Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 24 (2011) 778 – 782

Procedia Engineering

www.elsevier.com/locate/procedia

2011 International Conference on Advances in Engineering

Micro Friction Experimental Study Based on Parallel Cantilever

Ying Xu*, Hudong Yu, Zhangjiang Yu, Jinkai Xu , Qingyong Shi

Changchun University of Science and Technology ,college of mechanical and electric engineering ,Changchun 130022,China

Abstract

In this paper, the law of micro-friction in meso-scale is studied, one optical testing method of micro friction based on the structure of parallel cantilever is given and the testing system is designed, the composition of test system, testing method, the design of force sensor, the testing method and the calibration of force sensor are introduced. The force sensor is calibrated and the deformation of sensor is measured by light reflection. Then the micro friction is obtained by analyzing data. The results of experiment show the resolution of specification of micro friction testing is 10μN, which could meet the demands of micro friction testing with short stroke and high resolution and realize the precise test of micro friction, and the same time it has been analysed which load is unstable during testing.

Key words：Micro-Friction,Reflection method,Force sensor,Parallel Cantilever;

1. Introduction

With the rapid development and wide application of MEMS, it urgently needs to give a reliable reference data to the system of material properties, surface quality, structure, shape, etc. As the components have size effect and surface effect in the micro-system, the friction problem is very prominent in the course of work. The presence of micro-friction and micro-wear affect smooth movement of the components in the micro-system, loss the energy of the system, and even affect the performance and lifetime of the overall system [1-3]. In the micro-system, meso-scale friction is usually between macro-friction and micro-friction. Explore the difference of mechanism between meso-scale friction, macroscopic friction (in line with classical friction theory) and nano-friction (with a strong size effect) can not be ignored to improve the overall performance of the micro-system.

More mature testing instruments and equipment, mainly for macro-tribology and friction testing machine for nanotribology by atomic force microscopy, friction force microscopy tester, Therefore, meso-scale study for small friction tester has become extremely urgent. Research carried out at home and

* Corresponding author. Tel.: +86- 13654399874.

doi:10.1016/j.proeng.2011.11.2736

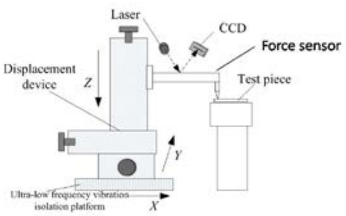
abroad are mostly based on pressure sensors, electromagnetic micro-motor, buoyancy, silicon micromachining, optical detection principle of micro-friction test [4-8]. In 2005,Chinese Academy of Sciences, Changchun Institute of Optics and Fine Mechanics and Physics Yu Zhenglin and others, who are being designed in a way to simultaneously apply a macro constant vertical load (1μN ~ 1 mN) and the macro lateral friction measurement equipment[9]. In 2005, Shanghai Jiaotong University Wang Liang and others, who developed a micro-friction test of micro-force sensor, This micro-force senso based on strain gauge method and displacement method can be simultaneous determination of macro friction and the corresponding size of positive pressure, It is suitable for mN-level friction test [10]. S.I.-U.Ahmed and other people designed a micro-friction tester in 2008, manufactured by lithography process, the cantilever beam which having the structure of bilobed spring, that the displacement of deformation is transfered from optical fiber sensor to a computer and then processed, and piezoelectric ceramics provide cycling movements.The testing range were 1μN-1mN and satisfied the order of an accuracy of nano-bovine.

In the application of a practical test, strain type micro-friction tester is mainly found at present, but the resolution is not high, generally is above the order of milli-bovine. In this paper, it considers the factor of measuring accuracy, stability and etc, and based on the parallel beam structure to design a micro-force sensor, using reflection method in a minimal-friction testing, through the samples' determination of minimal-friction and positive pressure to get a frication regular and evaluate the mocrotribological property in material surface.

2. The composition of test system

2.1. System hardware

The micro-friction test system is essentially composed of force sensor, displacement device, laser CCD, platform control system (Fig.1).The force sensor can contact with testing workpiece through Z movement of displacement device. Thereby the reflected focusing laser beam which irradiate at the side of force sensor receive by the photosensitive surface of CCD. All the pixel data are sent to computer and get the crest location(that is the center of light spot).The distance between CCD receiving surface and initial point can be real-time calculated, it can accurately measure the micro-friction.



