

Development of Three-Dimensional Profile Measuring Method for Microparts

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1. Introduction

Micromachine technology has considerable potential as a leading area of industry in future. For the progress of micromachine technology and microfabrication technology, it is necessary to devise a technique to measure both profile and dimension of microparts. Researches on measurement methods and instruments for microstructures have been reported[1-6].

For the inspection and measurement of micro parts, measuring methods for the profile and dimension including geometrical deviations such as straightness, circularity and perpendicularity are needed. It is thought that a small three-dimensional profile measuring apparatus with microprobe can be utilized as the measuring method for this purpose. In this paper a new three-dimensional profile measuring apparatus which has non-contact probe detecting proximity to measuring object through tunneling effect is described in detail. Then the validity of the measuring apparatus is shown through several specimens like roughness standard, micro hole and groove.

Tunnel effect is observed when gap between surface and probe is less than 1nm. In this research the tunnel effect is used to detect the contact of probe and surface, because no complicated devices are needed and measurement on the sloping surface is possible. The drawback of optical methods is the shadow effect of light beam against steep slope.

The trial apparatus is composed of X-Y-Z precision stages with linear encoders resolution of $0.1 \mu\text{m}$, θ (rotating) stage with rotary encoder and a personal computer controlling these stages through GP-IB interface. The probe is mounted to Z stage through piezo electric actuators so that it must be precisely controlled. The probes are most important components of this measuring method. Probes suitable for each microparts are fabricated by micro die-sinking electro discharge machining.

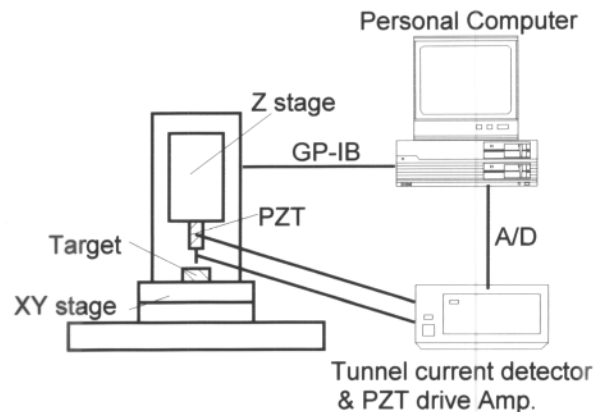


Fig. 1 Measuring principle

2. Measuring principle

Experimental apparatus for the three dimensional profile measurement for microparts was developed. A first generation apparatus shown in figure 1 consists of X-Y micro mechanical stages and a probe tip mounted on a Z micro mechanical stage through a PZT ceramic actuator. Proximity of the microprobe to object surface is detected by principle of STM (scanning tunneling microscopy). X-Y-Z stages are controlled by a personal computer through GP-IB interface and the position of stages are obtained by internal linear encoders (resolution of $0.1 \mu\text{m}$). Micropobes are fabricated by micro die-sinking electrical discharge machining.

When the probe approaches the object, the PZT actuator that holds the probe is fully expanded. The PZT actuator is shrieked when tunnel current is detected to avoid collision of the probe and the object before Z stage stops. The position of Z stage measured by internal linear encoder gives Z coordinate value. A personal computer is monitoring the applied voltage to the PZT actuator through A/D converter. When PZT voltage becomes zero, the computer stops Z stage. The error produced is depend on the linear encoder of the micro mechanical stages. The result obtained from the standard deviation value of 100 measurements was $0.2 \mu\text{m}$.

Figure 2 shows measured result for a standard surface roughness test piece. The test piece has wavelength of $100 \mu\text{m}$ and height of $11 \mu\text{m}$. The data was obtained while probe tip is moved every $2 \mu\text{m}$ in X direction. Accurate values for both wavelength and height were obtained.

