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# PROBE SYSTEM FOR DETECTING SMALL DISPLACEMENT

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*Abstract: We proposed the probe system for CMM, which consisted of elastic hinges, QPD and ball lens to detect the small displacement of stylus. The contact force increases rather than other probes; touch trigger probe etc., we try to totally reduce the contact force by the more sensitive detector.In our concept, as the stylus of this probe is supported by the elastic hinge rigidly, the probe system should detect the displacement of the stylus before the stylus make the plastic deformation on workpiece. Therefore, the detector should demand high sensitivity in order to prevent the deformation on workpiece as small as possible. In this paper, we will show the resolution, contact force and directional characteristics of this probe system.*
*Keywords: Contact Probe, Contact Force, Coordinate Measuring Machine*

## 1 INTRODUCTION

A touch trigger probe has been used for detecting the contact with the workpiece in coordinate metrology using CMM. However, recently it is known that the touch trigger probe makes a small deformation of workpiece in measuring. So a lot of researchers work on developing the new probe system of which the measuring force is so small that it never destroy the workpiece [1-3]. For this purpose, the most popular solution is that the stylus is supported by a thin metal film and the contact is detected by observing the deformation of the thin metal film. This method could detect the wrong contact signal from the vibration of the stylus in CMM's moving situation. We proposed another probe system of which the stylus is supported by the elastic hinge rigidly. This probe system relatively requires larger contact force than usual touch trigger probe. However, as the deformation of the workpiece comes from the contact force and the displacement of the stylus, we adapted the optical sensing system as the detecting device to prevent the stylus making the permanent deformation of the workpiece [4-5]. In this paper, the resolution, contact force and directional characteristics of this probe system are shown.

## 2 STRUCTURE OF PROBE SYSTEM

The probe system is shown in Figure 1. The stylus is supported by the elastic hinge. When the stylus tip contacts with the workpiece, the stylus can move only in a short distance. At another end of the stylus, the ball lens is attached. The ball lens can also move with the stylus. Therefore the contact with the workpiece is detected according to the displacement of the ball lens. This is the principle of the probe system.

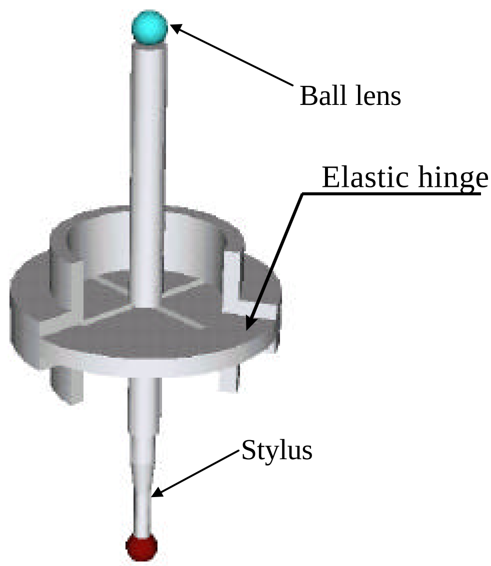


**Figure 1.** Configuration of probe system

## 3 DETECTING THE DISPLACEMENT OF STYLUS

The principle of detecting the displacement of the stylus is shown in Figure 2. The optical detector consists of the QPD, the ball lens and the laser. The laser through the ball lens is focused on the center of the QPD. The focal point of the ball lens should be located on the line, which is parallel to the laser beam and runs through the center of the ball lens. When the stylus contacts with the workpiece and the ball lens rotates around the point supported by the elastic hinge, the focal point also move in the plane of the QPD. As in the initial location, the optical power on each cell of the QPD is balanced, it becomes unbalanced when the focal point moves. Each optical detector can detect two-dimensional movement by the difference of the signal from the cells of the QPD. Therefore these optical detectors can detect three-dimensional displacement of the stylus in this probe system.

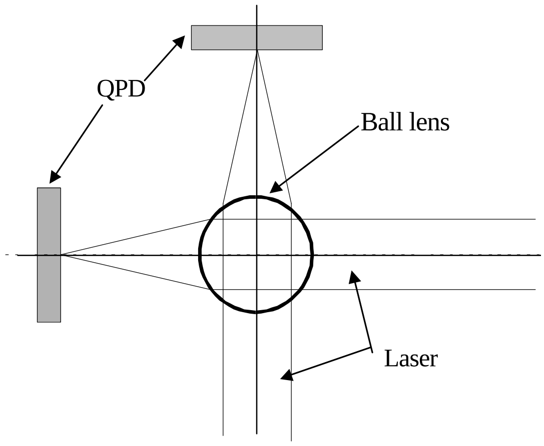



**Figure 2.** Principle of optical detector for xyz direction

## 4 EXPERIMENT

The experimental setup is shown in Figure 3. In this paper, we performed the following experiments.

1)The relationship between the displacement of Piezo actuator and the contact force at tip of flat spring
2)The relationship between the displacement of stylus tip and contact force in a different direction
3)The relationship between the output signals from two QPDs.

