Comparative Study of Three-Dimensional Measurement between CMM and CN Machine Tool – Case: Flatness and Cylindricity-

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***Abstract*—Three-dimensional measurement has taken an important place in the production systems. Indeed, the economic viability of automated means of production requires a rigorous and automatic control of manufactured products. That is to say, the quality of machining required, now, automatic monitoring means of tools and measuring dimensions during production. The evolution of modern machines tools led to an integration of measurement and control directly in the cycle of manufacturing. We present in this paper a comparative study of three-dimensional measurement of different geometric specifications between a coordinate measuring machine "CMM" and machine tool.**

Keywords—CMM; CN machine tools; probe; measure; control.

I. INTRODUCTION

Dimensional and geometric measure occupies the vast majority of control and metrology services of the companies. These techniques have been the last thirty years undergo a rapid development with the advent of the coordinate measuring machine. It helped to provide production workshops efficient and automated measuring means. The coordinate measuring machines, CMM, appeared in the 1970s. They then evolve during all these years both on the mechanical part and the software side. Long, the CMM had its place in an air conditioned room (stable thermal and vibrational level), metrology laboratory. Currently, with the mechanical and software developments, MMT find their place in environments more "hostile" as the workshop, or directly on the production lines. As the three-dimensional measurement of CN machine tools grows increasingly, thanks to increased possibilities of Directors of CNC (DCN) and the economic interests he represents. [1.2.3]

II. PRIINCIPLE OF THE THREE DIMENSIONAL MEASUREMENTS

Traditional means of measurement are now supplemented by three-dimensional measurement techniques that allow access to the geometry of complex parts with high accuracy and high speed. In the Three-dimensional metrology, the preferred tool of control is currently measuring ma-chine (CMM).

From a cloud of points taken from a real curve (or surface area), the software of the machine makes an identification of the probed element. This operation consists in associating a theorical curve (or surface area) and palped cloud of points, the criteria of the association most commonly used is: the criterion of least squares or Chebyshev criterion. The most current Geometries in this field are the right plan, circle, cylinder, sphere and cone [4.5.6]. The CMM consist mainly of three measurement axes and a probing system with a contact key attached to the end of the last axis. Depending on the movements of the axes of measures which are related to the rules of high precision measurement, it is possible to estimate the coordinates x, y and z of the point of contact between the touch probe and the measurement surface. The part to be measured is mounted on a marble. The probe system establishes a relationship between the physical contact of the tip of the probe on the surface to be measured and the displacement of the three reading Fig.1a.

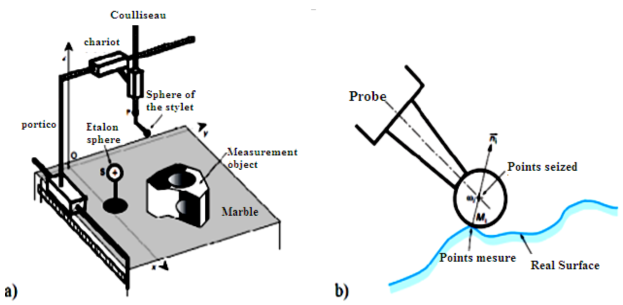

Fig.1 a) - Principle of CMM, b) - Measured point

To measure the shape of the surface of a piece positioned on the CMM table, the pen button, which is a sphere of ω_i center located at the end of the stylus, touch M_i different points on the surface to be measured (Fig .1 b). The control system of the machine captures the coordinates of the center of ω_i. According to the normal (to be estimated) to the surface at the point M_i and the apparent radius r_j (calculated for each orientation of each probe and stylus), the point coordinates are calculated M_i measured by the following equation: [7.8]

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$$\overrightarrow{SM_i} = \overrightarrow{S\omega_i} - r_j\overrightarrow{n_i} \quad (1)$$

III. THE DETERMINTION OF THE PARAMETRES OF THEORETICAL FORMS

In the field of surface metrology, the performance of control means are increasing in terms of accuracy and number of measured points. The measurements are quantities subject to disturbances difficult to synthesize and the information they contain is difficult to use. We try here to show how to get the parameters of the theoretical forms. All calculations are based on the principle of optimization by the method of least-squares.

