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ORIGINAL ARTICLE

PRAGMATIC APPROACH FOR ESTIMATING MEASUREMENT UNCERTAINTIES OR THE CAPABILITY OF CMM[1]S NC[2]

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ABSTRACT

In three-dimensional metrology. Three-dimensional measuring means the means have been widely multiplied in recent years, in metrology laboratories, in production workshops, with the evolution of technology in general, the software associated with these machines are multiplied and allow to obtain the results of measurements with different methods. In this paper we carried out a series of measurements of ten (10) identical parts on a numerically controlled three dimensional measuring machine. To do this we carry out computer-aided design, three-dimensional of the type of parts, in three-dimensional design software, for the manufacture of parts subject to experimentation. The least-squares method is applied for the evaluation of the geometrical specifications of the parts. A measurement repeatability procedure was carried out in order to overcome the influences of the operator in the measurement results. We define the parameters allowing to estimating the uncertainties of measurements or of the capacity to measure numerically controlled three-dimensional machine. After several studies and experiments, we have found it is important to estimate the capability of its three-dimensional digital control means. Our article series up a pragmatic approach to estimating the uncertainties of measurement results or the numerically controlled three dimensional machine-to-machine capability. In a simple tool for three dimensional controllers. From the results obtained from the software associated with the three-dimensional measuring machine. The approach makes it possible to estimate the uncertainties or the capability of numerically controlled three-dimensional measuring machines.

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INTRODUCTION

Three-dimensional metrology initially made it possible to realize the geometrical defects of mechanical products. As hardware and software developments evolve, resources are increasingly of good precision. master for the controller is the software tool by adapting as best as possible the control of the specifications of the products. Therefore, one of the major problems for many industries and laboratories using 3D means is the estimation of measurement uncertainties for each of the measured geometric specifications. Measurement uncertainties are a function of many factors. Very few 3D control reports reveal uncertainties in the estimated measurements. Only the uncertainties of the measured points are defined by the manufacturer and checked during the verification of a machine. Three-dimensional measuring machines (CMMs) have become widely used in metrology laboratories and workshops. The software associated with these machines has grown considerably, making it possible to work on the basis of the numerical definitions of the parts to be checked. However, the reliability of the measurements remains difficult to quantify and the calculations of uncertainties are not made according to the rules of the art or take too long! With these software it is estimated that the deviations between the measured and nominal values of the geometric specifications. Several studies are carried out on the subject of 3D measurement means (CMMs), to determine the parameters of uncertainty influences in the measurement results, and other studies have shown the concept of virtual measurements of CMM. The factors of influence in the results of 3D measurements due to software (Mahamat *et al*., 2017), And methods for evaluating geometric elements (Jalid *et al*., 2009; Pawel Swornowski *et al.*). But

[1] Coordinate measuring machine
[1]Numerical Control
[1] Three-dimensional

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always the estimation of the uncertainties of measurement results or the capability CMM NC is poorly mastered in the metrology laboratories using CMMs and the industries, reason why there is not for the moment an approach or a tool For CMM controllers. After several studies and experiments in 3D control. We found that it is important and necessary to put in place a pragmatic tool, making it easy to estimate the uncertainties of the results of measurements. And also the CMT NC capability which ensures the capability of the measuring system for the verified geometric specification. In this paper, we propose a pragmatic approach for controllers of CMMS NC, a tool that allows them to estimate the uncertainties of the measurement results, as well as the CMM NC capability.

Contexte

The objective of our research in general is to propose a methodology and a pragmatic aid tool for estimating the uncertainties of measurements of three-dimensional measuring machines. But in this paper we focus on the study of a pragmatic approach to the estimation of measurement uncertainties or the capability of numerically controlled three-dimensional measuring machines. A tool for 3D controllers' field! To do this we implement measurement methodology. And perform three series of three repeatability measurements of each of the ten identical mechanical parts on an CMMNC. We use the Metrolog X G 13 software, 3D measurement associated with MMT NC for the acquisition of measurement results.

