Special Issue
http://dx.doi.org/10.3786/sincs2011.22

NANO-MICRO LETTERS
ARTICLE
www.nmletters.org

(Proceedings of 2011 Shanghai International Nanotechnology Cooperation Symposium, SINCS 2011, Published online 10 January 2012)

Research on Capacitive Probing System Based on Micro/nano Measurement

Xin Lu[1,*], Mingxuan He[2], Yuan Li[1], Hong Wang[2], Yi Liu[1], Lihua Wang[1]

Abstract: With the trend for higher resolution and accuracy in dimensional measurements, the demands of coordinate measuring techniques are ever-increasing. Probing systems, as the major part of the coordinate measuring machine, plays an important role in the overall accuracy. Currently, various probe techniques have been proposed by different institutes. This paper presents a capacitive tactile probing system and the corresponding capacitance detecting system. The probe is consisted of a probe sphere, a stylus and a capacitance sensor. The displacement of the probe tip can be calculated by the circuit which detects the smallest changes of displacement and converts the displacement to capacitance. All data from circuit captured by VISA (virtual instrument software architecture of LabVIEW) through series ports. The preliminary design, simulation and experimentation are presented. The feasibility of the probing system can be confirmed by analyzing the experimental results.
Keywords: Micro/nano measurement; Probing system; Capacitive sensor; Detection circuit; VISA

Citation: Xin Lu, Mingxuan He, Yuan Li, Hong Wang, Yi Liu and Lihua Wang, "Research on Capacitive Probing System Based on Micro/nano Measurement", Proceedings of Shanghai International Nanotechnology Cooperation Symposium, 90-93 (2011). http://dx.doi.org/10.3786/sincs2011.22

Introduction

In order to satisfy the increasing demands of precision measurement and dimensional metrology in micro/nano scale [1], micro/nano coordinate measuring machines and the probes for these machines attracted more and more researches in recent times [2-3]. Therefore, it is very necessary to analyze the performance of probes before using on micro CMM or NMM. Currently, various probe techniques have been proposed by different institutes. Pril et al. designed a piezoresistive probe system which reaches an uncertainty of 20 nm in 3D and realize a probing speed of 1 mm/s [4]. Peggs et al. designed a probe system based on capacitive sensors. They claim a resolution of 3 nm, a working range of ±20 um, and an equal stiffness in all three directions of approximately 10 N/m [5]. Meli designed a 3D probe based on parallel kinematics with flexure hinges. The 3D uncertainty is 30 nm and the measuring range is 200 um [6]. Also, there are other institutions carry on the similar researches [7-9]. This paper presents a capacitive tactile probing system and the corresponding capacitance detecting system. The probing system here consists of a probe and a calibration system.

Structure and Principle of Probing System

Structure of the Probe System

The probe system includes a probe tip, a stylus and a base which is shown in Fig. 1. When the probe tip contacts the surface of the work piece in Z-axis, the stylus will makes some related displacements. According to the rigidity of the stylus is strong, these displacements can be completely passed to the base which is a

[1]Shanghai Institute of Measurement and Testing Technology, Shanghai 201203, China
[2]National Key Laboratory of Nano/Micro Fabrication Technology, Research Institute of Nano/Micro Science and Technology, Shanghai Jiao Tong University, Shanghai 200240, China
*Corresponding author. E-mail: luxinxinger@163.com

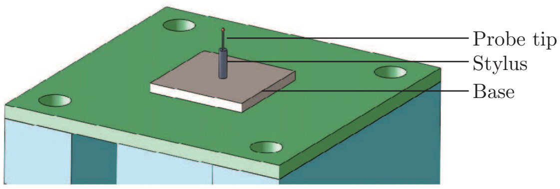


Fig. 1 Structure of the probe system.

capacitance sensor in this probe system. And the performance of the probe in Z-axis can be calibrated through the calibration system [10].

Calibration System

The probe calibration system consists of a support stent, a PZT and a triaxial displacement platform which is shown in Fig. 2. The calibration principle is that: fix the probe on the stent and check whether it is fixated; control the control boxes to make the probe just close and upon the center of PZT; drive PZT until the probe triggers and then record the position; return PZT to the original position and prepare for the next experiment. The precision displacement is provided by PZT while general displacement is driven by Z-axial displacement platform. Various tactile probes as 1D probe, 2D probe, 3D probe can be calibrated by this calibration system.

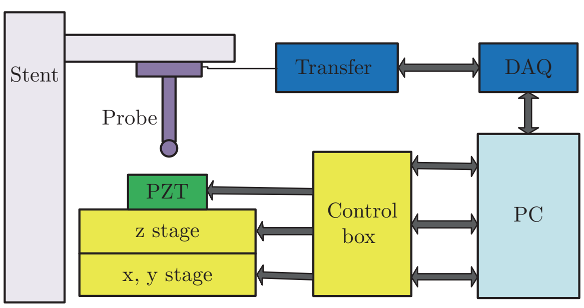


Fig. 2 Schematic diagram of the calibration system.

