XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

CMM PROBE TESTING BY MEANS OF A LOW FORCE SENSOR

A. Wozniak and M. Dobosz
Institute of Metrology and Measuring Systems, Warsaw University of Technology
Chodkiewicza 8 St. 02-525 Warsaw, Poland

Abstract: The method and the computerised set-up for the accuracy of touch trigger probe testing, outside CMM is discussed. A high resolution interference displacement transducer with a low measuring force is applied. The results of preliminary tests of TP2-5W and TP6 (Renishaw) probe in XYZ space are shown. The metrological characteristics of the probe are analysed.
Keywords: coordinate measuring machines; touch trigger probe

1 INTRODUCTION

Touch trigger probes are widely used with coordinate measuring machines (CMMs) to indicate the position of their axes when contact between probe tip and the object surface. A sketch of such a probe is shown in Fig. 1(a) [1,2]. The stylus is attached to a tripod structure whose three cylindrical arms are located at three pairs of crossed cylinders. It is a kinematics mechanism, which under the effect of the spring restores the stylus to its original position following the contact with the object being measured. An electric current normally flows through the arms and cylinders. Then the stylus moves, one of the contacts breaks and gives a binary signal. It is e very precise switch, which responds to stylus displacement of order several micrometers. The motion of the CMM between positions when a part contacts the probe stylus and the probe triggers is called “pretravel”. Because the CMM qualification procedures (using a master sphere of known radius) determine an affective stylus ball and the average pre-travel the most important parameters is pretravel variation. So, the most important error source in tough trigger probes is direction-dependent pretravel variation.

To measure the probe pretravel the actual contact of the probe tip with a surface must be detected. Next the displacement of the probe tip between the moment of the first contact and the probe triggering pulse should be measuring with high resolution. To detect the actual moment of mechanical contact we propose to apply low measure force, high-resolution displacement transducer, that is in continuos contact with the probe tip. To avoid probe stimulation, by the transducer its measuring force should be negligible in comparison with triggering force of the probe head.

2 METHOD AND EXPERIMENTAL SET-UP

The low measuring force transducer [3,4] is in mechanical contact with the probe stylus (Fig. 1(b)). It detects with 15 nm resolution the moment of the stylus movement and measure its pretravel. In order to avoid the probe stimulation through this contact applied measuring force of the transducer is about of 10 mN, so it is about fifteen times lower than that of the probe. Before the probe is triggered, the position of the transducer stylus is recorded.

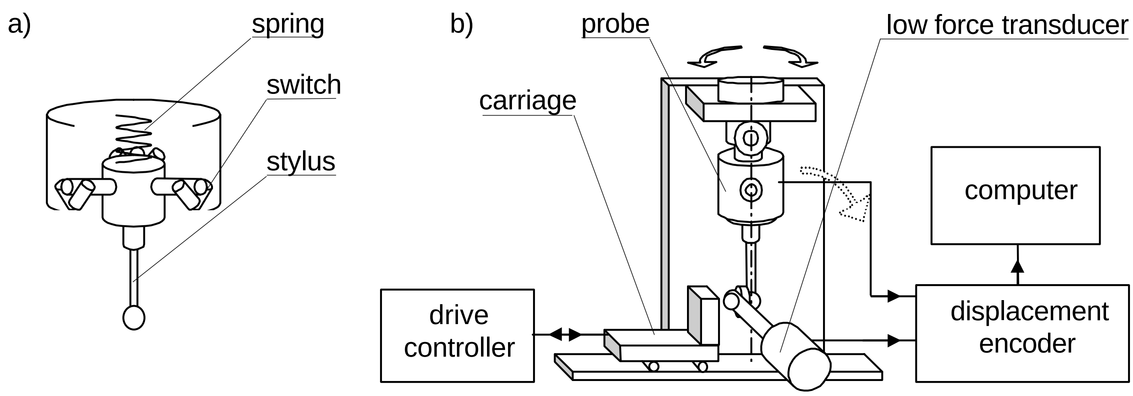


Figure 1. (a) Schematic diagram of a typical kinematic seat touch trigger probe (b) the experimental set-up with a high resolution low force transducer.