3. Configuration of measuring system and experimental results

Probe tip approach direction in the first generation apparatus is restricted only to Z direction. Therefore, form of measured objects is very limited, for example, measurement of inside hole and side of step are not possible. The second generation apparatus has θ rotating stage on

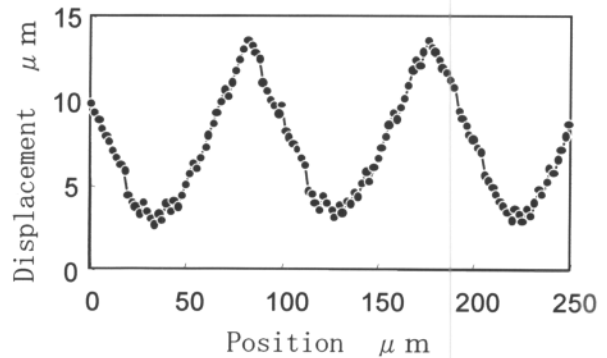


Fig.2 Measuring result from standard surface roughness test piece

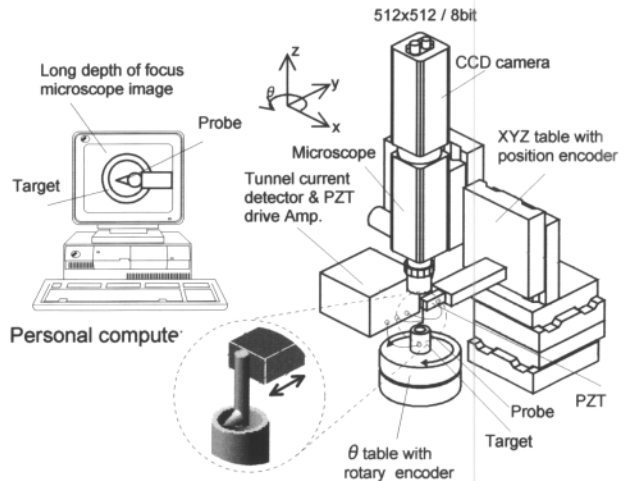


Fig.3 Configuration of experimental apparatus

X-Y stages. The rotating stage has internal rotary encoder (resolution of 3.48"). The apparatus has PZT actuator control system similar to the first generation apparatus, but expansion and contraction direction is optional. Figure 3 shows the second generation apparatus with PZT actuator control direction is set to X axis and installing X type probe that has probe projection in X direction. Figure 4 shows measured cross section of micro holes. Inside of micro holes of diameter about 300 μ m by drilling and electro discharge machining on aluminum plate are measured. Data are obtained at every 5 degrees of θ rotary stage positioning. Since the left side figures in Fig. 4 are showing measured data super positioned on base circle of 300 μ m diameter, they do not show inside diameter of the hole properly. Right side figures show the results after magnification: one scale unit is equivalent to 10 μ m. Because the measuring results are including rotational error of the θ stage, evaluation and compensation of the rotational error is needed for more accurate roundness measurement of the hole.

We have also developed probe tip fabrication method using micro die-sinking electro discharge machining. Figure 5 shows a photo micrograph of X-Z type probes. X-Z type probe has projections in both X and Z direction. By the X-Z type probe, continuous measurement of step shape object can