Capacitance Detecting System

The capacitance detecting system uses the machine-to-PC transmission. The graph of system principle is shown in Fig. 3. Signals outputted by the capacitance sensor are transformed to digital data by the measuring circuit. And then the data are processed by signal processing circuit and transmitted to the host computer via interface circuit. AD7747 is chosen in measuring circuit to realize the converting of capacitance to digit. The communication between PC and MCU (Micro Controller Unit) is realized by MAX232 and RS-232 standard serial port. All the processing of data is implemented by NI-VISA (virtual instrument software architecture of LabVIEW).

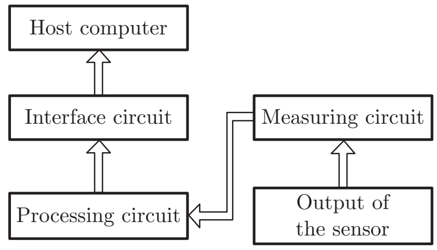


Fig. 3 Schematic diagram of capacitance detecting system.

Probe Calibration Experiments

The main probe parameters include resolution, repeatability, and stability, and so on. The following experiments aim to test these parameters. The experiments are done in the laboratory underground 6m. The temperature is (20±0.5)℃. The calibration system is placed on the air-bearing platform. As primary experiments, the calibration system operated only at z-axial orientation. The probe calibration system is shown in Fig. 5.

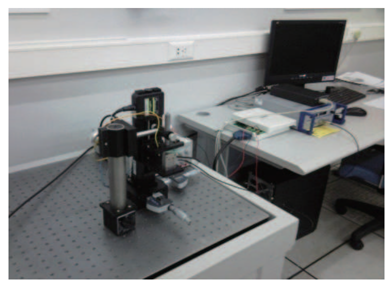


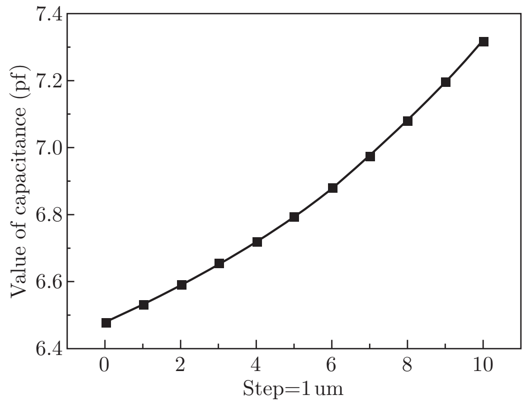
Fig. 5 Probe calibration system.

Resolution Experiment

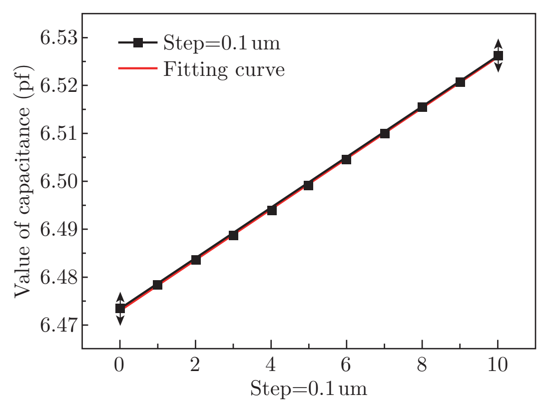
The purpose of this experiment is to make certain the smallest displacement while the system has a stable linear output. The piezoelectric is driven in 1um, 0.5 um, 0.2 um, 0.1 um, 0.05 um, 0.02 um, 0.01 um respectively to contact the probe. Data measured by the circuit is correlative with the displacement between two plates. The experimental results show that the probe has a well linear output at the step of 1 um, 0.1 um and 0.02 um. When testing at the step of 0.01 um, the probe output data are not stable. The coefficient of correlation R^2 is 0.99968. Therefore, it is judged that the probe resolution is 0.02 μm. The measured results and their fitting curves are shown in Fig. 6.

Repeatability Experiment

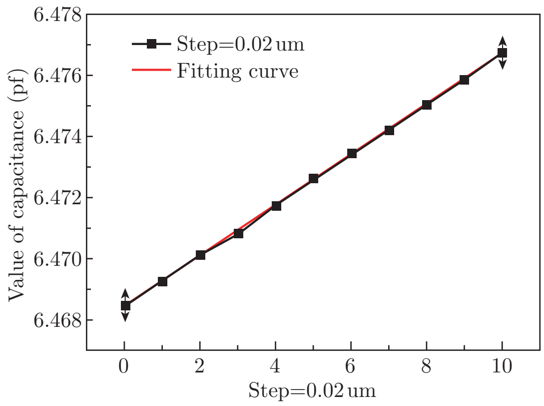
The purpose of this experiment is to make sure whether the repeatability of the probing system is good. The method is that driving PZT at step of 1um to make to the work piece connected the probe, and recording the position, then returning PZT to the original position. The experiments are operated 5 times. The data