After the probe tip is moved (together with transducer arm) the probe output pulse releases the reading of the transducer position. The difference between these consecutive readings of the displacement transducer is a measure of the pretravel. The measurements are repeated to evaluate the probe repeatability. Additionally the probe is rotated to evaluate the pretravel spatial variability. All the data from the transducer are send to the computer and stored in its memory. Fig. 2. show the experimental set-up for testing the CMM triggering probes developed in Institute of Metrology and Measuring Systems at Warsaw University of Technology.

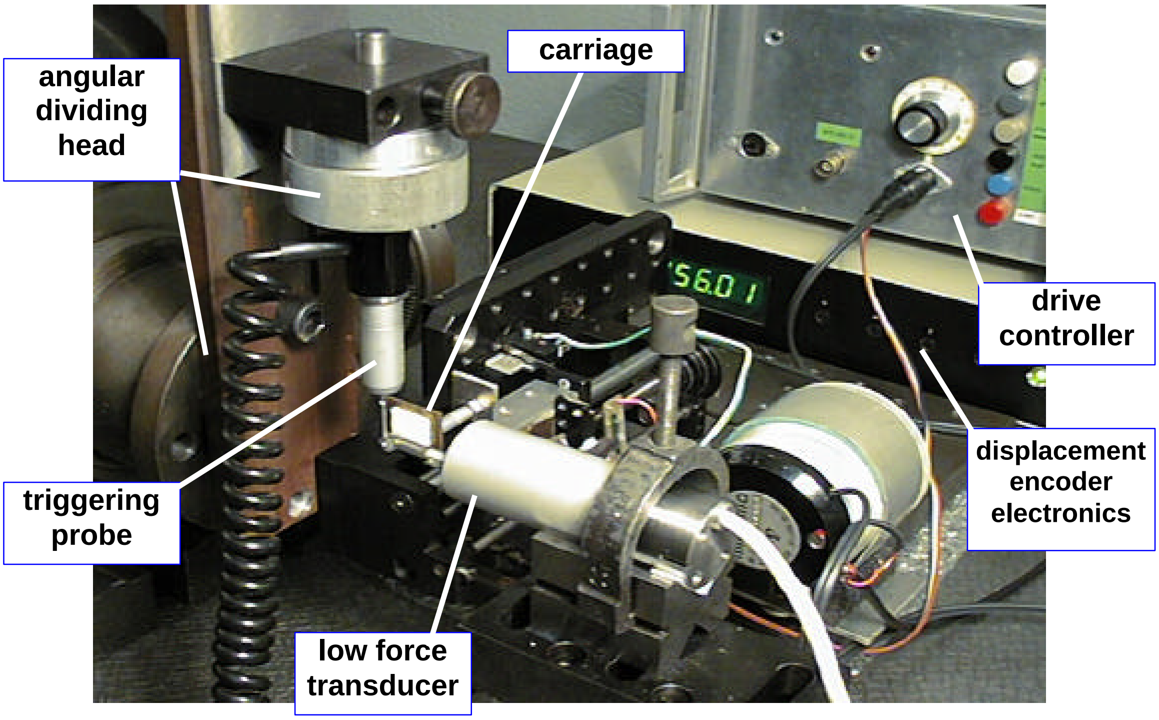


Figure 2. Experimental set-up the set-up for testing the CMM triggering probes using low force transducer

Since the measuring force of the displacement transducer (due to the lever balancing) is about ten times lower than that required to switch over the probe, the interaction between the displacement transducer stylus and the probe stylus can be neglected.

The interference displacement transducer [3,4] ensures continuous measurement of the probe stylus position (Fig. 3). The x_1 read-out takes place at the moment of carriage return and it corresponds to the rest point of the probe stylus. Then the carriage moves in the normal direction in relation to P surface until at the output of the probe transducer the signal of touch (point x_2) appears. The probe pretravel w is expressed as a difference between the measuring probe read-outs for the rest point (real contact point) and the pretravel point of the probe

$$w = x_2 - x_1 . \tag{1}$$

Average value of $\overline{w}$ is calculated, from the n measurements of pretravel w as