A. *Flatness*

For flatness, we move from one-dimensional to two-dimensional, the right plan Fig.2. For this we must calculate the characteristic coefficients of the optimal plan, knowing that his equation in space is written as follows. [9.10]

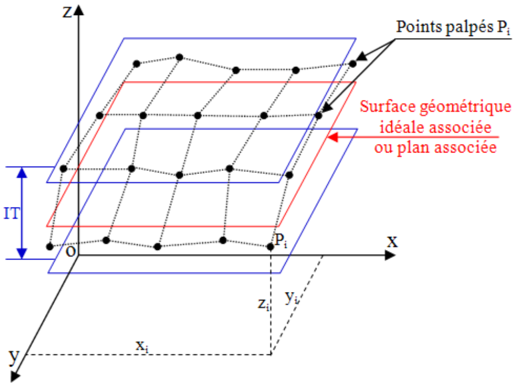

Fig.2 Theoretical Reference For The Flatness

$$Z = Ax + By + C \quad (2)$$

It is therefore about determining coefficients A, B, and C according to relations:

$$A = \frac{\left[n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right] - B\left[n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right]}{\left[\left[n\sum_{i=1}^{n} y_i^2 - \left[\sum_{i=1}^{n} y_i\right]^2\right] - \left[n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right]^2\right]} \quad (3)$$

$$B = \frac{b_1 - b_2}{\left[\left[n\sum_{i=1}^{n} y_i^2 - \left[\sum_{i=1}^{n} y_i\right]^2\right] - \left[n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right]^2\right]} \quad (4)$$

$$C = \frac{\sum_{i=1}^{n} z_i}{n} - A\frac{\sum_{i=1}^{n} x_i}{n} - B\frac{\sum_{i=1}^{n} y_i}{n} \quad (5)$$

With

$$b_1 = \left[n\sum_{i=1}^{n} x_i^2 - \left[\sum_{i=1}^{n} x_i\right]^2\right]\left[n\sum_{i=1}^{n} y_i z_i - \sum_{i=1}^{n} y_i \sum_{i=1}^{n} z_i\right]$$

And

$$b_2 = \left[n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right]\left[n\sum_{i=1}^{n} x_i z_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} z_i\right]$$

B. *Cylindricity*

In this section, we present the cylindrical Fig.3. We recall the equation of a cylinder centered: [10]

$$(x-a)^2 + (y-b)^2 = D^2 \quad (6)$$

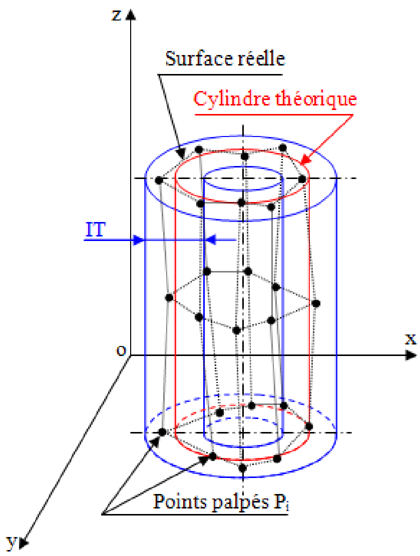

Fig.3 Theoretical Reference for the cylindricity

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Where D is the cylinder radius

$$b = \frac{[b_3 - b_4]}{\left[\begin{array}{c} 2 * \left[n \sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right] * \left[n \sum_{i=1}^{n} y_i^2 - \left[\sum_{i=1}^{n} y_i\right]^2\right] \\ -2\left[n \sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right]^2 \end{array}\right]} \quad (7)$$

$$a = \frac{\left[\begin{array}{c} \left[n \sum_{i=1}^{n} x_i z_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} (x_i^2 + y_i^2)\right] \\ -2b\left[n \sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right] \end{array}\right]}{\left[2\left[n \sum_{i=1}^{n} x_i^2 - \left[\sum_{i=1}^{n} x_i\right]^2\right]\right]} \quad (8)$$

With

$$b_3 = \left[n \sum_{i=1}^{n} x_i^2 - \left[\sum_{i=1}^{n} x_i\right]^2\right]\left[n \sum_{i=1}^{n} y_i z_i - \sum_{i=1}^{n} y_i \sum_{i=1}^{n} (x_i^2 + y_i^2)\right]$$

$$b_4 = \left[\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right]\left[n \sum_{i=1}^{n} x_i z_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} (x_i^2 + y_i^2)\right]$$

