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MODELING OF THE CORRECTION MATRIX FOR THE CALIBRATION OF MEASURING MACHINES

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ABSTRACT:

The dimensional measurement and geometric was subjected the last thirty years has trend thanks to the emergence of the machine to measure three-dimensional. They have then made that evolve during all these years as well on the mechanical part, that on the software part. In effect, the measure on MMT and the computer processing which follows, leads to many sources of dispersions. According to the standard ISO 10360, the calibration of a MMT allows to determine the errors of correctness and fidelity in introducing almost all of the influence factors including those relating to palpages. The object of our study is to determine a matrix of correction in order to calibrate the MMT.

Keywords: CMM, calibration, ISO 10360,

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1. INTRODUCTION:

Machines with three-dimensional measure (MMT) are the instruments used in the Dimensional Metrology. They allow to obtain the coordinates of the points palpated on a mechanical part. These coordinates will be subsequently processed by a software associated with the machine to verify if the dimensional specifications geometric and brought on the design of the exhibit are respected.

The verification and calibration of the machines to three-dimensional measure has been the subject of several studies. In effect, several techniques have been used to determine the errors of measures either by laser or well to the help of artifacts. The study proposed by G. Zhang **[1]** is based on the assumption of rigid bodies for modeling the machine to measure three-dimensional, the author proposes 22 lines of displacement in the measuring volume of the machine. The Travel errors are obtained using the laser interferometer. While J.Chen **[2]** has developed a system of laser interferometer auto aligned in order to decrease the time of the calibration of the machines. G.Chen **[3]** proposes an alternative method to the method of G. Zhang. This method is to measure the errors of positioning of the machine 3 following axs 15 directions in order to quickly determine the 21 geometric discrepancies. CK.Lim and Mr Burdekin **[4]** have designed a bar to holes in steel in form of a profile in I of 540 millimeters, characterized by a good dimensional stability, a good resistance to wear and a very good surface condition of E.Curran **[5]** has proposed a rapid method for the verification of the MMT. This method uses a ball Telescopic bar that we measure in a plan, the first ball is attached to the aid of a magnetic media, the second ball rotates around the first ball and is measured at several positions by palpating 4 points at each position. S.Phillips **[6]** has developed a method for the calibration of the machines to three-dimensional measure of large sizes that have pins which exceed the 4 meters in length, this method uses a caliber equipped with a laser interferometer.

Unlike the research already developed on the calibration of MMT, our article reflects on the calibration by measuring tracer which allows palpate parts of very small sizes without the deform and in any position.

2. PRINCIPLE OF THE CALIBRATION OF THE MMT:

To carry out the measures, it moves a contact sensor fitted with a feeler (stylus with spherical Ruby in most cases) in the coordinate system of the machine. This sensor supplies a "top" when it comes in contact with the surface to measure on the part. The position of the center of the probe at the time of the contact is then saved. The coordinates of the measured points are fuelling a database of metrology. The data thus stored by the software GEOPACK, are subsequently used to perform the desired calculations. The software allows you to make associations and constructions of the geometric elements necessary to determine the quantities to measure. The results can then be printed or recovered in an exploitable file on a spreadsheet for further analysis.

3. THE CONDITIONS OF REALISATION OF THE CALIBRATION:

- Reference temperature 20°C
- Place of realization: metrology room air conditioned at 20°C±0.5°C
- Equipment used: machine to measure Mitutoyo three-dimensional C544
- GEOPACK software
- Standard Blocks of type steel and reference:

Ln=125mm	N°06277
Ln=150mm	N°10646
Ln=175mm	N°06289
Ln=200mm	N°06151
Ln=250mm	N°06235

The measures are carried out by placing the shim following 7 different orientations in the three axis, the three reference planes and following the diagonal of the space of measurement. The range of measurement used is to palpate a plan PL on one of the sides of the standard shim and a point PT in the center of the opposite side. The measurement of the shim is then obtained by the calculation of the distance (PL-PT). Each shim is measured three times. The following tables give the values obtained and their average for each of the 7 positions. These are the measures that we are going to use for the calculation of the value corrected by our model of matrix of correction.