Presentation of the experimental parts

The experimental study consists in designing a type of parts to be manufactured. And make measurements of ten (10) identical parts on CMMNC. We have made a program of the series of measurements of these parts, for the measurement of the geometrical elements. And control of geometric specifications. The results obtained from the series of measurements of the software associated with the CMM are taken for the estimation of measurement uncertainties or of the capability. The design of the 3D CAD[4] of the coin type was carried out with CATIA software (Raynaud, 2014). Is a software mainly used in the industry and design that allows to carry out 3D dimensioning of the CAD, developed by the company Dassault Aviation.

Figure 1 shows the model of 3D parts.

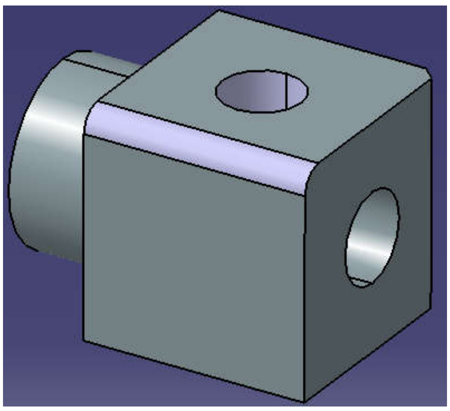

Figure 1. 3D experimental type

[4]Computer Assisted design

The Figure 2 shows the 3D CAD sectional view showing some geometric specifications to be verified in this experiment.

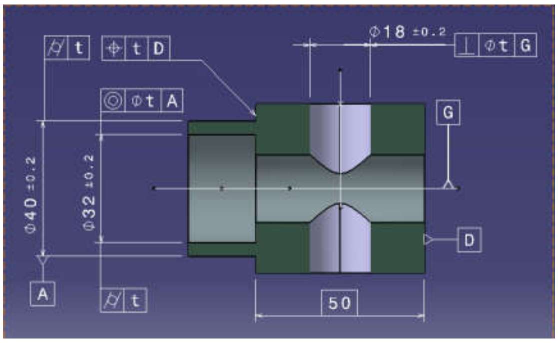

Figure 2. 3D cutting view

In figure 3 and figure 4, we present the geometrical specifications of the parts subjected to the control.

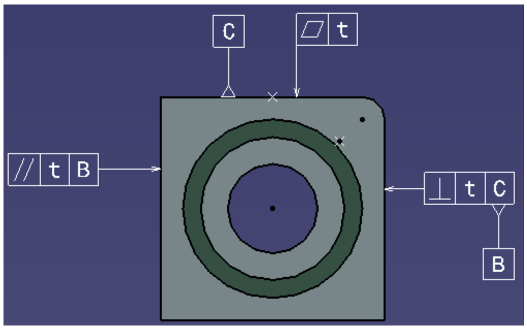

Figure 3. Front view

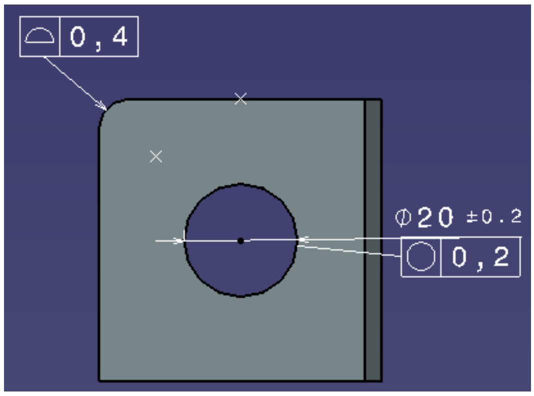

Figure 4. View from behind

In figure 5, the ten (10) made for the experimentation of our work are presented.

Figure 5. The experimental pieces

Means of measurement and Method

Means

The means used in these experiments are the software of 3D measurement means for the Technical Center of Innovation MECA3D - Laboratory MIP2-Metrology Quality Digitization, INSA of Lyon. A three-dimensional measuring machine to which a 3D measurement software is associated to obtain the palpated points (contact between the probe and the surface of the part to be checked), the association of the geometrical elements and the verification Geometric specifications. And also the virtual construction, virtual 3D measurements, from clouds of theoretical points. The software used in this study is: the Metrolog XG 13 software, often used in three-dimensional metrology.

Table 1 shows the 3D measurement means used.