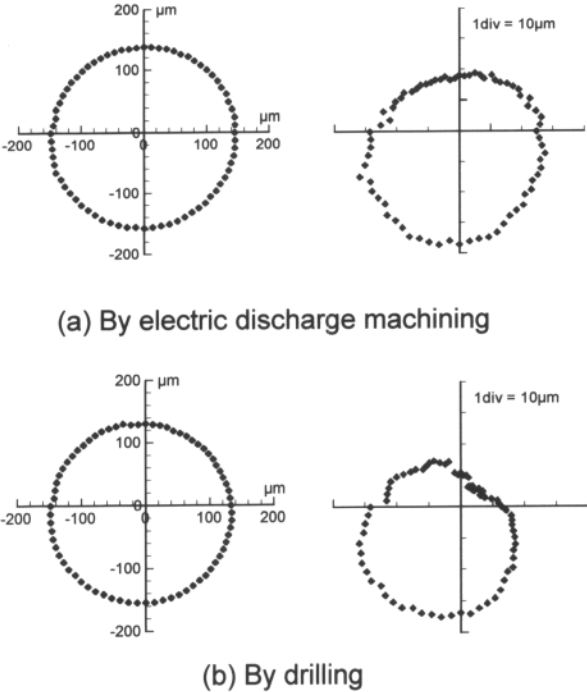


Fig. 4 Cross section of microholes

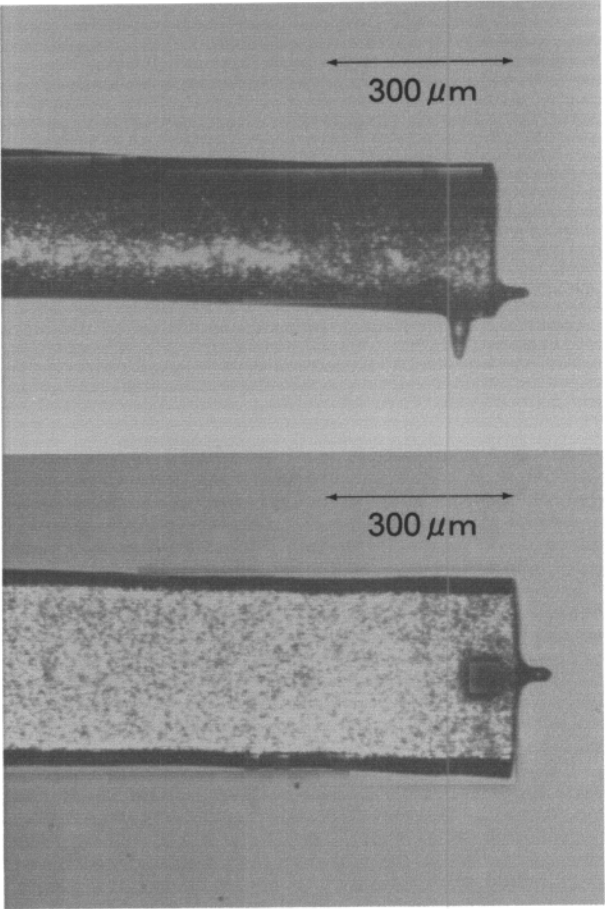


Fig. 5 Fabricated X-Z probe

be possible. Also perpendicularity of bottom and lateral surfaces, angular parallelism of bottom and upper surfaces can be evaluated.

4. Conclusion

The main conclusions obtained from this report are summarized as follows:

- 1) The measuring principle of three-dimensional profile measuring method for micro-parts and configuration of the apparatus were presented.
- 2) Metal surface with grooves can be measured continuously by X-Z type probe fabricated by micro die-sinking electro discharge machining.

References

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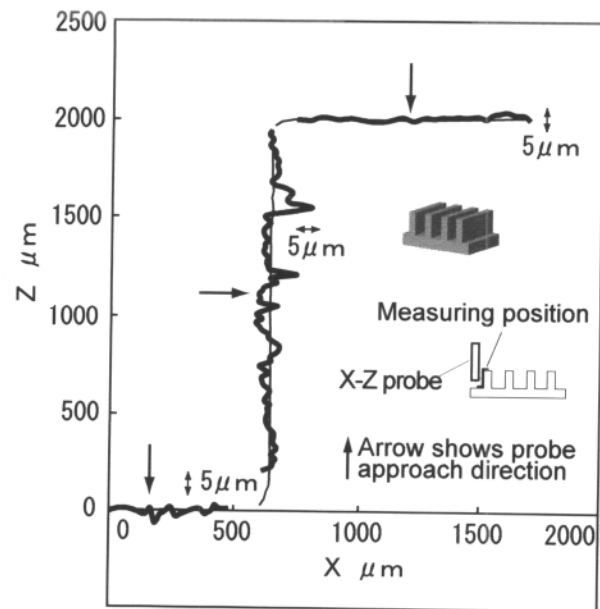


Fig. 6 Measuring results from metal surface with grooves