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SELF-CALIBRATION OF A 3DOF PARALLEL MECHANISM

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Abstract: Most of positioning devices are calibrated by comparing with an artifact or other measuring machine. These methods need an artifact or a measuring machine.

On the other hand a Self-calibration is the best method for small or big positioning devices which are hard to make artifacts, because the method does not need an artifact.

In the purpose of this study is to apply the Self-calibration to a parallel mechanism. In this paper, we built a small 3DOF (x and y direction and rotational movement around stylus) parallel mechanism and studied its movement. It was proved the method had the benefit for the mechanism by previous study.

Keywords: Self-calibration, 3DOF parallel mechanism, Elastic hinge, Piezo Actuator.

1. INTRODUCTION

Most of positioning devices are calibrated by comparing with an artifact or aother measuring machine. These methods need an artifact or a measuring machine.

Self-calibration method does not need to prepare an artifact because it can calculate the kinematic parameters from redundancy of mechanism (Fig, 1). It is advantage of this method.

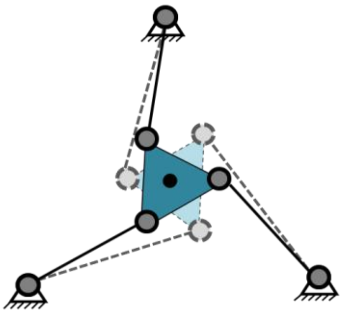


Fig.1 Redundancy of a mechanism

It is the useful feature for calibration of small or big positioning devices which are hard to make artifacts.

The purpose of this study is to build a small 3DOF parallel mechanism and to apply self-calibration method to the parallel mechanism.

2. SELF-CALIBRATION METHOD

Calibrate positioning device is calculating kinematic parameters of a machine. If the movement of mechanism can expressed by formula which contain the kinematic parameters, kinematic parameters can be estimated by a lot of simultaneous equations.

This mechanism is shown in Fig. 2. The kinematic parameters in Fig. 2 are shown in Table 1. Then the equations are expressed as equation (1). The kinematic parameters are calculated by least squares method from data in different angle at same position.

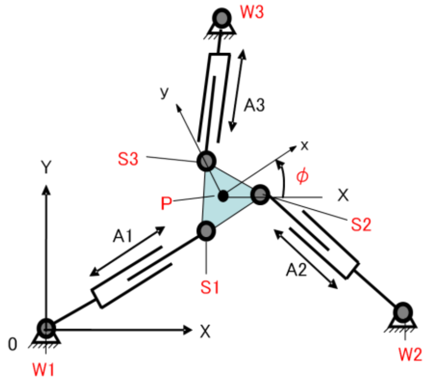


Fig.2 Modelization of a mechanism

Table 1 Kinematic parameters

Base coordinate	$W_n(wx_n, wy_n)$	(n=1,2,3)
Stage coordinate	$S_n(sx_n, sy_n)$	(n=1,2,3)
Stylus coordinate	$P_n(px_n, py_n)$	(n=1,2)
Rotation angle	ϕ_m	(m= number of angles)

$$A_n{}^2 = \{wx_n - (sx_n \cos\phi_m - sy_n \sin\phi_m + px)\}^2 + \{wy_n - (sx_n \sin\phi_m + sy_n \cos\phi_m + py)\}^2$$

(n=1~3,m=number of angles)

(1)

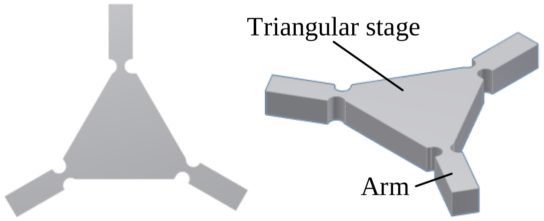
3. 3DOF PARALLEL MECHANISM

This section explains about 3DOF parallel mechanism. The mechanism consists of stage, arms, actuators, anchors and base plate. These parts are bonded by epoxy bond each other.

3.1. STAGE AND HINGE

Fig.3 shows the form of a stage and elastic hinges. Three arms are extended from that triangular stage through an elastic hinge. These arms are pushed by actuators, then the stage can move.

The triangular stage was cut out from aluminium plate by wire electric discharge machine.



(a) Top view (b) Isometric view

Fig.3 A triangular stage and an elastic hinges

The elastic hinge is set between the stage and the arm, and a hinge is bended at this point. The elastic hinge is shown in Fig. 4.

The elastic hinge is offset from line connecting points of the center of stage and a vertex of stage, so that the stage is rotated when it is pushed by actuators.

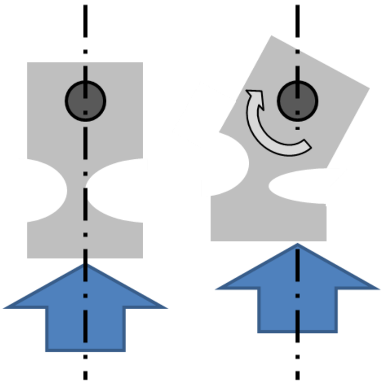


Fig.4 Function of an elastic hinge

3.2. ACTUATOR AND ANCHOR

Fig.5 shows a piezo actuator which pushes an arm to move the stage. The actuator is expended when voltage is applied. The specification of actuator is shown in Table 2.