Table 1. Measurement means used

Machine	Software
Zeiss MC 550	Metrolog XG 13 M8.1250.XG 13 Serial Number: 9479 (10 /2010)

Method

There are many methods of association of elements, some are developed theoretically in algorithms without being implemented the software, others described in the scientific literature. It is imperative to know the methods available in the software to make the best measurements. For our study, we chose the least squares method for the evaluation of geometric specifications. The least squares method is a criterion that minimizes the sum of the deviations (ei) from the squares of the points to the ideal element, whatever the number of points. And regardless of the extent of the area measured, this criterion has the advantage over other criteria of giving a reliable and robust result. (Mahamat *et al.*, 2017; Raynaud, 2009; Bernard Anselmentti, 2011; Geometric Product Specification (GPS), 2002) It is defined by a function W as follows:

$$w = \sum_{i=1}^{n} e_i^2$$

Figure 6 shows a plane and a circle of least squares.

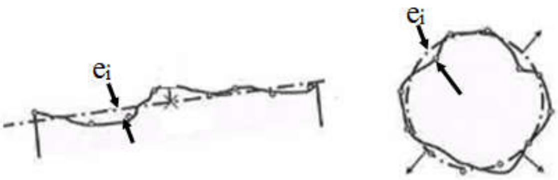

Figure 6. Plane and a circle of least squares (Bernard Anselmentti, 2011)

Procédure de mesure

For the realization of measures, by our approach. A measurement repeatability procedure was performed (FIG. 8). In order to overcome the influences of the operator in the measurement results. The positioning frame of the part is traced (FIG. 7). The part is peeled off and rested in the same place between the two measurements. Measurements are made automatically by the measuring program after the work piece is machined. We made measurements of three series of three measurements on each of ten parts.

The parts are numbered so as not to repeat the same series, and for the processing of measurement results.

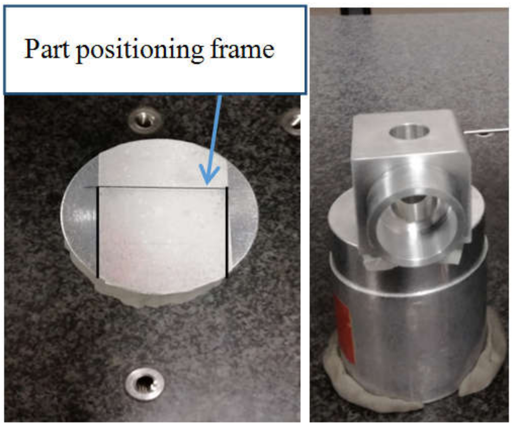

Figure 7. Part positioning frame and assembly

Figure 8 shows the flow chart of the procedure of the measurements.

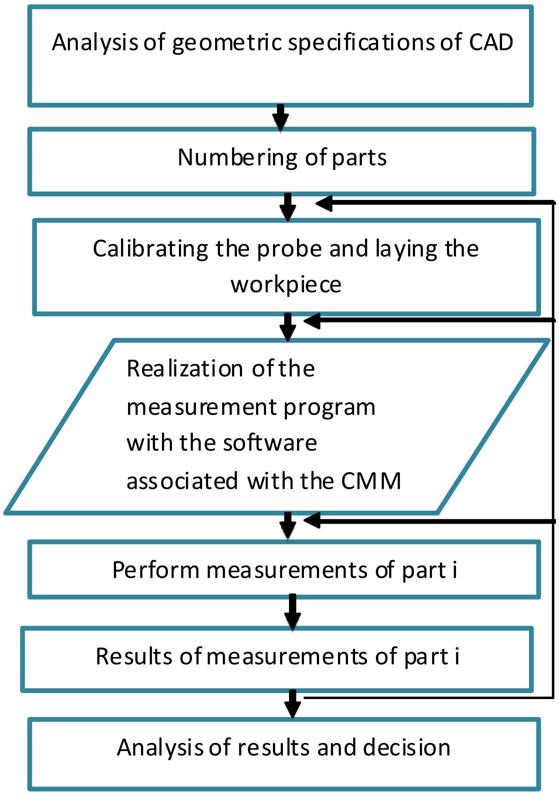

Figure 8. Measurement procedure

In the Programming of Measures section, It is defined how and with what methods the measurements are made, according to the possibilities available to the software associated with the selected CMM for the measurements. Figure 9 shows the execution of the measurement program carried out with the Metrolog XG 13 software associated with the CMMNC Zeiss.