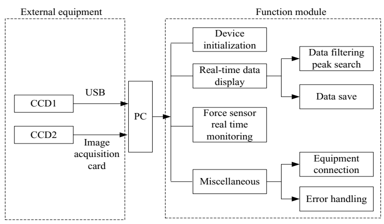


Fig 1 Diagram of system structure; Fig 2 Diagram of software system framework

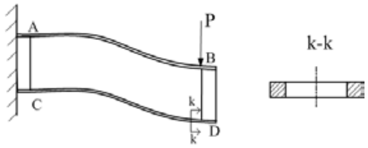
2.2. System software

The function of text system software includes: data acquisition, data display, data anaiysis, data preservation, errortreatment and the monitoring of the motion state of the force sensor etc, Fig.2. the data of real-time collection by linear array CCD would be transferred to the computer through USB. Filtering and peak searching of date is processed in the computer, also real-time data displaying and data saving. Circumscribed matrix CCD joined by image acquisition card, and transport the acquisition of images to PC at real-time, used to monitoring the motion state of a force sensor, designing functions according to the acquisition of times and time on the data acquisition module, for the convenience of users to make a single-time acquisition and multiple-dynamic acquisition.

3. Experimental principle

3.1. Analysis of the force transducer structure and optical path

The force sensor structure is double parallel beam structure the two spring chips AB and CD are parallel fixed. The two spring chips A and C are fixed on the stable plate. B and D are fixed on the mobile plate. While in the ideal status, the upper and lower spring chips of the parallel beam structure was forced and from the completely same elastic deformation. The mobile plate only has the translational motion, and there is no rotation motion. The Fig. 3 shows the deformation situation when applied load to the transducer. The detailed theory of calculation and analysis Refs[11].



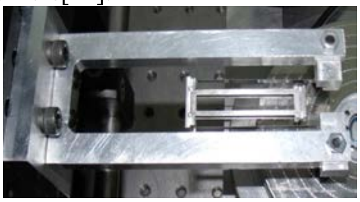


Fig 3 Diagram of sensor deformation under load of P; Fig 4 Diagram of structure of the force sensor

In the friction testing, vertical parallel cantilever will produce the phenomenon of bending due to the force of F, as the deformation of parallel cantilever is very small, the laser spot position o′ is near to the middle of the beam after cantilever deformation, The elastic modulus of material E=200GPa, the length, width and thickness of the vertical cantilever respectively are 50mm,3mm,0.1mm， when friction force is *f*=20uN,the distance is 60mm，the angle is 30°，after the calculation ,obtained the result is $\delta = 0.625 \times 10^{-4}$ rad, Pixel length of CCD is greater than 8μm, so the resolving power is 10μN.

3.2. Strong light for peak treatment

The pixel position of the peak on the CCD imaging curve is the spot center of the CCD photosensitive surface. The horizontal spring lamination and the vertical spring lamination of the force sensor were placed in vertical state，it will produce shakes when under the positive pressure and the level frictional force，the laser beam of the reflection laser will offset the corresponding angle，the center of the spot on the CCD also has a corresponding change. The deformation of the force sensor reflects the size of the force between the probe and the test specimen, reflected in CCD, it is a geometry change of pixel of the spot, and through the calibration can get the size of the pressure and friction.

4. The system calibration of the sensor

The theoretical calculation gives the range of the friction measured and the reference range of the accuracy. The measuring system is calibrated with a simple and accurate measurement in the next step. Use precision displacement platform and high-precision electronic balance for calibration experiments (Figure 5),respectively, the calibration of the relationship between the horizontal beam deformation and their corresponding positive pressure (Table1), and the relationship between the vertical beam deformation and the their corresponding friction (Table 2). And also pass the test software to read out the spot displacement on the CCD, in order to obtain the relationship between the changes of the pixel position on the CCD and the deformation of the leaf springs on the parallel beam (Table 3).

