GEOMETRIC MEASUREMENT OF ROCKWELL DIAMOND INDENTER USING TRACED MOCRO-CMM IN CMS

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Abstract: The Primary Rockwell Hardness Standard System was set up in the Center for Measurement Standards since July 1996 till June 1997. During the time, a laser interferometer, HP10737R 3-axis compact interferometer system was used to measure the effect of pitch and yaw of the Rockwell Hardness machine. While the geometry of the diamond was not determined. In order to increase the performance of hardness measurement .In this paper, we will present the results of indenter geometry by μ -CMM in CMS.

Keywords: μ -CMM(Coordinate Measuring Machine) / Rockwell diamond indenter / Tungsten sub-micrometer tip/ laser interferometers

1. INTRODUCTION

Rockwell hardness is the most commonly used hardness standard in the industry.This standard is traced to from the indentation depth and load. While the largest part of uncertaintyis from the geometry of hardness indenter. Hardness measurement uncertainty of about 50% from the hardness indenter. For the assessment of the geometry of the indenter is according from the ISO 6508-1. Which specific provisions for the arc angle and radius for the hardness. The laboratory must establish the hardness indenter group for each indenter area function determination, As the basis of the retrospective of Rockwell hardness standard.

In the studies of the Rockwell's indenters, There are several methods used. These works were early done by J. Song using tip touch method [1,2,3]. After then, the more study were continuously by Song in NIST and by Dai in PTB[4]. While the optical method was also used, Germak utilized the confocal microscope and proper analysis to improve the geometry calibration of the Rockwell diamond indenter in IMRIN [5]. In this paper, we introduced aμ -CMM(Coordinate Measuring Machine) to measure the geometry of Rockwell diamond indenter.

2. PRINCIPLES AND SETUP

The Rockwell hardness number is calculated from the difference in the penetration depths before and after application of the total force, while maintaining the preliminary test force. For scales that use a spheroconical diamond indenter, the Rockwell hardness number is determined by [6,7,8]:

$$HRC = K_1 \quad (h_1 \quad h_0) / K_2 \qquad (1)$$

HR :Rockwell hardness unit

K_1 =100:for diamond cone indenter, for Superficial Rockwell hardness

K_1 =130:for steel ball indenter

K_2 =0.002:for Rockwell hardness

K_2 =0.001:for Superficial Rockwell hardness

h_0 : depth of indenter under preliminary test force before application of additional test

h_0 : depth of indenter under preliminary test force after removal of additional force

Rockwell hardness indenter using a diamond indenter or the steel ball. When we .scan the top geometry of the indenter. The area function can be engaged in addition to be determined. As the μ -CMM measurement system was frequently employed to characterize the appearance of profiles. For instance, the benefits of surface profiles, roughness study etc. The μ -CMM system in CMS was shown in Fig. 1. It included the x-y-z stage with less than 50 nm in resolution. And a rotation stage used to rotate the indenter with the various angles. The z-direction was the Tungsten tip with micrometer radius in Fig. 2. The moving distances were measured by laser interferometers. These resolutions were 0.32 nm in x and y directions. While the resolution of z direction was 1.2 nm. All the information were transferred by VME-Bus to IPC data access.

Fig. 1 The μ -CMM(Coordinate Measuring Machine) components: 1.The z-axis laser interferometer for proofing indenter. 2.The y-axis laser interferometer 3. The x-axis laser interferometer. 4. The Rectangular mirrors 5.Rotation stage for the scanning in different angles 6.The x-y stage 7.Fine tuning for scanning tip

Fig. 2 The tip etching machine. Left side is the controller and the left side is the etching part