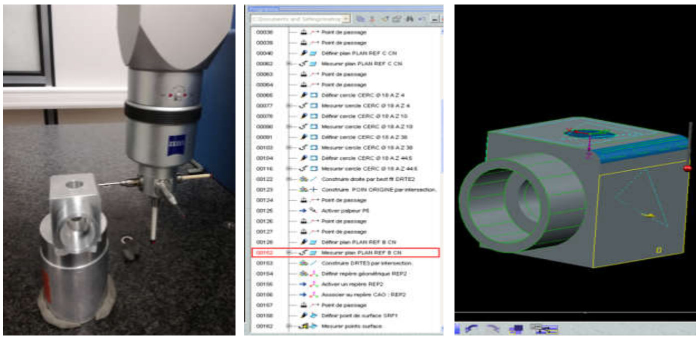

Figure 9. Running the program of measures

Parameters for estimating measurement uncertainties for CMM capability

Several parameters of dispersion of the measurements are used for the estimation of the uncertainties or the capability CMMNC. We define these parameters of estimation of the dispersion of measurements by equations (Measurement systems analysis, Reference Manual, Fourth Edition, 2010) which bind to each other in a first time. And then we will implement them in a calculation tool Excel format for the processing part of the results measures this work. These measurement dispersion estimation parameters are defined as follows:

The dispersion of the repeatability of the EV (équipemment variation) measurement means is defined by:

$EV = \bar{X}/\mathrm{K2}$, where$\bar{X}$is the mean extent; K2 coefficient depending on number of measurements.

The reproducibility of the measurements AV (Appraiser variation) Is defined by:

$AV = \sqrt{\left(\frac{\bar{\bar{X}}}{\mathrm{K2}}\right)^2 - \left(\frac{EV}{\mathrm{nr}}\right)^2}$, $\bar{\bar{X}}$Is the average of the mean, n Is the number of pieces measured, and r Is the number of measurements per series.

The repeatability and reproducibility of R & R:
$R\&R = \sqrt{EV^2 + AV^2}$.

The dispersion of the VP parts is defined by: $Vp = Rp$*K_3, where R_p Is the extent of the averages of the coins, and K_3Is the coefficient depending on the number of parts.

The total variation of the TV measurement system:

$$TV = \sqrt{GR\&R^2 + Vp^2}$$

The variation of the system can also be defined by two other methods:

For the decision on the capacity of the measuring system, the percentage (%) of these parameters. % repeatability (%GR) =100*$\left[\frac{EV}{TV}\right]$, Represents the percentage of repeatability due to the influence of CMM. % reproducibility (%R) =100*$\left[\frac{AV}{TV}\right]$, Represents the percentage of reproducibility due to the influence of the operator. In this approach, we consider that the influence of the operator is not significant. And is not taken into account in the processing of the results. Since the results of measurements taken into account are those obtained by the automatic measurements by the CMM.

if %GR <10%, The measuring system is good,

If% GR is between 10% et 30%, The measuring system may be acceptable,

If% GR> 30%, the measuring system is not accepted.

From the variation (GR) repeatability MMT NC, and the number of data classification (ndc=1,41) For a confidence level of 97%, And the variation of the parts (PV) the value of the CMM capability is estimated.

CMM NC capability=1.41 $* \left[{}^{PV}/_{GR}\right]$, If a capability greater than or equal to 4 is obtained, the CMM is able to evaluate the verified specification. And if the value is less than 4 then the CMM NC is not capable for the evaluation of this specification. Therefore it is necessary to repeat the measurements while checking the steps of figure. 8.

The uncertainties of the measurement results are estimated using the formulas by the equations below.

We estimate the uncertainties-type ups of the measurement results (9), (10), (11), (12) a series of measurements.

$Ups = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(Xi - \bar{X})\verb|^|2}$ From where $\bar{X} = 1/n\sum_{i=1}^{n} xi$, : x_i Are measures , $\bar{x}$, is the average. of measurements in the series, and n is the number of measurements in the series.