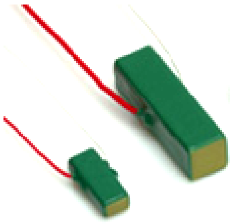


Fig.5 Piezo actuator

Table 2 Specification of actuator

Model	AE0505D16F
Drive voltage	0～150[V]
Maximum displacement	17[μm]
Force	850[N]

One end of the actuator is held on an anchor to push the arm. Bonding area is large, because it needs to hold the base to keep a position.

3.3. ASSEMBLE A MECHANISM

Mechanism parts are assembled as shown in Fig.6 and are set on the base.

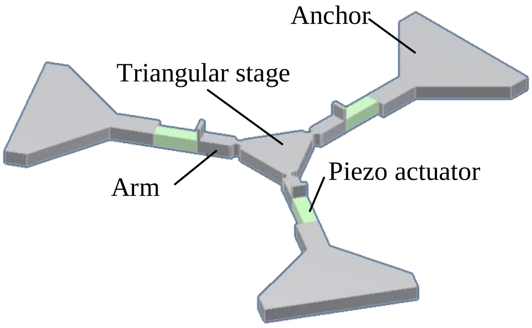


Fig.6 Assembled parts

3.4. DISPLACEMENT METERS

This mechanism has six displacement meters (Fig.7) which can non-contactly measure the stage motion. Three sensors are monitoring extension of actuators, and the others are monitoring position and rotation angle of stage.

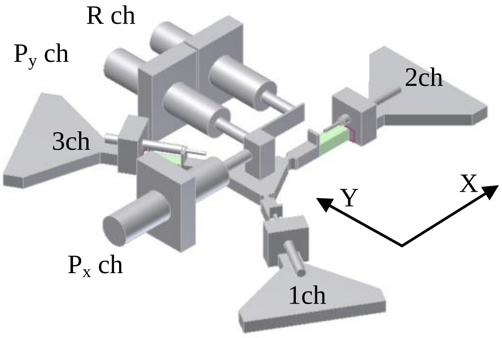


Fig.7 Set up of displacement meters

Rotation angle is calculated by sensor value of $P_y$ch and Rch, using equation (2) where the distance of sensor-$P_y$ch to sensor-Rch is 30mm

$$\theta = \tan^{-1}(\mathrm{Rch} - \mathrm{P_ych})/30 \qquad (2)$$

3.5. CONTROL SYSTEM

The mechanism is drived and monitored by a computer. The system is shown in Fig.8

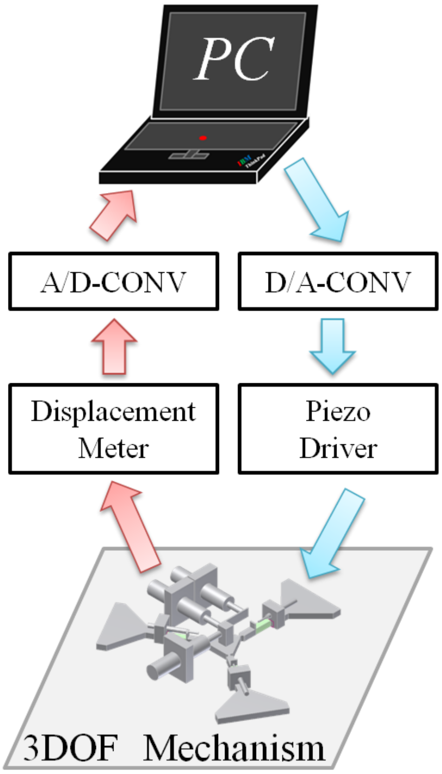


Fig.8 Experiment system

The mechanism needs the functions transferring to the specified position and angle.

4. MEASURE A ROTATIONAL ANGLE

4.1. PURPOSE

Therefore in this section, angle range of stage rotation and range of movement were investigated.

4.2. METHOD

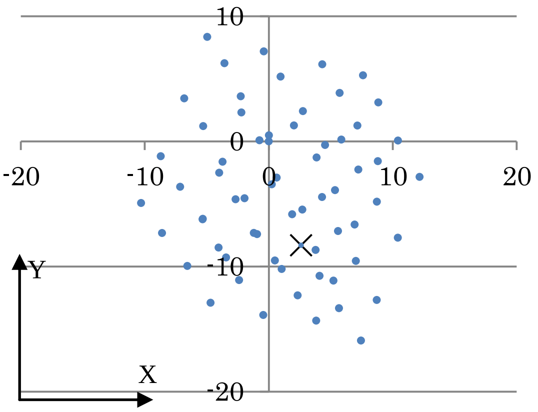
Actuators applied voltage, in all combinations of “0, 50, 100, 150 [V]” applied to actuators. Applying a voltage, stylus movements are measured and plotted and a rotation angle are calculated.

4.3. RESULT

The data of each displacement meter are shown in Table 3, and range of stylus movement is shown in Fig.9.

Table 3 Experimental Data

	Min	Max
1ch[μm]	-3.462578	5.852445
2ch[μm]	-5.955902	4.667429
3ch[μm]	-2.980392	5.579614
Rotation[deg]	-0.111365	0.003363



×:Max rotational point

Fig.9 Range of motion P(X,Y)[μm]

It is proved that this mechanism can position within 10 micrometer radius from the experiment. Range of rotation angle is 0.108 degree, it is too low to calibrate. Therefore, the range of rotation angle needs to be improved.

5. CONCLUSION

The mechanism is using piezo actuator to move although it extends range is 17 micrometer. It is too small and restricts rotation angle. The mechanism needs an improved mechanism to accomplish wide range of movement. The mechanism should be improved to make rotation angle larger to befit for Self-calibration method.

6. REFERENCES

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