P1(x)	Vc (mm)	124.9999		
	Measures (mm)	124,998	124,999	125,001
	Average	124,999333		
P2(y)	Vc (mm)	124.9999		
	Measures (mm)	124,999	124,999	124,999
	Average	124,999		
P3(z)	Vc (mm)	124.9999		
	Measures (mm)	124,999	124,999	125,001
	Average	124,999667		
P4(xy)	Vc (mm)	124.9999		
	Measures (mm)	124,999	124,999	124,999
	Average	124,999000		
P5(ZX)	Vc (mm)	124.9999		
	Measures (mm)	124,999	124,999	125,001
	Average	124,999667		
P6(YZ)	Vc (mm)	124.9999		
	Measures (mm)	124,999	124,999	125,001
	Average	124,999667		
P7(xyz)	Vc (mm)	124.9999		
	Measures (mm)	125,001	124,999	124,999
	Average	124,999667		

P1(x)	Vc (mm)	150,0004		
	Measures (mm)	149,999	150,001	150,002
	Average	150,00067		
P2(y)	Vc (mm)	150,0004		
	Measures (mm)	149,999	149,999	150,001
	Average	149,99967		
P3(z)	Vc (mm)	150,0004		
	Measures (mm)	149,999	150,001	149,999
	Average	149,99967		
P4(xy)	Vc (mm)	150,0004		
	Measures (mm)	149,999	150,001	150,001
	Average	150,00033		
P5(ZX)	Vc (mm)	150,0004		
	Measures (mm)	149,999	150,001	149,999
	Average	149,99967		
P6(YZ)	Vc (mm)	150,0004		
	Measures (mm)	150,001	149,999	150,001
	Average	150,00033		
P7(xyz)	Vc (mm)	150,0004		
	Measures (mm)	149,999	150,001	150,001
	Average	150,00033		

P1(x)	Vc (mm)	174,9992		
	Measures (mm)	174,999	174,999	175,001
	Average	174,9996		
P2(y)	Vc (mm)	174,9992		
	Measures (mm)	174,999	174,999	175,001
	Average	174,9996		
P3(z)	Vc (mm)	174,9992		
	Measures (mm)	174,999	175,001	174,999
	Average	174,9996		
P4(xy)	Vc (mm)	174,9992		
	Measures (mm)	174,999	174,999	174,999
	Average	174,999		
P5(ZX)	Vc (mm)	174,9992		
	Measures (mm)	174,999	175,001	175,001
	Average	175,0003		
P6(YZ)	Vc (mm)	174,9992		
	Measures (mm)	175,001	174,999	174,999
	Average	174,9996		
P7(xyz)	Vc (mm)	174,9992		
	Measures (mm)	174,999	174,999	175,001
	Average	174,9996		

P1(x)	Vc (mm)	199.9996		
	Measures (mm)	199,999	199,999	200,001
	Average	199,99967		
P2(y)	Vc (mm)	199.9996		
	Measures (mm)	199,999	199,999	200,001
	Average	199,99967		
P3(z)	Vc (mm)	199.9996		
	Measures (mm)	199,999	200,001	199,999
	Average	199,99967		
P4(xy)	Vc (mm)	199.9996		
	Measures (mm)	199,999	200,001	199,999
	Average	199,99967		
P5(ZX)	Vc (mm)	199.9996		
	Measures (mm)	199,999	199,999	200,001
	Average	199,99967		
P6(YZ)	Vc (mm)	199.9996		
	Measures (mm)	200,001	199,999	200,001
	Average	200,00033		
P7(xyz)	Vc (mm)	199.9996		
	Measures (mm)	200,001	199,999	200,001
	Average	200,00033		

