipulation

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Abstract:
In this paper, we describe design and control of the newly developed versatile micro robot which can be applied to microscopes. In order to provide microscopic manipulation, the unique locomotion mechanism which is composed of four piezo elements and two electromagnets is proposed. Here two legs arranged on cross each other are connected by four piezo elements so that it can move in any directions, i.e. in X and Y directions as well as rotate at the specified point precisely with the manner of inch worm. Moreover the combination of particular wave forms for piezo elements can provide "arc trajectory", that is important for the micro manipulator to keep its tip end within the microscopic area. In the primary experiments, several performances such as motion accuracy, reliability and precise dexterity are checked by the CCD camera based microscope image tracker. The design procedure, basic performance and biomedical application of this tiny robot also are discussed to open the new field for micro-robotics in precision region.

Key word : versatile micro robot, piezo element, electromagnet, arc trajectory, microscopic manipulation

1. Introduction

In the field of micro system and precision engineering, there are many reports concerning micro robotics and its trial applications. Some of them are based on the advanced technology including micro battery, micro motor and tiny computational facility[1], the others are made by the sophisticated precision machining techniques[2-4] However it is still very important to find the industrial application where such micro robots can provide effective benefits. It is well known that the *Desk top Factory* [5] has the potential application not only for the production engineering but also for the chemical and biotechnology. For these years, our group has developed insect size robots equipped with various micro tools and instruments[6]. Particularly the in-situ micro processing in the scanning electron

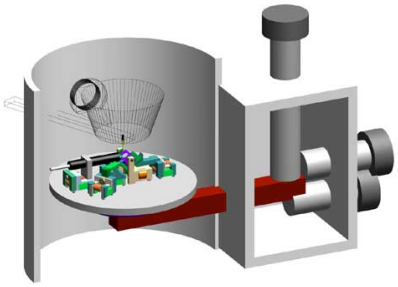


Fig.1 Flexible micro processing system by micro robots in SEM vacuum chamber

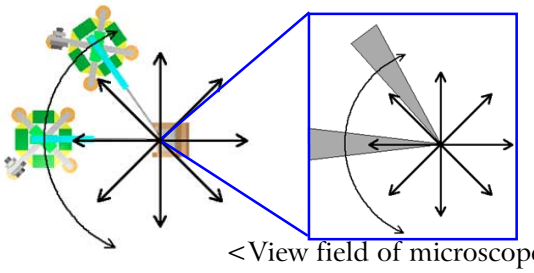


Fig.2 Motion pattern required at microscopic operation

microscope is one of interesting application although it needs much of cost to install the fine mechanism into the small chamber[7]. For these years, we have proposed the flexible micro-processing system organized by multiple miniature robots in SEM vacuum chamber as shown Fig.1[8]. And we provide a simple manipulation system for micro objects and micro processing system assisted by fiber guided YAG-laser. In these previous experiments, we concluded that we needed to arc trajectory motion as well as XY orthogonal motions with facing center to keep its tip end within the microscopic monitoring area. In this paper, we describe design and control of the newly developed versatile micro robot which can move any direction. In the experiment, several performances such as motion accuracy, reliability and precise dexterity are checked by the CCD based image analyzer.

2. Design and Principle of Versatile Micro Robot

2-1. Design and Structure

Fig.2 shows the motion pattern required at microscopic operation and in order to realize these motion pattern at the same time, we need to design the structure which can move in XY directions and in rotation independently.

Fig.3 shows the structure of the micro robot. Here two closed loop electromagnets which are arranged to cross each other are connected by four piezo elements so that it can move in any direction with the manner of inch worm. Also we design the special joint at one of the 4 legs to get the stable 4 legs contact on the surface at once.

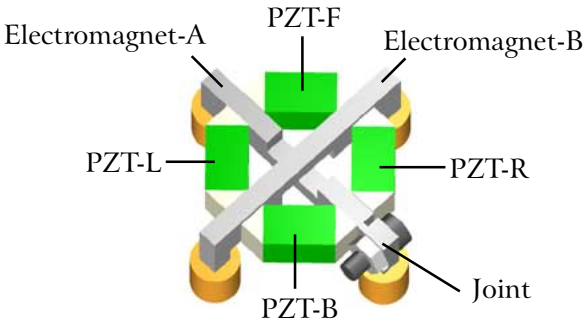


Fig.3 Structure of versatile micro robot

2-2. Principle of Versatile Motions

(1) Basic Motion

Fig.4 shows the motion sequence of forward motion. Here we use right and left PZT actuators. At first the robot can