### 4.1 Contact force at tip of flat spring

The flat spring is used to push the stylus with a constant force. In order to measure the relationship between the contact force and the displacement of Piezo actuator, when the Piezo actuator had been extended, the contact force was measured with the electric balance. The experimental result is shown in Figure 4.

This figure shows that the contact force at the tip of the flat spring is proportional to the displacement of the flat spring. In following experiments, the contact force is calculated from this result.

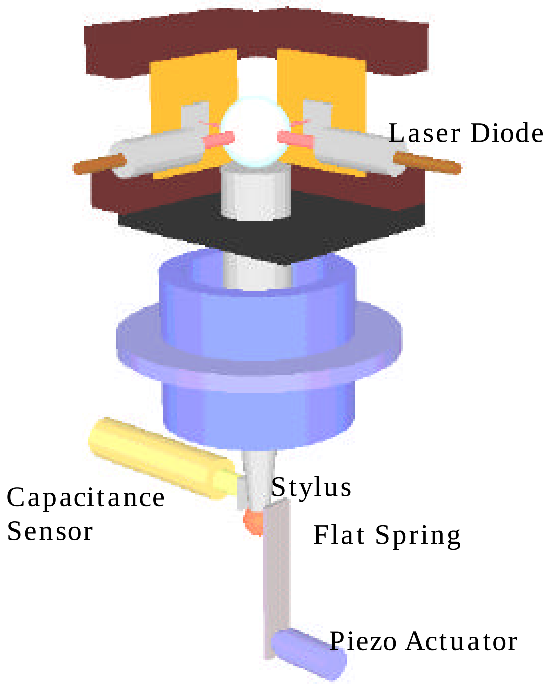



**Figure 3.** Experimental Setup

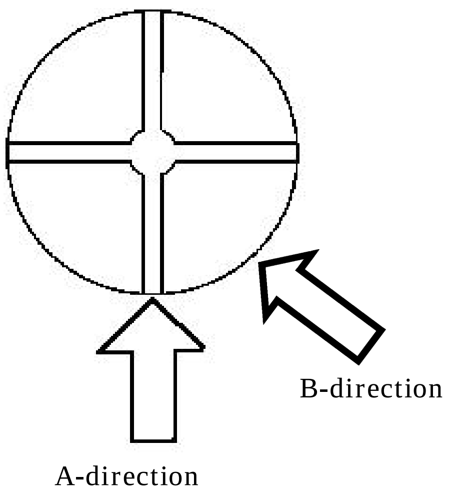



**Figure 5.** Direction of contact force with flat spring

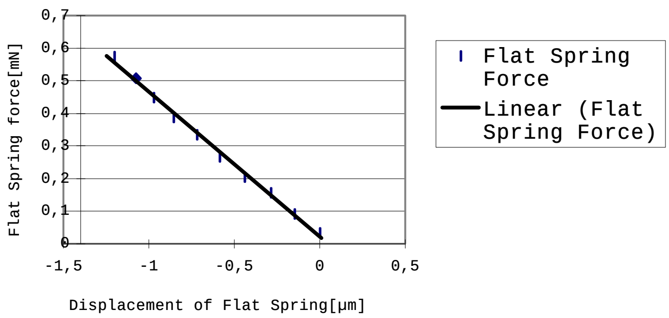
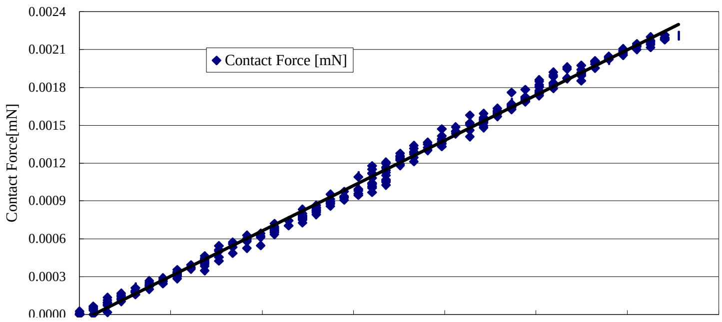
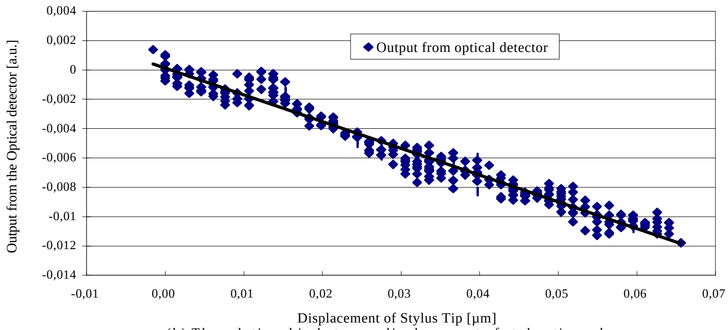