P1(x)	Vc (mm)	250,0007		
	Measures (mm)	249,999	249,999	250,002
	Average	250		
P2(y)	Vc (mm)	250,0007		
	Measures (mm)	249,999	249,999	250,001
	Average	249,99967		
P3(z)	Vc (mm)	250,0007		
	Measures (mm)	249,999	249,999	250,001
	Average	249,99967		
P4(xy)	Vc (mm)	250,0007		
	Measures (mm)	249,999	249,999	250,001
	Average	249,99967		
P5(ZX)	Vc (mm)	250,0007		
	Measures (mm)	249,999	249,999	250,001
	Average	249,99967		
P6(YZ)	Vc (mm)	250,0007		
	Measures (mm)	250,001	250,001	249,999
	Average	250,00033		
P7(xyz)	Vc (mm)	250,0007		
	Measures (mm)	250,001	249,999	250,001
	Average	250,00033		

With:

P1(x): is the position following the X axis

P2(y): is the position following the Y axis

P3(z): is the position following the axis (z)

P4(xy): is the position in the plan (XY)

P5(ZX): is the position in the plan (ZX)

P6(YZ): is the position in the plan (YZ)

P7(xyz): is the position following the diagonal (XYZ)

4. DETERMINATION OF THE MATRIX:

The determination of systematic errors of a machine is mainly based on a calibration in relation to standards connected to the system if by an uninterrupted chain of comparisons until the primary standard. The calibration by laser system allows you to determine the geometric errors without taking into account the errors due to palpages. However, the ISO standard 10360 allows you to take account of this effect. It recommends to use the calibration shims to determine these errors which the objective of the offset during the measurement.

The errors of accuracy are obtained on the seven directions, by performing 3 measures for each of the five positions located on a direction.

4.1. Modeling and writing matrix:

In a first approach, for each direction, the errors obtained, will be modeled by a linear interpolation. The equations are going to participate in the contribution of the matrix of correction. The steps are:

A) Definition of equations of the seven directions

The results of calibration of the7 Directions X, Y, Z, XY, YZ, XZ and XYZ can written in the form of the following form:

P1(x): $\vec{P}_x = (A1L+B1)\ \vec{x}$

P2(y): $\vec{P}_y = (A2L+B2)\ \vec{y}$

P3(z): $\vec{P}_z = (A3L+B3)\ \vec{z}$

P4 (XY): $\vec{P}_{xy} = exy.\cos(\alpha)\ \vec{x} + exy.\sin(\alpha)\ \vec{y}$

P5 (YZ): $\vec{P}_{yz} = eyz.\cos(\beta)\ \vec{y} + eyz.\sin(\beta)\ \vec{z}$

P6 (ZX): $\vec{P}_{zx} = exz.\cos(\omega)\ \vec{x} + exz.\sin(\omega)\ \vec{z}$

P7 (XYZ): $\vec{P}_{xyz} = exyz.\cos(\theta).\cos(\mu)\ \vec{x} + exyz.\sin(\theta).\cos(\mu)\ \vec{y} + exyz.\sin(\mu)\ \vec{z}$

Where:

- A1X, A2Y and A3Z respectively are the slopes of the right of interpolation.
- B1, B2 and B3 are respectively the slopes of the right of interpolation
- -α, β, ω, μ, and ɵ are respectively the angles between the plans (XY), (YZ), (ZX), (XYZ).

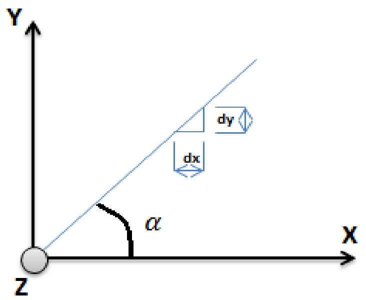

Figure 1 Projection of the position 4 on the XY plane

b) Consolidation in the form of a matrix of correction:

The error of accuracy is written: Ei=Vref-Vc

With:

