GEOMETRIC AND DIMENSIONAL PRECISION CONTROL WITH COORDINATE MEASURING MACHINES

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Abstract: *The present paper aims to briefly present some aspects concerning the automated control of mechanical parts by aid of Coordinate Measuring Machines (CMM's). Several aspects must be taken into consideration when planning a geometric and dimensional precision control application, which are briefly reviewed in the present paper. For a particular mechanical part, the dimensional precision control implies taking several steps in order to generate the appropriate CMM measurement program. The present paper describes the main steps taken in order to control several geometric and dimensional characteristics of a given mechanical part, as well as some practical results using an ARES NT coordinate measuring machine and the TouchDMIS software.*

Keywords: *Coordinate measuring, dimensional precision,*

1. Coordinate metrology principle

The main function of coordinate metrology is to measure and assess parts surface and dimensions, to compare the results with the specifications and eventually to provide and evaluate metrological information with respect to dimensions, shape, orientation and position deviations and precision.

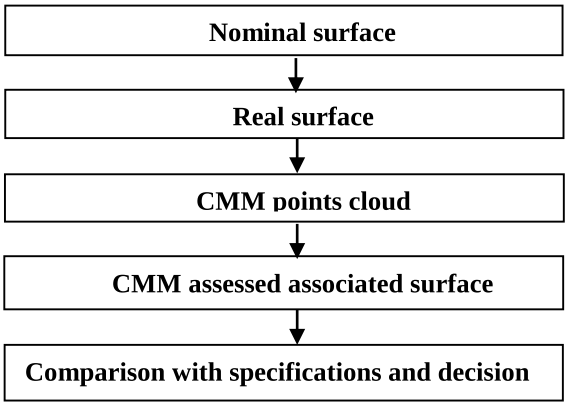


Figure 1: *Principle and stages of the coordinate measuring process*

A characteristic of coordinate measuring machines (CMM) is the determination of the parts spatial coordinates through point by point covering and measuring, in a three axis system. The parameters which describe the real surface are thus calculated using the coordinate measuring machines' computer. Finally, the parameters resulted in this way allow the comparison with the specification in order to decide about the manufacturing precision of the part to be checked on CNM (figure 1).

2. Considerations on 3D measurement methods and equipment

2.1 Measurement software

Various companies developed CAD-based metrology software packages specifically designed in order to conduct accurate control and inspections of various features by inputting 3D measurements.

There is practically no limit to the types of measurements you can perform and analyze this way. By aid of various software programs like ProEngineer, CATIA, etc..., data can be exchanged with any number of CAD programs and systems. For instance, CAM2 Measure Version 10.5 is used for portable measurement equipment TouchDMIS is whereas Metrosoft Quartis is the new universal software for Wenzel measuring equipment [1], [2].

All the above mentioned software is based on similar working principles and their results can be interchanged.

2.2 Setting of the method, means and measurement strategy

When choosing a coordinate measuring equipment there are many factors to be considered, such as the measured part shape, dimensions, required precision, batch size, etc.

Technical control activities in modern production processes rely more and more on „Coordinate Measuring Machines „CMM" and their performances–with impact on the control precision, as well as on productivity, [3].

Moreover, parts with complex geometrical configuration (e.g. gear, propellers, etc...) which traditionally needed different and specific instruments can be now checked on these machines.

Overall, quality of parts and products rely not only on machine-tools performances, but on the precision, accuracy and fidelity of the controlling equipment as well: a high performance manufacturing equipment combined with a poor performance and low precision measuring system cannot guarantee good quality products, whereas a reverse combination – with the cost of a big percentage of scrap parts – may solve this problem. Of course that the best strategy is to have, both, high performance manufacturing and control equipment, [3].

The first important criterion when selecting the CMM is the equipment's measuring range – to be established taking into account the dimensions and characteristics of the parts to be checked.

The next important criterion concerns the „measuring uncertainty". ISO 10360-2:2009 standard specifies, [4]:

- "the acceptance tests for verifying the performance of a coordinate measuring machine" (CMM) used for measuring linear dimensions as stated by the manufacturer. It also specifies the re-verification tests that enable the user to periodically re-verify the performance of the CMM", [4]:
- "performance requirements that can be assigned by the manufacturer or the user of a CMM, the manner of execution of the acceptance and re-verification tests to demonstrate the stated requirements, rules for proving conformance, and applications for which the acceptance and re-verification tests can be used". [4]:

When establishing the performances and specifications of the CMM the general rule is to consider the ratio uncertainty – tolerance.