On or

$$D_i = \sqrt{(x_i - a)^2 + (y_i - b)^2} \quad (9)$$

And

$$D_{opt} = \frac{\sum_{i=1}^{n} D_i}{n} \quad (10)$$

IV. EXPERIMENTAL

We propose, in this second part, to evaluate the three-dimensional measuring geometric specifications by two machines (CMMs and NC machine tool). As a first step, we measure the flatness of a standard room and the cylindricity of a standard bore. This is why the tests are performed by the MP700 probe system which is installed on our machine tool numerical control, and a coordinate measuring machine [11.12.13.14.15]. So we must perform the following steps:

- Select the form control (flatness and cylindricity Fig.4-a Fig.5-b)
- Gridline the surface according to the dimensions of the parts;
- put down the piece on the machine table;
- Palpate the room (about 20 points palpated for flatness and 27 points for cylindricity);
- Identify the coordinates of the probed points and enter them into tables;
- Validate the control treatment.

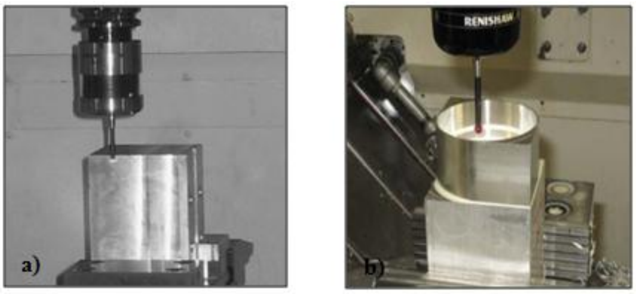

Fig.4a) - Measurement of flatness b) - Measurement of cylindricity

IV. RESULTS AND DISCUSSIONN

A.Results of measurement

Figures 5 and 6 summarize shown the flatness measurement by CMM and NC machine tool

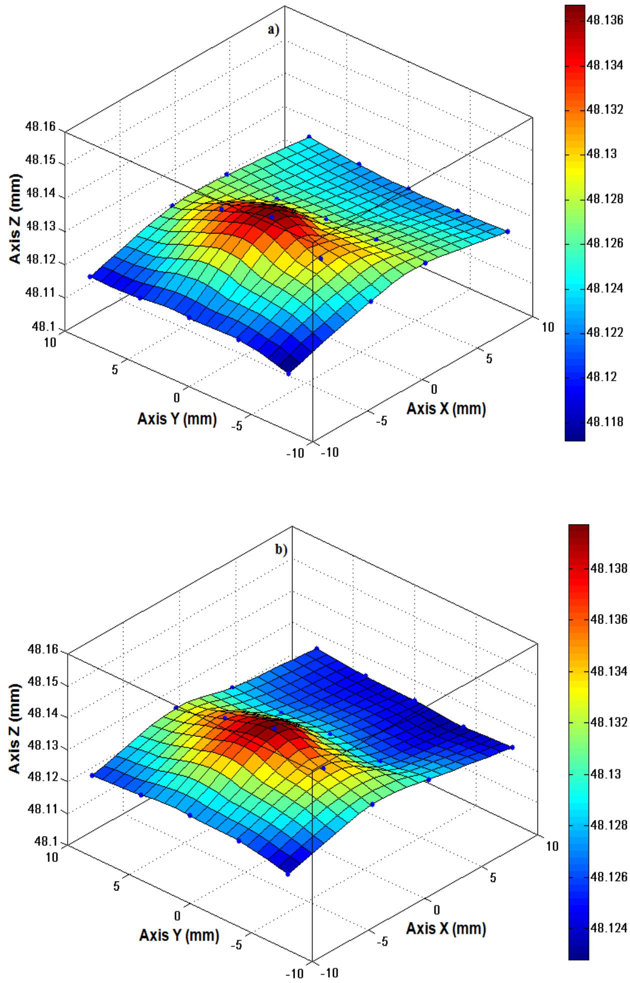

Fig.5 Optimal surfaces measured by CMM "a) - measure 1, b) - measure 2"