The tip was made by chemical Tip-Etcher. The diagram of Tip-etcher is shown in Fig. 2. The Tip-etcher contains an Electronic control unit, Carbon Electrode, Beaker and Tip's electrode etc. A tungsten wire with diameter of 5 mm was etched. The principle is to use the high current through a tungsten wire, tungsten, and high concentrations of KOH concentration of liquid formation pathway. The concentrated liquid corrosion of tungsten in the surface of the thick liquid to form a current circuit, made in the appropriate current. When we use 1.5 ampere passed through the wire in KOH liquid. The tip will be good aspect ratio.
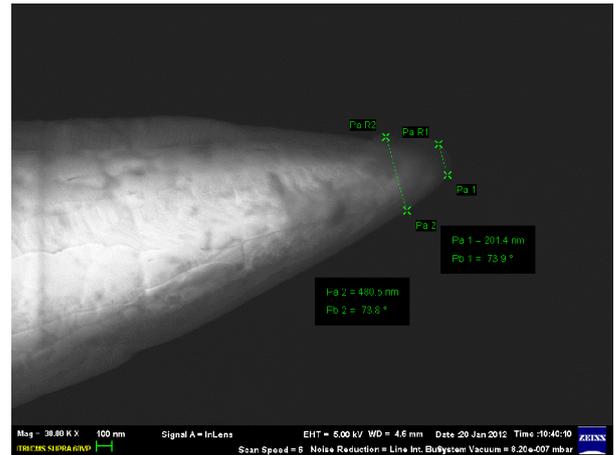

Fig.3 Tungsten tip in SEM picture. The width of the tip is smaller than 150 nm

The etched-tip was scanned by scanning electron microscope Typical result was shown in Figure 3. The sharp of the tip was smaller than 50 nm in radius. Then the tip was mounted on a soft flexure (in Fig. 4).
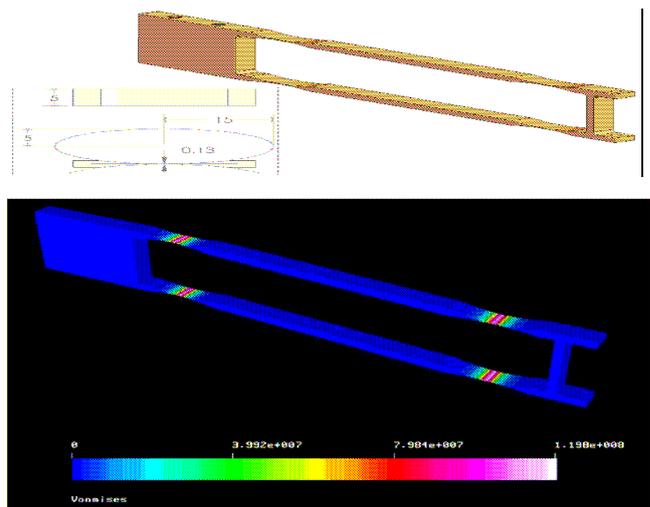

Fig. 4 The Cu-Be flexure with low stiffness and simulation results

Probe is fixed in the bottom of the flexible structure at one end, above the same side of the fixed mirror. The other end of the flexible structure is fixed adjustment in a three-dimensional mobile units, used to adjust the μ -CMM probe the appropriate location.. The spring constant of the flexure was nearly 19.1 N/m. The tip touches the surface of the indenter slightly. Then it scanned when the x-y stage slowly moved. All the moving distances were record by the laser interferometers. The verify and check of the μ -CMM were used to measure the geometry of Rockwell diamond . The information will improve our measurement of Rockwell hardness.

3. RESULTS

We used the probe to scan a Rockwell hardness indenter. Rotating the axis of the indenter every increase of 45 degrees. Then Scanning the profile of the tip of indenter in accordance forth and back scan of 1200 microns. Interferometer were recorded in three directions, two-dimensional xy mobile station to the z direction to scan the ups and downs of the location of the Rockwell hardness indenter. Sampling rate of 2 Hz, respectively, by the computer records position; mobile station does not closed control solely of interferometer records. The DTS-47127 indenter was scanned. Typically scan sweep results was shown in Fig. 7.
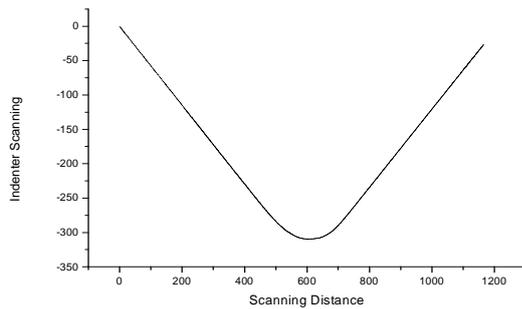