Vc= $\|\vec{P}\|$ Corrected value

Vref: reference value

Ei: Error of accuracy

As well in this form:

$$\begin{pmatrix} Ei(x) \\ Ei(y) \\ Ei(z) \\ Ei(xy) \\ Ei(xz) \\ Ei(yz) \\ Ei(xyz) \end{pmatrix} = \begin{pmatrix} Vref(x) \\ Vref(y) \\ Vref(z) \\ Vref(xy) \\ Vref(xz) \\ Vref(yz) \\ Vref(xyz) \end{pmatrix} - \begin{pmatrix} A1l + B1 \\ A2l + B2 \\ A3l + B3 \\ a1l + b1 \\ a2l + b2 \\ a3l + b3 \\ a4l + b4 \end{pmatrix}$$

Knowing that:

$e_{xy} = a_1.L + b_1$

$e_{zx} = a_2.L + b_2$

$e_{yz} = a_3.L + b_3$

$e_{xyz} = a_4.L + b_4$

Thus, the coefficients a1, a2, a3, a4, b1, b2, b3, b4 are obtained with the help of the Calibration Curve in the plans (XY), (YZ), (ZX) and the direction (XYZ).

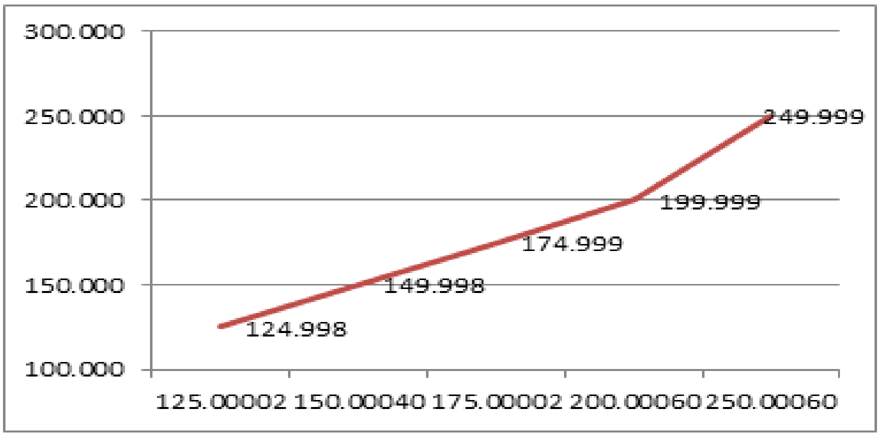

Figure 2 calibration curve following the X direction

5. RESULTS AND INTERPRETATIONS:

By introducing the values of the coefficients and those of the measurements obtained during the sampling in the matrix of corrections and by a programming under Excel, we find the values of the errors below:

Value of reference-value proposed by the model corrected		
Vc=124,9999		
Direction X	Eix	0.0005
Direction y	Eiy	0.0013
Direction z	Eiz	0.0003
Direction xy	Exy	0.0012
Direction XZ	Exz	0.0001
direction YZ	Eyz	0.0001
Direction XYZ	Exyz	0.0001
Reference value- value proposed by the model corrected		
Vc=150,0004		
Direction X	Eix	-0.0003
Direction y	Eiy	0.0012
Direction z	Eiz	0.0009
Direction xy	Exy	0.0001
Direction XZ	Exz	0.0008
direction YZ	Eyz	0.0000
Direction XYZ	Exyz	0.0000

Reference value- value proposed by the model corrected		
Vc=174,9992		
Direction X	Eix	-0,0004
Direction y	Eiy	0.0000
Direction z	Eiz	-0,0002
Direction xy	Exy	0.0006
Direction XZ	Exz	-0,0010
direction YZ	Eyz	-0,0006
Direction XYZ	Exyz	-0,0006
Reference value- value proposed by the model corrected		
Vc=199,9996		
Direction X	Eix	0.0001
Direction y	Eiy	0.0004
Direction z	Eiz	0.0003
Direction xy	Exy	0.0004
Direction XZ	Exz	0.0002
direction YZ	Eyz	-0,0008
Direction XYZ	Exyz	-0,0008
Reference value- value proposed by the model corrected		
Vc=250,0007		
Direction X	Eix	0.0010
Direction y	Eiy	0.0015
Direction z	Eiz	0.0016
Direction xy	Exy	0.0016
Direction XZ	Exz	0.0015
direction YZ	Eyz	0.0002
Direction XYZ	Exyz	0.0002