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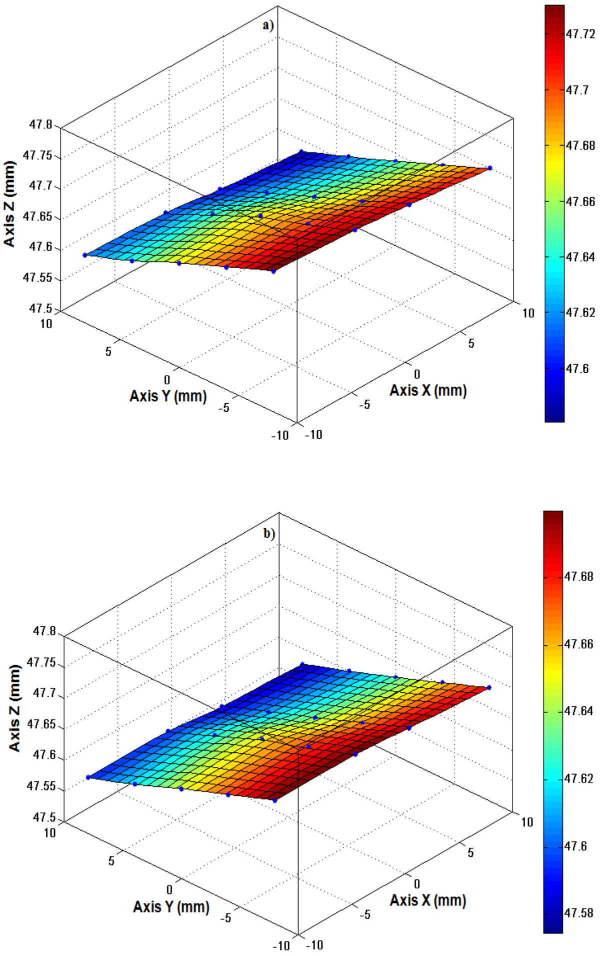
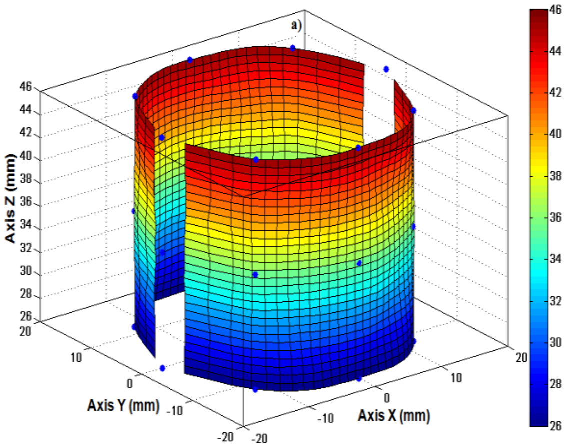


Fig.6 Optimal surfaces measured by CN machine tools "a) - measure 1, b) - measure 2"

Figures 7 and 8 summarize shown the cylindricity measurement by CMM and NC machine



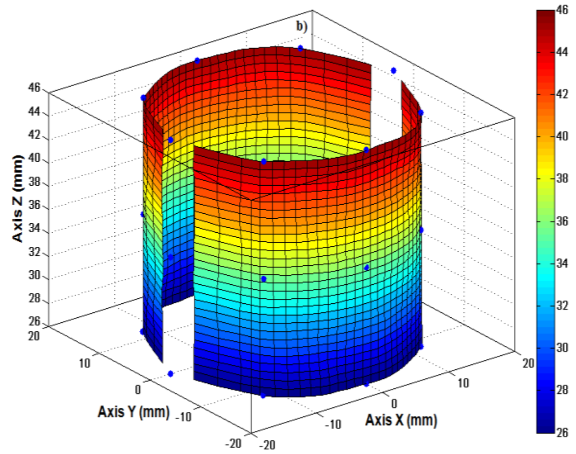


Fig.7 Optimal surfaces measured by CMM " a) - measure 1, b) - measure 2"