**Figure 4.** Relation between the displacement and contact force of flat spring

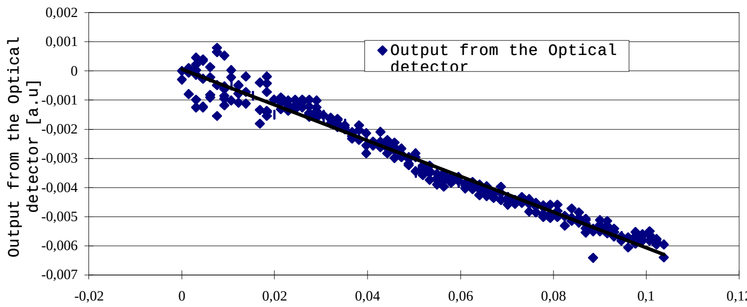
## 4.2 The directional characteristics of probe system

The equipments are setup as shown in Figure 3. The stylus is pushed by the flat spring in A-direction and B-direction as shown in Figure 5. The capacitance sensor observed the displacement of stylus in the resolution of 2nm. The measurement results are shown in Figure 6.




(b) The relationship between displacement of stylus tip and
output signal in A-direction




(c) The relationship between displacement of stylus tip
and
output signal in B-direction

**Figure 6.** Directional characteristics of probe system

From Figure 6 (b) and (c), It is proved that the resolution of displacement is 4 nm in A-direction and 5nm in B-direction. When the displacement of stylus tip is 60nm, the contact force is 2.1 $mN$ in A-direction and 1.1 $mN$ in B-direction.

## 4.3 Output signal from Y-Z QPD in X-direction

As the QPD can detect only the displacement of two directions, the output signal from QPD should be a constant value in the displacement of another direction. The experimental setup is shown in Figure 3. When the stylus is pushed in X-direction, the output signals from both QPDs are shown in Figure 7. From these figures, It is proved that X-Z QPD can detect the displacement of the stylus in X-direction and Y-Z QPD is not affected by the movement of the stylus in X-direction.

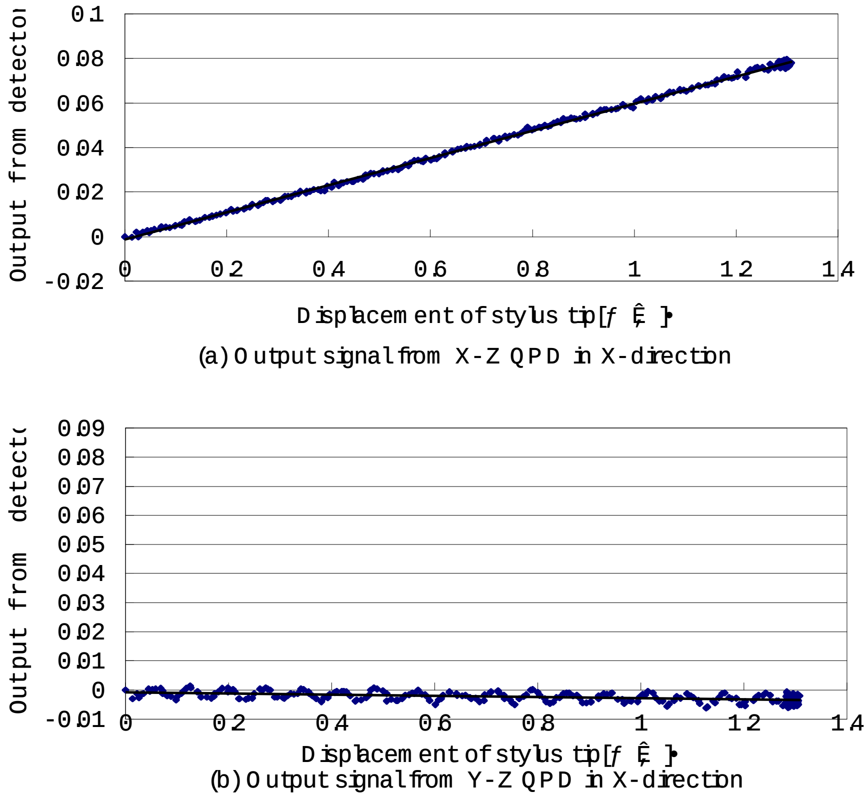



**Figure 7.** Output signals from both QPDs in the movement of stylus in X-direction

## 5 CONCLUSION

The probe system, of which the stylus was supported by the elastic hinge rigidly, was proposed. It was shown that this probe system could detect the 3-dimensinal displacements of the stylus in the theoretical and experimental ways.

It was proved from some experiments that

(1) The resolution of the probe system is 4 nm in A-direction and 5 nm in B-direction.

(2) When the displacement of stylus tip is 60nm, the contact force is 2.1 $mN$ in A-direction and 1.1 $mN$ in B-direction.

In this paper, the static characteristics were examined. So it is necessary to examine the dynamic characteristics in order to apply to CMM.

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