We estimate uncertainty-up results of measurements of three series of measurements of a coin as follows:

$u_{\mathrm{ppièces}} = 2 * \sqrt{{U_{ps1}}^2 + {U_{ps2}}^2 + {U_{ps3}}^2}$

The enlargement factor K = 2

RESULTS AND DISCUSSION

L'application de l'approche nous a permis d'effectuer des mesures sur les dix(10) pièces et d'obtenir des résultats de mesures. We have checked basic geometric specifications often controlled in 3D measurement. We find that performing three series of three measurements on the ten (10) parts takes a lot of machine time, which is not economical for 3D metrology laboratories and workshops. To optimize this measurement time allowing CMM users to estimate the uncertainties of the measurement results or the MMT NC capability, we process the results of measurements in five (5) measurement category.

Categorie 1:3 series, 3 measures, 10 parts, (3S_3M_10P),
Categorie 2:3 series, 3 measures, 5 parts, (3S_3M_5P),
Categorie 3: 2 series, 3 measures, 5 parts, (2S_3M_5P),
Categorie 4: 2 series, 2measures, 5 parts, (2S_2M_5P),
Categorie 5: 2 series, 2 measures, 3 parts, (2S_2M_3P).

The results of the control of the geometrical specifications are entered in the data entry tool for the estimation of the uncertainties or the CMM NC capability (Figure. 10). From the results entered, our approach makes it possible to calculate the various parameters (Figure. 10) for estimating the uncertainties and the capability CMMNC.

The average of three measurements of each part,

- Measurement range of all parts,
- Averages (Xs1, Xs2, Xs3) of each measurement of all series,
- Averages of averages of all measuring series parts,
- Averages of the ranges (Rs1, Rs2, Rs3) of each measurement series,
- Average of parts of all series of measurements,
- Average ($\bar{\bar{X}}$) of averages of all coins of all series of measurements,
- Average ($\bar{\bar{R}}$) of the averages of the ranges of all the series,
- Range (Rp) of averages of all parts of all series,
- Maximum averages the averages of all series of measurements,
- Minimum average the averages of all series of measurements, La différence (ΔX) Between max and min.

The figure. 10 shows the model of the data capture tool for estimating the uncertainties or the CMMNC capability.

Saisie des résultats pour l'estimation des incertitudes ou de la capabilité MMT												
Séries	Mesures	N° de pièces										Moyenne
		1	2	3	4	5	6	7	8	9	10	
S1	1	0,043	0,028	0,046	0,041	0,032	0,053	0,050	0,042	0,040	0,045	0,042
	2	0,046	0,029	0,046	0,037	0,034	0,053	0,049	0,042	0,044	0,047	0,043
	3	0,042	0,029	0,047	0,039	0,033	0,054	0,050	0,037	0,045	0,047	0,042
	Moyenne	0,044	0,029	0,046	0,039	0,033	0,053	0,050	0,040	0,043	0,046	Xs1 = 0,042
	Etendue	0,004	0,001	0,001	0,004	0,002	0,001	0,001	0,005	0,005	0,002	Rs1 = 0,003
S2	1	0,039	0,037	0,046	0,040	0,032	0,052	0,049	0,044	0,043	0,048	0,043
	2	0,040	0,035	0,045	0,043	0,032	0,052	0,053	0,043	0,043	0,046	0,043
	3	0,040	0,032	0,045	0,039	0,032	0,052	0,056	0,041	0,042	0,046	0,043
	Moyenne	0,040	0,035	0,045	0,041	0,032	0,052	0,053	0,043	0,043	0,047	Xs2 = 0,043
	Etendue	0,001	0,005	0,001	0,004	0,000	0,000	0,007	0,003	0,001	0,002	Rs2 = 0,002
S2	1	0,040	0,033	0,047	0,041	0,034	0,052	0,050	0,039	0,042	0,047	0,043
	2	0,040	0,034	0,046	0,043	0,033	0,052	0,050	0,039	0,042	0,048	0,043
	3	0,038	0,033	0,048	0,043	0,035	0,053	0,050	0,040	0,042	0,048	0,043
	Moyenne	0,039	0,033	0,047	0,042	0,034	0,052	0,050	0,039	0,042	0,048	Xs3 = 0,043
	Etendue	0,002	0,001	0,002	0,002	0,002	0,001	0,000	0,001	0,000	0,001	Rs3 = 0,001
Moyennes de pièces		0,041	0,032	0,046	0,041	0,033	0,053	0,051	0,041	0,043	0,047	$\bar{\bar{X}}$ = 0,043
Max X = 0,04		Min X = 0,04		ΔX = 0,00		Rp = 0,02						$\bar{\bar{R}}$ = 0,0021