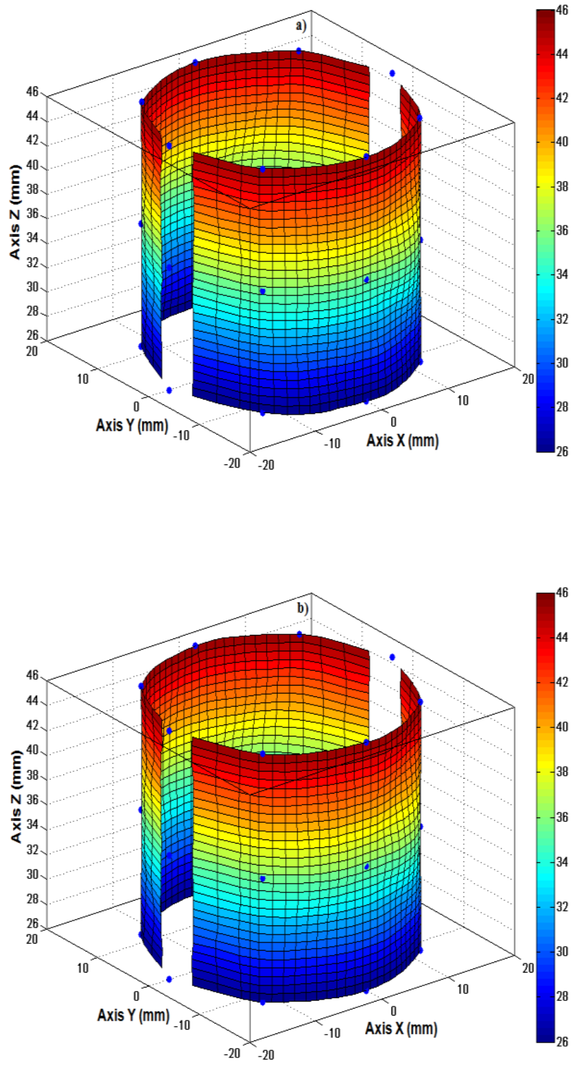


Fig.8 Optimal surfaces measured by CN machine tools "a) - measure 1, b) - measure 2"

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B. Discussion of results

It is noted that the measurement of the flatness defects gives following form:

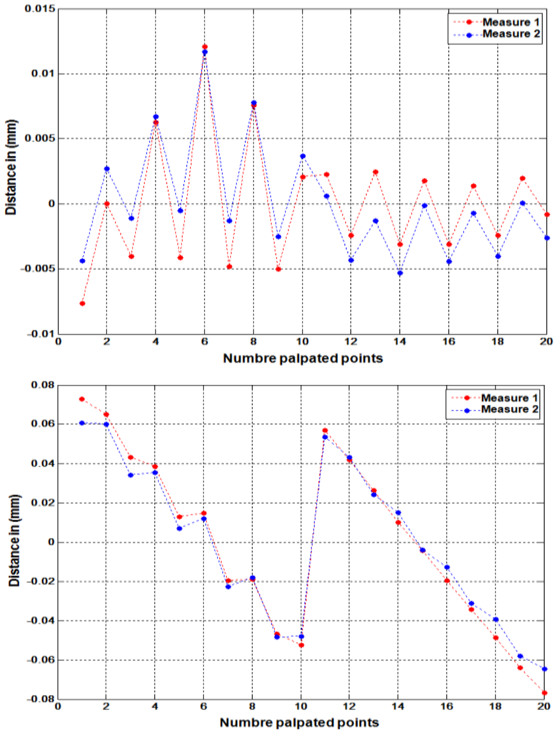

Fig.9 Measured deviations from flatness "a) - MMT, b) - NC Machine tool"

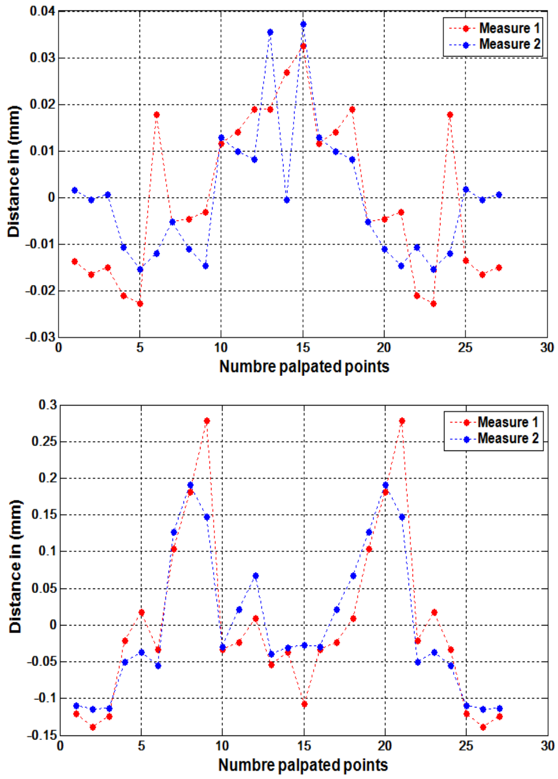

Fig.10 Measured deviations from flatness "a) - CMM, b) - NC Machine tool"

If the measurement results of the flatness between CMM and comparing NC Machine tool, respectively is obtained a 83.4% decrease of deformity. On the other hand, we can say that the deformity in the case of measuring the roundness is reduced by 86.33% between NC Machine tool and CMM. So measuring a geometric specification by the three-dimensional machine is more accurate than measuring by the machine tool CNC. (Table.1 and Table.2)

Table.1 Default measurement from CMM.