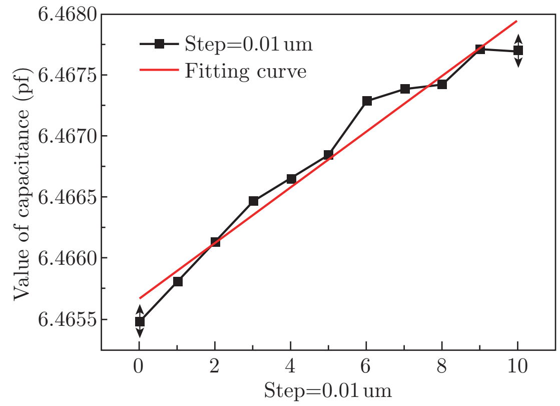
(a) The step is 1 um



(b) The step is 0.1 um



(c) The step is 0.02 um



(d) The step is 0.01 um

Fig. 6 Measured results and fitting curves in different steps.

are recorded in Table 1. It is illustrated that there exist a deviation when the capacitance plate back to the original location. That's because the measurement system only calibrated once before experiments, returning to the original position may bring some errors. And also the capacitance measuring circuit may drift in measuring processing. However, the distribution and the trends of the drift are basically the same. That can be proved that the repeatability of the probing system is quite good.

Table 1 repeatability experiment (pf).

位置	0	1	2	3	4
1	5.677985	5.705967	5.753967	5.770049	5.805355
2	5.664816	5.696216	5.746398	5.764851	5.801963
3	5.663068	5.693088	5.738775	5.758081	5.792853
4	5.654316	5.685814	5.736289	5.753967	5.790803
5	5.651611	5.682179	5.734220	5.746398	5.780931
	5.662359	5.692653	5.741930	5.758670	5.794381
	0.015626	0.013314	0.012037	0.012271	0.013450

Drift Experiment

The purpose of this experiment is to make sure how much the probing system will drift in 30 minutes. The method is that measuring the system in the same surroundings such as the same displacement between the capacitance plates 30 minutes. The results recorded every minute which are shown in Fig. 7. It illustrates that the probe system drifts 0.02886pf in 30 minutes. At the beginning, system is in cooling state, and the circuit is not stable. Over time, the circuit becomes stable slowly and the curve of the system goes smoothly gradually.

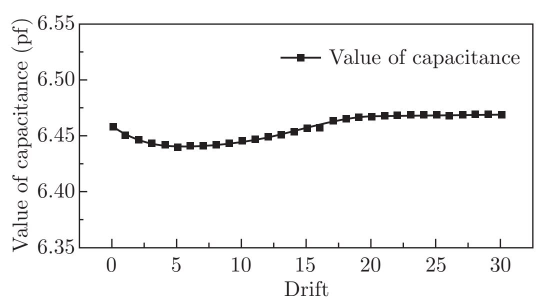


Fig. 7 The drift curve of the probing system.

Conclusions

According to the principle of the tactile probe system, this paper presents a capacitive tactile probe system, a calibration system and the corresponding capacitance detecting circuit. Through the experiments, it is proved that the tactile probe is feasible. The resolution of the probing system in z-axial is 0.02 um. It has a good repeatability. And the drift is 0.02886 pf in 30 minutes. After analyzing the results, it is found that the drift of the probe should be decreased by improving the detecting circuit and other elements. The performance of the probe in x/y-axial and other characteristic also should be operated in the future research.

References

[1] H. N. Hansen, K. Carneiro, H. Haitjema, etc. CIRP Annals–Manufacturing Technology. Vol. 55. No. 2, 721 (2006).

[2] E. J. C. Bos, F. L. M. Delbressine and H. Haitjema. VDI BERICHTE. (2004).

[3] A. Weckenmann, G. Peggs and J. Hoffmann. Meas. Sci. Technol. Vol. 17, No. 3, 504 (2006).

[4] W. O. Pril. PhD. Thesis, Technische Universiteit Eindhoven (2002).

[5] G. N. Peggs, A. J. Lewis and S. Oldfiead, Annals of the CIRP. 48, 417 (1999).

[6] F. Meli, A. Küng and R. Thalmann. Meas. Sci. Technol. Vol.18, No. 2, 319 (2007).

[7] U. Brand, T. Kleine-Besten and H.Schwenke, ASPE, (2000).

[8] Jon R. Pratt, D. Newell, J. Kramar, etc. Proceedings of the American Society for Precision Engineering 2003 Winter Topical Meeting. University of Florida, 64 (2003).

[9] G. Dai, S. Bütefisch and F. Pohlenz. Meas. Sci. Technol. Vol. 20, No. 8, 084001 (2009).

[10] Li Yuan. PhD. Thesis, Tianjin University (2007).