Figure 10. Model for input of results for estimation of uncertainties or capability

We have presented in the tables the estimated capacities of all category. The objective of processing the results by category is to be able to find the most convenient for an economic temp, giving the estimation of the uncertainties of the measurement results or of the CMM. And wherein the CMM is capable of evaluating more geometric specifications. In order to analyze and interpret the results of the category capabilities, we have plotted the capability graphs of all category in Figure 14. By comparing the graphs one can see for which specification and in which category the CMM NC is capable or not and also the category better adapted to all the specifications for an economic time. We find the highest values of capability in all category of geometrical elements where measurements requiring little variation on the Z axis of the CMM.

Constantly these results made it possible to diagnose CMMNC where it was found that the cross of the Z axis is somewhat degraded. We see in these graphs (Figure 14), the category 2S_2M_3P, allows a considerable time saving compared to the others, and also values of capabilities of specifications are often greater than four (4). For uncertainties, in this article we do not present the estimated uncertainties of all specifications. We present only the estimated standard uncertainties of two geometric specifications, cylindricity and circularity (Figure 12 and Figure 13).

The figure. 11 shows the model of the estimation ratio of the MMT capability. The coefficient values K1, K2, and K3 (Measurement systems analysis, Reference Manual, Fourth Edition, 2010) vary according to the number of series, measurements and Parts

Rapport d'estimation de la Capabilité MMT						
Nom pièce: mpm	Nom machine:				Date:	16/6/17
Type de pièces:	ID machine:				No rapport:	42902/mpm/3
Spécification évaluée: Localisatiion					Réalisé par:	Charfadine
Nbre de Séries	3	Nbre de pièces(n):	10	nombre des mesures(r):		3
K1 =	0,5908	K2 =	0,5231		K3 =	0,3146
$\bar{\bar{R}}$ =	0,0057	ΔX =	0,0007		Rp=	0,043
Analyse de paramètres					Variation en %	
Variation de la Répétabilité (VR) MMT						
EV = $\bar{\bar{R}}$ x K1		mesures	K1		% EV = 100 [EV/TV]	
= 0,0057 x 0,5908		2	0,8862		= 100 [0,00335/0,01397]	
= 0,00335		3	0,5908		= 23,96 %	
		Série	K2			
		2	0,7071			
		3	0,5231			
Variation de la Répétabilité					% GR = 100 [GR/TV]	
GR = (EV^2)^0,5					= 100 [0,00335/0,01397]	
= (0,00335^2 + 0^2)^0,5		Pièces	K3		= 23,96 %	
= 0,00335		2	0,7071			
Variation de piècs (PV)		3	0,5231		% PV = 100 [PV/TV]	
PV = Rp x K3		4	0,4467		= 100 [0,01356/0,01397]	
= 0,043 x 0,3146		5	0,403		= 97,09 %	
= 0,01356		6	0,3742			
Total Variation (TV)		7	0,3534		ndc = 1,41 (PV/GRR)	
TV = (GR^2 + PV^2)^0,5		8	0,3375		= 1,41 (0,01356/0,00335)	
= (0,00335^2 + 0,01356^2)^2		9	0,3249		= 5,712	
= 0,01397		10	0,3146		≅ 6	
Commentaire du Contrôleur:			Decission			

Figure 11. Model estimate of the capability

The NC Zeiss CMM capabilities of different specifications, obtained by the five (5) category are presented in the following tables.

In Table 2, the CMNNC capability of the category of three series, three bars and ten parts is presented.