The calibration of positive pressure uses two kinds of feed methods, such as each feed 10μm, 80 times and each feed 15μm, 54 times. The calibration of friction uses two kinds of feed methods, such as each feed 5μm, 80 times and each feed 10μm, 40 times. Use Matlab for linear fit of measuring data. After experimental data analysis, ff=10.2Dp, fn=33.32x, ff being the friction, Dp being the pixel displacement, fn being positive pressure, x being the vertical feed of the displacement platform.

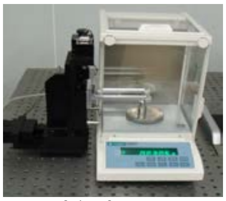
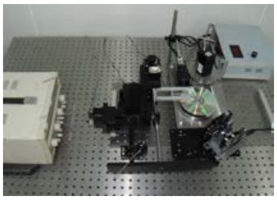



Fig 5 Calibration diagram of the force sensor;Fig 6 Picture of experimental device of micro friction

5. Analysis of experimental results

The experiment loads positive pressure with a micro-displacement platform whose resolution is 0.625μm, a laser with 650nm wave length and 3mW power is used for the light source in the experiment, the light receiver is a linear CCD with 3648 pixels and the parallel beam of the force sensor are all alloy films with 0.1mm thick. Before the experiment the load caused by the deformation of parallel beam have to be determined by a Electronic Analytical Balance with 0.1mg accuracy, calibrating the platform displacement and load and platform displacement and beam displacement, getting the relationship between the load and displacement spot indirectly by analysis the linear fit calibration data, and denoting it with discrete scale whose smallest scale is 10μN and load scale interval is 10μN.

In order to validate the feasibility of this testing method, the super-smooth surface disc is uses as specimens. Adopting the aluminum probe which the oxide film in its surface is removed to carve on the surface of the specimen, the experiment of friction testing is performed on the specimen through the testing system of micro-friction of the specimen surface friction.

The carved length is 10μm each time. The Friction Coefficient between testing A1 and surface material of CD. The diameter of probe is 30μm，the P-V value of CD surface is 25nm, and its Ra is 5.76nm. The testing equipment is in the Fig.6. Through loading positive pressure uniformly and in different experiments, the testing curve of positive pressure and friction is shown in Fig.7.

According speed and contact time, we perform friction experiments respectively in the process of experiment. The result of experiment can be seen in Fig.8-10.The testing result shows that, in spite of the experiment is performed on the slippery round surface, the loading of position pressure is not stable and there is rebound phenomenon periodically which leads to the testing friction is unstable. To analyze the causes, at the condition of small load, high speed, shot time, the rebound phenomenon do not easily happen in a small area. However, in the larger measurement range, large load, low speed, long contact time, rebounder phenomenon usually happen, this will affect the measurement precision.

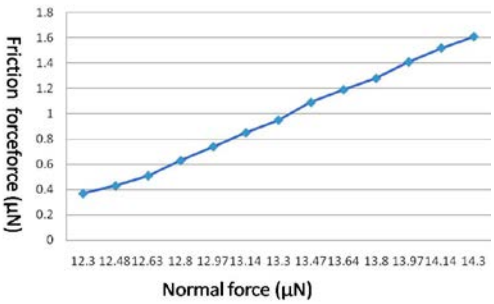


Fig 7 Experimental values of normal load and friction

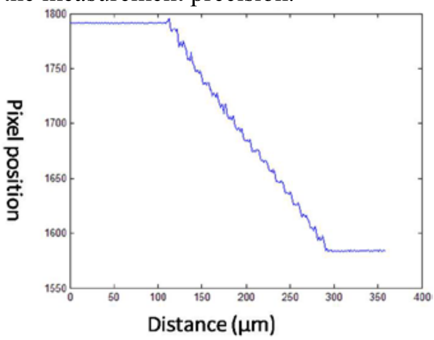


Fig 8 Diagram of friction trend（test conditions：long feed to20μm , traverse into to 10μm every time）