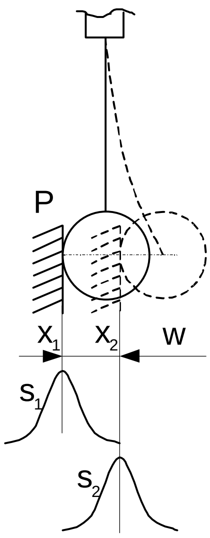


Figure 3. The touch trigger probe pretravel measurement

$$\overline{w} = \frac{\sum_{i=1}^{n} w_i}{n} \tag{2}$$

The repeatability of the probe rest point is measured by the standard deviation:

$$s_1 = \sqrt{\frac{\sum_{i=1}^{n}(x_{1i} - \bar{x}_1)^2}{n-1}} \tag{3}$$

where:

x_{1i} - position of the probe stylus at the moment of the contact at the ith measurement,

$\bar{x}_1$ - arithmetic mean of n measurements.

The dispersion of the triggering points of the testing probe is measured by the standard deviation:

$$s_2 = \sqrt{\frac{\sum_{i=1}^{n}(x_{2i} - \bar{x}_2)^2}{n-1}}\ , \tag{4}$$

where:

x_{2i} - position of the probe stylus at the moment of the contractors opening in the ith measurement,

$\bar{x}_2$ - arithmetic mean of n measurements.

The measure of the dispersion of the determined pretravel can be expressed standard deviation:

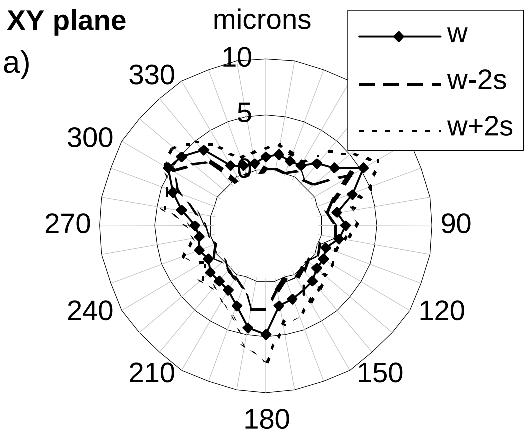
$$s = \sqrt{s_1^2 + s_2^2}\ , \tag{5}$$

where:

s_1, s_2 – standard deviations of the position values $\bar{x}_1$, $\bar{x}_2$.

3 RESULTS OF TESTS

In order to verify experimentally the proposed method, the pretravels of TP2-5W and TP6 (Renishaw) probes were tested in the XYZ space. The stylus of both probes was 21 mm long, ended with a ball of 2-mm diameter for TP2-5W and 4mm for TP6. The measuring force of the probes was set to 0,15 N (15 G). The stylus velocity was equal to 5 mm/s. For each of the thirty six directions of the force affecting the probe stylus, a series of ten measurements of the pretravel were carried out. The force direction was changed every 10^0 in the horizontal plane and every 10^0 in the vertical plane. The values of the pretravel *w* (continuous line) as the function of the angle of the triggering force direction are presented in a diagram in the polar coordinate (Fig. 4, 5).



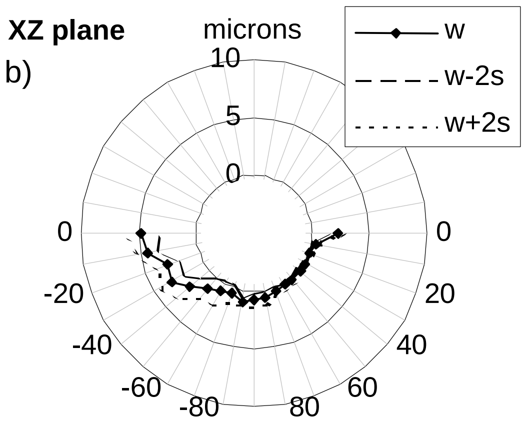


Figure 4. TP6 probe experimental results in 3D: (a) in horizontal XY plane, (b) one vertical section shown in XZ plane.