Table 2. Capabilities CMM of the category 3S_3M_10P

category: 3S_3M_10P	
Spécifications	Capabilities
Coaxialité du cylindre ø32	8
Perpendicularité du plan B	9
flatness of plane C	3
Diameter of cylindre_ø40	11
Distance 50 mm	35
Circularity of circle ø20	1
Cylindricity Cyl_ø40	3
Diameter of cylindre_ø32	29
Parallelism of Plane B	7
Perpendicularity of the axis	6
Localisation du plan D	6
Cylindricity of cylinder_ø32	6
Form of a line	3

Table 3 presents the estimated capability of the category of three series, three measurements and five parts.

Table 3. Capabilities CMM of the category 3S_3M_5P

category : 3S_3M_5P	
Spécifications	Capabilities
Coaxialité du cylindre ø32	5
Perpendicularité du plan B	10
flatness of plane C	3
Diameter of cylindre_ø40	18
Distance 50 mm	43
Circularity of circle ø20	2
Cylindricity Cyl_ø40	3
Diameter of cylindre_ø32	40
Parallelism of Plane B	8
Perpendicularity of the axis	8
Localisation du plan D	6
Cylindricity of cylinder_ø32	9
Form of a line	2

In Table 4, we find the estimated capability of the category of two series, three measures and five parts.

Table 4. Capabilities CMM of the category 2S_3M_5P

Category: 2S_3M_5P	
Spécifications	Capabilité
Coaxialité du cylindre ø32	4
Perpendicularité du plan B	13
flatness of plane C	3
Diameter of cylindre_ø40	21
Distance 50 mm	62
Circularity of circle ø20	2
Cylindricity Cyl_ø40	3
Diameter of cylindre_ø32	67
Parallelism of Plane B	8
Perpendicularity of the axis	8
Localisation du plan D	7
Cylindricity of cylinder_ø32	7
Form of a line	2

The capabilities of the category of two series, two measurements and five parts, is presented in Table 5

Table 5. Capabilities CMM of the category 2S_3M_5P

Category: 2S_2M_5P	
Spécifications	Capabilites
Coaxialité du cylindre ø32	6
Perpendicularité du plan B	10
flatness of plane C	3
Diameter of cylindre_ø40	21
Distance 50 mm	55
Circularity of circle ø20	5
Cylindricity Cyl_ø40	4
Diameter of cylindre_ø32	52
Parallelism of Plane B	7
Perpendicularity of the axis	6
Localisation du plan D	7
Cylindricity of cylinder_ø32	6
Form of a line	1

In Table 6, we present the estimated CMM NC capability of two series, two measurements and three parts.

Table 6. Capabilities CMM of the category 2S_2M_3P

Category: 2S_2M_3P	
Spécifications	Capabilité
Coaxialité du cylindre ø32	6
Perpendicularité du plan B	3
flatness of plane C	1
Diameter of cylindre_ø40	25
Distance 50 mm	53
Circularity of circle ø20	16
Cylindricity Cyl_ø40	3
Diameter of cylindre_ø32	81
Parallelism of Plane B	8
Perpendicularity of the axis	7
Localisation du plan D	10
Cylindricity of cylinder_ø32	8
Form of a line	1

Figure 12 shows the estimated uncertainties of the measurement results of the cylindrical cylinder evaluation of 32 mm diameter.

Estimation of uncertainties										
	Parts									
Séries	1	2	3	4	5	6	7	8	9	10
S1	2,31E-03	5,77E-04	1,15E-03	1,00E-03	5,77E-04	1,15E-03	3,21E-03	5,77E-04	5,77E-04	5,77E-04
S2	5,8E-04	2,6E-03	4,2E-18	1,0E-03	1,2E-03	5,8E-04	2,3E-03	1,2E-03	5,5E-03	5,8E-04
S3	0,00E+00	4,71E-04	0,00E+00	1,17E-03	2,35E-04	4,72E-04	7,06E-04	2,35E-04	0,00E+00	2,36E-04
Up parts	4,76E-03	5,50E-03	2,31E-03	3,68E-03	2,62E-03	2,75E-03	8,04E-03	2,62E-03	1,11E-02	1,70E-03

Figure 12. Model of presentation of the estimated uncertainties, of the evaluation of the cylindricity

Figure 13 shows the estimated uncertainties of the measurement results of the circularity evaluation of the circle.