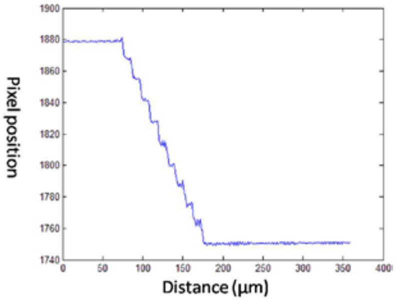


Fig 9 Diagram of friction trend（test conditions：long feed to40μm, traverse into to 10μm every time）

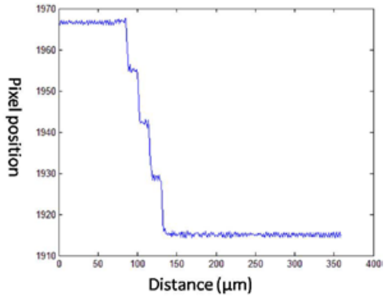


Fig 10 Diagram of friction trend（test conditions：long feed to80μm, traverse into to 10μm every time）

According to the graph drawn to the experimental data, we can easily see there is natural vibration phenomenon of measurement arm during the test, when feed distance is more than 40mm, this phenomenon can be ignored, But when less, it will affect the measurement precision. At the same time, within the small feed distance, the arm rebound phenomenon is outstanding, which affect the measurement precision, this problem is similar with Refs[7], by the experiment analysis, with the continuous of feed movement ,when the energy is larger than measuring arm have store, it will produce rebound phenomenon, which affect the measurement precision.

6. Conclusion

In this paper, the experimental design method of micro friction is presented by using the force sensor of the structure of parallel cantilever. The micro deformation of sensor is accurately measured based on light reflection through loading micro-table, then the positive pressure and friction are measured.The results of experiment show that the system has high test precision and sensitivity, and has advantages of good accuracy, strong anti-interference ability, good repeatability and high testing precision .The resolution of the system is 20μN. At the same time, the problem of instability in the measurement process is analyzed, making the structure which can test arm of force modular with further work , then not only is the system easy to be replaced, but also it can be accurately measured in a certain measurement range, avoiding the rebound phenomenon.

References

[1] Lu Xinchun, Luo Jianbin, Wen Shizhu. Development of Experimental Studies on Nano-scale Friction and Wear[J]. *Chinese Journal of Scientific Instrument*. 1995,2:60-63.

[2]ZHOU Zhaoying, ZHOU Zhaoying, et al. Micro-electromechanical Systems[J]. *China Mechanical*. 2000,11:163-196.

[3]Xue Qunji, Zhang Jun. Advancing in Microtribology Research[J]. *Tribology*,1994,14(4):360-369.

[4]Liu Ying, Wen Shizhu. STUDY ON PERFORMANCES OF MICRO-FRICTION AND ITS CONTROL IN MEMS[J]. *Chinese Journal of Mechanical Engineering*, 2002,38(3):1-5.

[5]Tian Wenchao, Jia Jianyuan. Seven Key Problems in MEMS[J]. *Chinese Journal of Scientific Instrument*. 2004,8:395-97.

[6]Liu Yongping, Gong Jun, Xin Zhou, et al. Design of reciprocating friction and wear testing machine and its computer control system[J]. Aug.2010: 1750-1755.

[7]Dong yunkai. Study of Friction Characteristics on Micro-textured Silicon Surfaces[D]. *Tsinghua University*. 2007,10.

[8]Cao Changjiang, Zhang Chen, Jiang Yinglan. A Testing Instrument for Micro-friction Based on Electromagnetic Micro-motor[J]. *Instrument Technique and Sensor*,2000(10): 36-38.

[9]Yu Zhenglin, Wu Yihui, et al. Testing Apparatus for Micro-Friction Using Reflection Method[J]. *China Mechanical Engineering*, 2005, 7(2):1299-1302.

[10]WANG Liang,CHENG Xian-hua. The Micro Force Sensor for Micro Friction Testing [J]. *Journal of Shanghai Jiaotong University*. 2005, Vol. 39, No. 11: 1792-1798.

[11]Huadong ,Yu Qingyong Shi, Yiquan Li,et al.Design and Calibration of Sensing System forHigh-precision Meso-scale Friction Test[C].Proceedings of the 2011 IEEE ICMA ,2011:1093-1097.