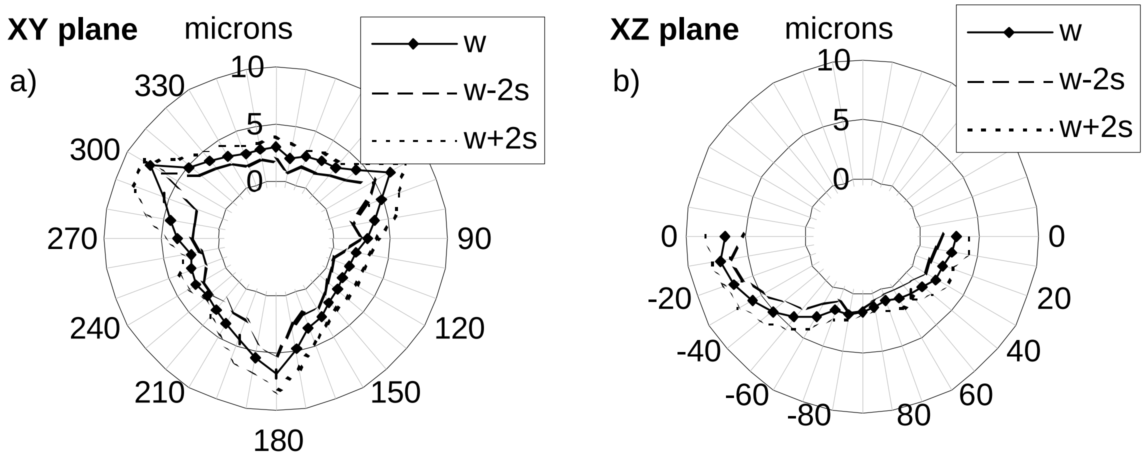


Figure 5. TP2-5W probe experimental results in 3D: (a) in horizontal XY plane, (b) one vertical section shown in XZ plane.

The uni-directional variation of the pretravel are expressed by the standard deviation *s* (dashed line). Fig. 4 and Fig. 5 shows that the variability of pretravel exists not only in the plane perpendicular to the probe stylus but it is also in the plane parallel to the stylus. In Fig. 4, 5(a) we observe a similar triangular pattern. The orientation of this characteristic is dependent to the tripod structure of probes switching mechanism. Fig. 4, 5(b) shows a particular test plane with corresponds to that containing the maximum and minimum horizontal pretravel. The general shape of characteristic in a vertical plane is a asymmetrical variation from 90^0 down to 0^0 or -90^0. Finally, the TP2-5W probe pretravel in 3D plane was found to vary from 1 to 7 µm. The TP6 probe pretravel was changed from 0,2 to 5,2 µm.

The method is not only suitable for the measurement of the pretravel variation. Also the actual pretravel of the touch probe is evaluated. The experimental results confirm the validity of the method. The triangular form of the observed curves in XY plane is explained by the three-armed design of the probe transducer.

4 CONCLUSIONS

The new method based on the use of a low measuring force and high resolution displacement transducer gives detailed characterisation of the touch trigger probe pretravel independently of the CMM. The resolution of the proposed method is about 0,02 µm. The pretravel is obtained for any spatial direction of the triggering force. The significant variation of the pretravel both in the plane perpendicular and in the plane parallel to the stylus arm indicates the need of the probe tests to be performed in 3D space.

REFERENCE

[1] F. Chan and all, Some performance characteristics of a multi-axis touch trigger probe, *Meas. Sci. Technol*. 8 (1997) 837-848.
[2] W. Tyler Estler and all, Error compensation for CMM touch trigger probes*, Precision Engineering* 19 (1996) 85-97.
[3] M. Dobosz, Application of a divergent laser beam in a grating interferometer for high resolution displacement measurements, *Opt. Engineering* 33 (3) (1994) 897-901.
[4] M. Dobosz, New stylus probe with interferometric transducer for surface roughness and form profiling, *Opt. Engineering* 33 (3) (1994) 902-908.

AUTHORS: A. WO• NIAK and M. DOBOSZ, Institute of Metrology and Measuring Systems, Warsaw University of Technology Chodkiewicza 8 St. 02-525 Warsaw, Poland
Phone: (4822) 660-8347, Fax: (4822) 49-03-95, E-mail: wozniaka@mp.pw.edu.pl