Estimation of uncertainties										
	Parts									
Series	1	2	3	4	5	6	7	8	9	10
S1	1,15E-03	0,00E+00	5,77E-04	0,00E+00	1,00E-03	2,31E-03	5,77E-04	0,00E+00	5,77E-04	1,73E-03
S2	5,3E-19	5,8E-04	0,0E+00	1,2E-03	2,3E-03	0,0E+00	1,0E-03	5,8E-04	3,8E-03	1,7E-03
S3	2,35E-04	2,35E-04	2,36E-04	4,72E-04	9,41E-04	0,00E+00	2,36E-04	0,00E+00	2,35E-04	1,86E-03
Up parts	2,36E-03	1,25E-03	1,25E-03	2,49E-03	5,37E-03	4,62E-03	2,36E-03	1,15E-03	7,67E-03	6,15E-03

Figure 13. Model of presentation of the estimated uncertainties, the evaluation of a circularity

In Figure 14, the CMT capabilities graphs are presented of specifications by category, which we have previously presented in tables 2 to 6.

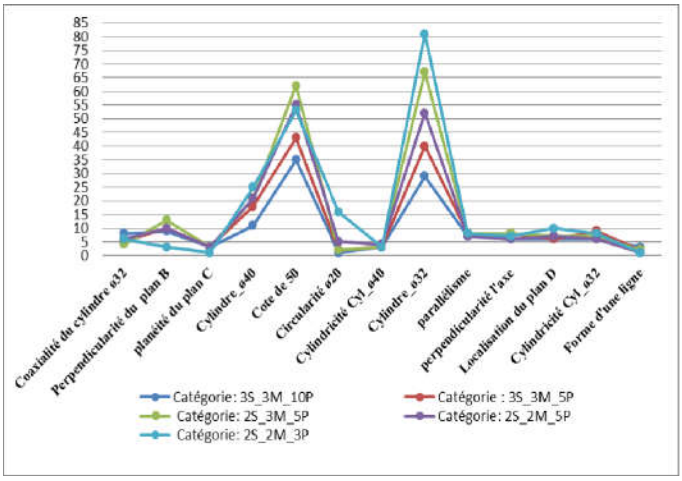

Figure 14. Estimated Category Capabilities Comparison Graphs

Conclusion

In this paper, we carried out an experimental study of a pragmatic approach for estimating uncertainties or CMM NC capability. By measuring ten (10) identical mechanical parts on a three dimensional measuring machine, by developing a measurement methodology, illustrated by a flowchart comprising the various steps of the 3D control. We have also defined the method of calculating the parameters allowing the estimation of the uncertainties of measurement results or of the capability CMT NC. It was presented a model of the tool for capturing the results of measurements for the estimation of the uncertainties or the capability CMT NC from the various parameters and also a model of the ratio of the estimated MMT capability NC. Measurements of three series of three measurements per piece were made on the ten pieces with a CMM ZeissNC. The results of measurements of parts are treated with the approach developed, this tool gave satisfactory results compared to the expectations. However, the machine occupancy time is long (15 minutes per measurement) when three series of three measurements are made on each of the ten (10) parts.A time-saving study, was carried out in five categories on the results of measurements. The CMM capabilities of these different categories are compared in graphs. The 2S_2M_3P category (Table 6) greatly reduces the measurement time and without degrading the CMMNC capability as shown in Table 6 and Figure 11. In this article we have developed a pragmatic approach which makes it possible to estimate the uncertainties of measurement results or of the CMM NC capability. Knowledge of the capability of its measurement means is an indispensable element for the estimation of measurement uncertainty. For decision-making on measurement results, and to comply with normative guidelines (Measurement uncertainty - Part 3: Guide for the expression of measurement uncertainty (GUM: 1995)), (Measurement management systems: Requirements for measuring processes and equipment, 2003) which requires that each measure be accompanied by its uncertainty. In this paper, we discussed a new pragmatic approach, which allows CMM NC measurement controllers to estimate the uncertainties of CMM measurement results or CMM capabilities. Until here was the difficulty of users of CMMs in general. In prospects, it would be interesting to also carry out studies to set up a tool, for portable coordinate measuring machines. Which makes it possible to take into account all factors of influence, for the estimation of uncertainties or capability.

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