We have modeled the problem to determine the gaps following the different directions, and this between the reference value and the corrected by the model, where this difference does not exceed 1.92µm which is the maximum uncertainty of our model. We have subsequently conducted to the correction of the values standards by the reverse path. The results obtained have been compared and validated by report to the reference values.

6. CONCLUSION:

In the course of the measure, we have attempted to have several tests and make a calculation while ensuring that the way to account does not give an erroneous result of the conventional value. Thanks to the correction matrix obtained earlier, we have been able to find the initial values of the standards in doing the reverse path with a gap not exceeding the maximum uncertainty of the correction matrix (1,92µm). As well each value measured on the machine will be corrected by adding the correction matrix. In consequences, the model that has been developed is validated and can be applied either to the final check carried out by the supplier or the one made by the client.

REFERENCE

[1] G. Zhang, Error compensation of Coordinate Measuring Machines Tianjin University/PRC, R. Veale, T. Charlton, 6. Borchardt and R. Hocken (2). National Bureau of Standards, Gaithersburg, MD 20899.

[2] Jenq Shyong Chen, Tzu Wei Kou, Shen Hwa Chiou; Geometric calibration error of multi-axis machines using an auto-alignment laser interferometer; Department of Mechanical Engineering, National Chung Cheng University160, San-Hsing, Ming-Hsiung, Chia-Yi, 621, Taiwan, R.O.C. received 27 April 1999; accepted 17 March 1999.

[3] Guiquan Chen, Jingxia Yuan, Jun nor S.M. Wu; A displacement measurement approach for machine geometric error assessment Manufacturing Research Center, The University of Michigan, Ann Arbor, MI 56,145, USA received 10 December 1999; accepted 7 June 2000.

[4] C K Lim and M Burdekin; Rapid volumetric calibration of coordinate measuring machines using a hole bar artifact; Department of Mechanical, Aerospace and Manufacturing Engineering, University of Manchester Institute of Science and Technology, Manchester, UK.

[5] Emmett Curran, Pat Phelan; Quick check error verification of coordinate measuring machine; Manufacturing and Operations Engineering Department, University of Limerick, Ireland.

[6] Steve Phillips, Daniel Sawyer; Laser Trackers for large-scale Dimensional Metrology: A review Bala Muralikrishnan, Engineering Physics Division, National Institute of Standards and Technology, Gaithersburg, MD 20899, United States

[7] Ibrahim M. I. Ramadan and Naglaa kamal Rashwan, Calibration of Vehicle Emissions-Speed Relationships for the Greater Cairo Roads, International Journal of Civil Engineering and Technology, 7(1), 2016, pp. 74-82.

[8] Vidhya Sivasailanathan, Prabhat Kumar, Dr. N. Manoharan and Dr. F. Emerson Solomon, Radiological Safety Practices Experienced In Handling of Radioactive Source During Radiographic Testing, Calibration And Response Check of Instruments During The Project Stage of 500 MWE Prototype Fast Breeder Reactor (PFBR). International Journal of Advanced Research in Engineering and Technology, 6(8), 2015, pp. 118-134.

[9] K. Chandrasekhar Reddy, Evaluation and Calibration of Temperature Based Methods for Reference Evapotranspiration Estimation in Tirupati Region, International Journal of Advanced Research in Engineering And Technology (IJARET), Volume 5, Issue 2, February (2014), pp. 87-94

[10] Yashraj D. Kunte, B.M. Patil and Santosh S. Thorat, Calibration of a Water Distribution System - A Case Study. International Journal of Civil Engineering and Technology, 8(7), 2017, pp. 642–652.