Fig. 7 scan sweep results: The x-axis is the scanning range. The y-axis is the scanning tip profile

Using the third order polynomial regression analysis such as (2) as shown:

$$y = p_1 \cdot x^3 + p_2 \cdot x^2 + p_3 \cdot x + p_4 \qquad (2)$$

while,

   y is the depth of indenter scanned
   x is the range of indenter scanned
   p_i :fitting parameters

Cubic polynomial linear regression to determine the curvature of the indenter radius around the top of the scan range of 95 microns.

On both sides of the points in the interval of plus or minus 95 microns, respectively, a linear regression, then obtain the angle between two straight lines, arc angle as a Rockwell hardness indenter. Results obtained were as shown in Table 1.

Table 1. Results of DTS-47127 indenter

scanned-angle	tip angles (degree)	ave rage tip radius(μ m)	MIn tip radius(μ m)
0°	120.937	243.577	216.433
45°	121.845	210.883	185.943
90°	122.518	202.369	175.131
135°	122.614	201.494	174.235
180°	125.396	249.555	228.859
225°	121.682	210.340	178.081
270°	121.139	211.825	186.896
315°	121.590	206.215	179.507

4. OUTLOOKS

The system does not make closed loop control.All observed values traced back to the length of the interferometer measurement standards, through good vertical movement of the flexible structure as scanning Probe the surface morphology of the tool. During this period did not consider the cosine error caused by the up and down the probe scanning; about 1 degree offset affects approximately 1% of the angle determination. In the future, we will use closed loop control probe and moving stage, making the system scan to scan in a fixed surface force. As a basis for future system improvements

5. REFERENCES

 [1]   Song, J., Rudder, F., Vorburger, T., and Smith, J., "Microform calibration uncertainties of Rockwell diamond indenters," *J.Res. NIST*, **100**(5), 543-561, 1995.

[2]   Song, J., Low, S., Zheng, A., ″Geometric measurement comparisons for Rockwell diamond indenters″ in the proceedings of the IMEKO XIX World Congress, Lisbon, Portugal, 2009.

[3]   *J. Song , S. Low*, *A. Zheng* and *P. Gu,"*GEOMETRICAL MEASUREMENTS OF NIST SRM ROCKWELL HARDNESS DIAMOND INDENTERS" in the proceedings of the IMEKO 2010 TC3, TC5 and TC22 Conferences Metrology in Modern Context November 22−25, 2010, Pattaya, Chonburi, Thailand

[4]   *Gaoliang Dai, Jian Zhao, Febo Menelao, Konrad Herrmann*1*, Uwe Brand*, "IMPROVED METHODS FOR ACCURATELY CALIBRATING THE 3D GEOMETRIES OF ROCKWELL INDENTERS", in the proceedings of the IMEKO 2010 TC3, TC5 and TC22 Conferences Metrology in Modern Context November 22−25, 2010, Pattaya, Chonburi, Thailand.

[5] Alessandro Germak and Claudio Origlia,″New POSSIBLIBITY IN THE GEOMETRICAL CALIBRATION OF DIAMOND INDENTERSRS″ in the proceedings of the IMEKO XIX World Congress, Lisbon, Portugal, 2009

[6] ASTM E18-89a, "Standard test methods for Rockwell hardness and Rockwell superficial hardness of metallic materials", ASTM, New York(1989).

[7] ISO/FDIS 6508-1,2,3, "Metallic materials-Hardness test-Verification of Rockwell hardness testing machines (Scales A-B-C-D-E-F-G-H-K) ", ISO/TC 3 (1999).

[8] Center for Measurement Standards of Industrial Technology Research Institute, "The Evaluation of Rockwell Hardness Primary Standard System" series number 07-3-87-0002",2001