CMM	Form errors mini, mm		Form errors maxi, mm	
	Measure 1	Measure 2	Measure 1	Measure 2
Flatness	0.0001	0.0001	0.0121	0.0117
Cylindricity	0.0031	0.0005	0.0326	0.0373

Table.2Default measurement from CN machine tool

CN machine tool	Form errors mini, mm		Form errors maxi, mm	
	Measure 1	Measure 2	Measure 1	Measure 2
Flatness	0.0043	0.0039	0.0768	0.0644
Cylindricity	0.0089	0.0217	0.2782	0.1911

VI. CONCLUSION

We conclude the presence of a probe Renishaw MP700 on our machine tool numerical control «EMCO PC Mill 155 «enables real metrology operations, similar to measuring machines. However, it can also perform measurements which are very useful to improve productivity. Thus this system costs 20 times less than three-dimensional measuring machine. It is also observed in all cases of measurements, a significant gain deformity between the measurement by the two «CN machine tools and CMM "machines. Measured by CMM is more accurate than the measurement error due CN machine tool behaviour of the geometric and kinematic structure of the CN machine tool combined mechanical, thermal and inertial stresses developed during the machining operation. If known, they can be compensated by means of a module internal or external control that can integrate into the CN machine tool.

VI. REFERENCES

[1] S. Merghache, A. Ghernaout, A. Cheikh, « Probing on machine tools with numerical control», International Congress on Technology Mechanical, 05 and December 6, 2009, Tlemcen.

[2] Xiu-Lan,WenJia-Cai,Huang,Dang-Hong,Sheng,Feng-Lin Wang,«Conicity and cylindricity error evaluation using particle swarm optimization», département AutomatiqueNanjingInstitute de Technologie,Nanjing211167, Chine,Precision Engineering34(2010)338-344.

[3] XiangchaoZhang, XiangqianJiang,PaulJ.Scott,«the evaluation of the minimum zone form errors quadric surfaces», Precision Center and Technologies, University of Huddersfield, Huddersfield HD1 3DH, UK, Precision Engineering 35 (2011) 383-389.

[4] J. A. Bosch,« Coordinate measuring machines and systems», Marcel Dekker Ed. New York 1995.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

[5] P. Bourdet, « Metrology tree dimensional and geometric of parts mechanics», University Paris VI-ENS of Cachan, mechanical technology License 1998/1999.

[6] A. Nafi, « Verification and diagnosis of coordinate measuring machines with engine decoupling and probe», Department of Mechanical Engineering, Ecole Polytechnique de Montreal. PhD thesis June 2011.

[7] S. Merghache, A. Ghernaout, A. Cheikh, « Installing a module MP700 Renishaw probing on machine tools with numerical control: EMCO PC Mill 155 » CPI 2013 - Tlemcen Algeria - 21-23 October 2013.

[8] ISO10360-1,« Geometrical Product Specifications (GPS) - Acceptance and reverification tests for coordinate measuring machines (CMM)», Part 1: Vocabulary. ISO (Switzerland), 2001.

[9] M. Boumahrat, A. Gourdin, Edition O.P.U 1993, « Numerical method applied».

[10] Adamaneo, Hoang-Ky, Ouaklin, Edition O.P.U 1991, « Statistique ».

[11] B. Mery, Hermes Edition 1997, «Numerical Control Machine», the Graduate School of Arts and Crafts ENS Cachan Paris

[12] RENISHAW, Edition April 2, «System MP700 probe», Operator Manual H-2000-5133-06.A, RENISHAW SAS 15 Rue Albert Einstein, 77437 Marne la Vallée Cedex 2 France.

[13] RENISHAW 2008 Edition, «Installation Manual MP700 probe system», Programming Guide H-2000-5143-01-A, RENISHAW SAS 15 Rue Albert Einstein, Champs sur Marne, 77437 Marne la Vallée Cedex 2 France.

[14] EMCO MAIER, A2001-04 Edition, «EMCO PC Mill 155: Strawberry controlled by PC Training», Department Technical Documentation A-5400 Hallein, Austria, Ref-Nº. FR 4345.

[15] Favrelière H., G. LeGoïc, S. Samper, «Calibration of the flatness of mounting micro XY positioning approach modal parameter», University of Savoie, Laboratory SYMME, BP 80439, F 74944 Annecy old cedex, 5th International Congress of Metrology, Paris: France, 2011.

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