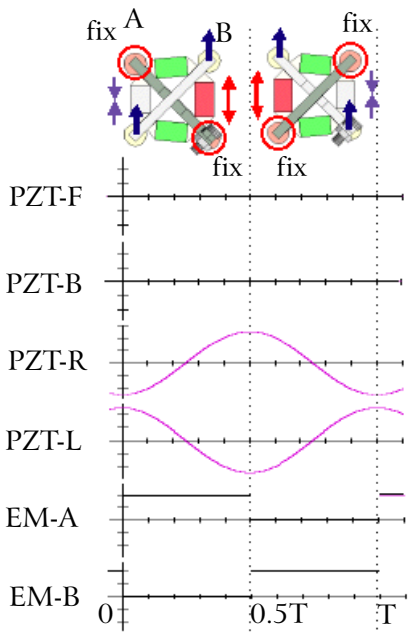


Fig.4 Sequence of orthogonal motion

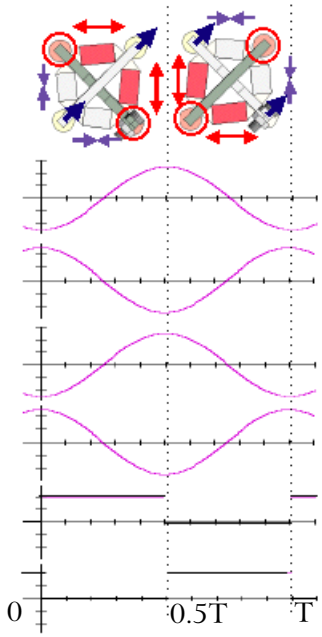


Fig.5 Sequence of diagonal motion

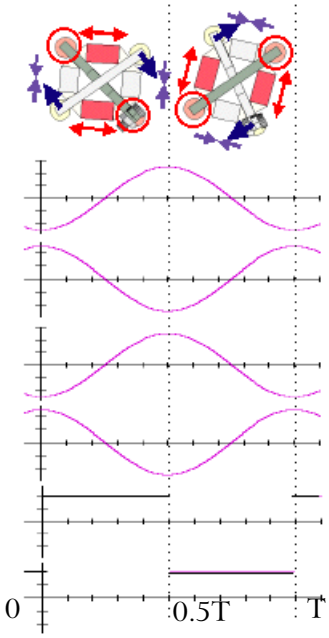


Fig.6 Sequence of rotation

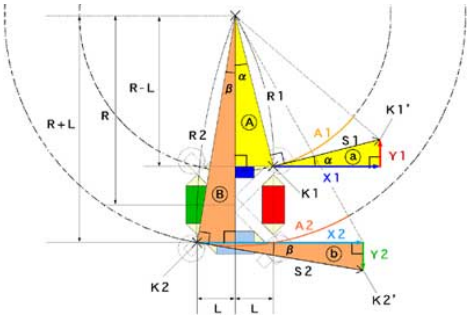
fix the electromagnet-A and constrict the PZT-L and expand PZT-R, then the body can move one step forward. In the next step, the robot can fix the electromagnet-B, expand the PZT-L and constrict the PZT-R, then the electromagnet-A can be moved forward. The robot can repeat the sequence, then the robot can move forward precisely with the manner of inch worm. If the similar sequence are operated, the robot can move in the diagonal direction as depicted in Fig.5.

(2) Arc Trajectory

We also give the unique signal to the small robot so that it can rotate as in Fig.6 Additionally we can consider the specified model of this piezo based small robot as depicted in Fig.7 to move on the arc trajectory. In this figure, we give the approximation that the two points, K1, K2 on the contact point of magnets can move to the K1', K2' on the arc. We can tune the amplitudes and the phase difference of 4 PZT elements' sine wave. Then the small robot can move on the arc path with respect to the center point for rotation.

3. Experiments

As shown in Fig.8, we provided the versatile robot to check its primary performance. The robot is 30mm in



$$V-F = (Pmax)\left(\frac{R-L}{R+L}\right)\sin t$$

$$V-B = (Pmax)\sin(t+\pi)$$

$$V-R = (Pmax)\left(\frac{L}{R+L}\right)\sin t$$

$$V-L = (Pmax)\left(\frac{L}{R+L}\right)\sin t$$

Fig.7 The mechanical model of arc trajectory

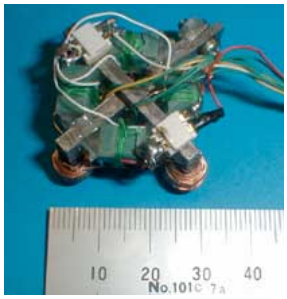


Fig.8 Versatile micro robot provided for microscopic operation

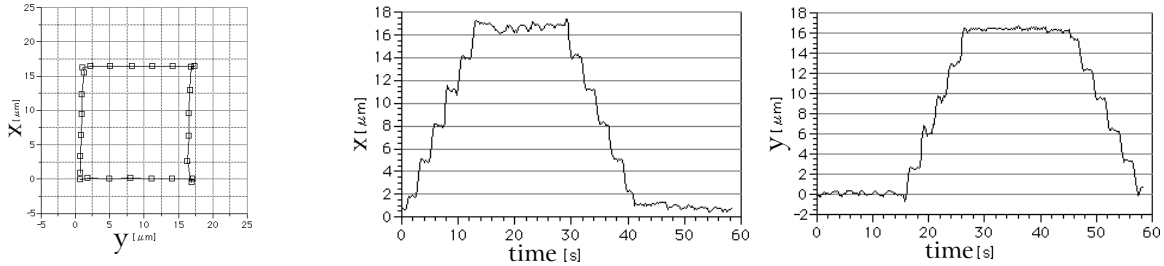


Fig.9 Experimental result of square path motion
(5 steps at each movement, 0.5[Hz])

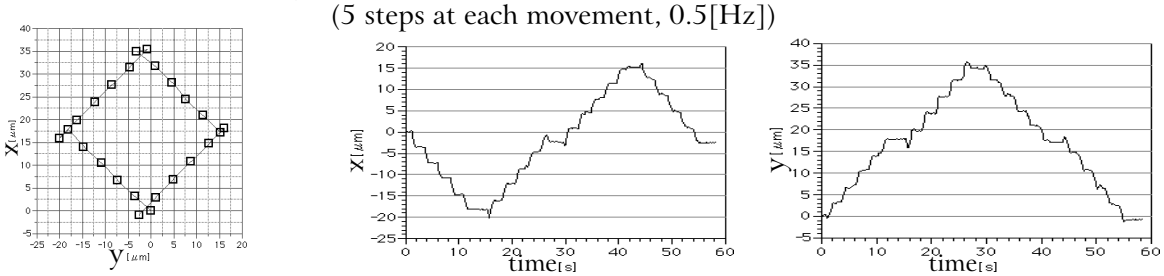


Fig.10 Experimental result of diagonal movement
(5 steps at each movement, 0.5[Hz])

length, 30mm in width and 15mm in height. We use the stacked type PZT elements of 5mm x 5mm x 10mm. Each piezo element is connected with the electromagnet leg with the plastic insulator.

3.1 Fine motion accuracy

In the experiment, we used the microscope with CCD based image analyzer to measure its motion accuracy. Fig.9 and Fig.10 show the results of fine motion experiment. We can confirm that the robot can move in both the orthogonal and the diagonal directions.

3.2 Arc trajectory motion

In another experiment, we succeeded in controlling the small robot to move on the arc trajectory with fixing center point as depicted Fig.11. This performance should be useful to manipulate the small object in the focused area such microscope.

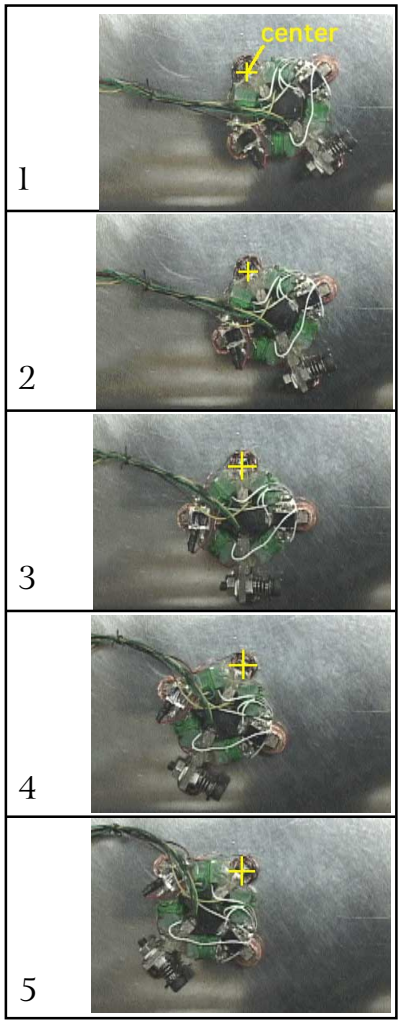


Fig.11 Experimental result of arc trajectory motion (150[Hz])

4. Conclusion & Future Works

Versatile micro robot which can move any direction and rotate with respect to the specified point precisely was proposed and developed. And the typical performances of this robot were confirmed by the experiments. Furthermore in order to realize more advanced and complicated motion such as any angle diagonal movement or any radius arc trajectory motion at any point, we will improve our robot, develop the PC controlled system with the help of the visual feedback system. We are also developing micro tools which can be implemented on the robot to achieve the flexible micro processing system under the collaboration by this versatile micro robots.

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