The abovementioned ratio depends on the measurement specifications and can vary in the range 1:3 to 1:20, but the usual range is somewhere between 1:5 and 1:10. For example, in order to maintain a 1:5 ratio uncertainty-tolerance, the CMM specifications should be 5 times more accurate as compared to the tolerance of the part to be checked.

The measuring uncertainty should be determined for all the characteristics to be controlled: diameters and distances, shape, orientation and position. For example, for distances and diameters, the smallest tolerances specified in the documentation have to be considered.

Of course that the selection of measuring equipment also has to take into consideration other aspects, such as:

- environmental conditions: temperature, vibrations, etc.;
- batch size and, hence, recommended productivity,

2.3 Measuring process stages

Once the equipment has been selected, the measuring and control sequence have to cover the following stages, [5]:

- ✓ measuring specifications analysis;
- ✓ measuring technology elaboration;
- ✓ measuring strategy elaboration;
- ✓ measuring sequence programming;
- ✓ measuring execution;
- ✓ interpretation of measuring data;
- ✓ evaluation of the uncertainty;
- ✓ elaboration of the documentation

3. CMM preparation and programming

In order to practically implement the principles described herein, the present paper aims to briefly describe the procedure followed in order to control a given mechanical part. For that purpose, in the present work, a high performance CMM ARES NT, produced by COORD3, [6] and controlled by means of TouchDMIS software, was used to control the part presented in Figure 2 and Figure 3.

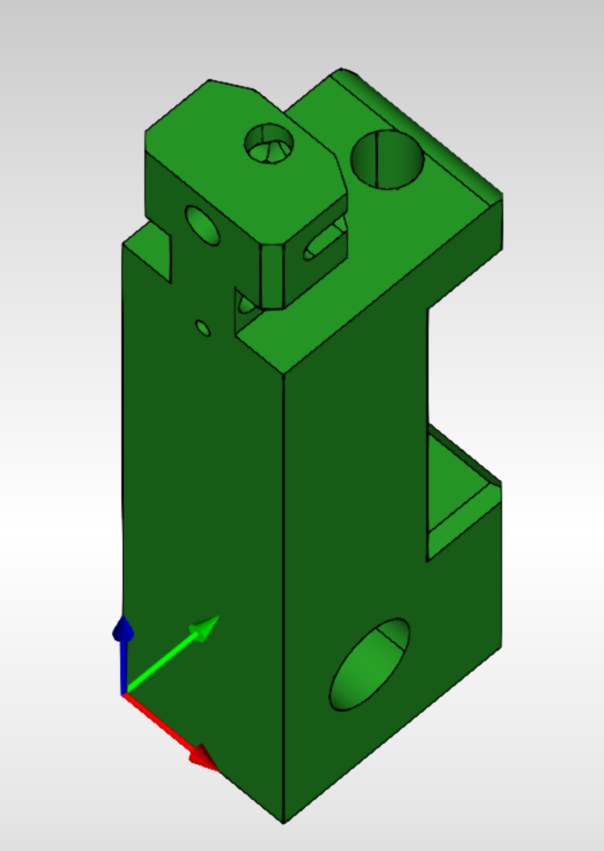


Figure 2: 3D model of the investigated part

In order to be able to create an automated control sequence, the 3D model of the investigated part was first imported in the CMM software TouchDMIS, as shown in Figure 2.

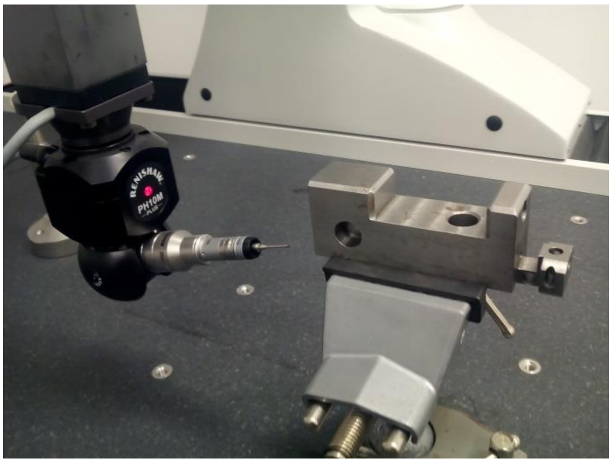


Figure 3: Part fixed in position on the CMM table

The first step in controlling the proposed part was to position it on the CMM table so that as many features as possible can be measured without changing the position of the part. The used vise clamping system allowed to position the part as illustrated in Figure 3. This position allows the CMM probing system to reach almost all part features without changing its position on the table.

In order to create an automated control sequence, the CAD model and the physical part must be first aligned with the CMM's coordinate system, as shown in Figure 4. A "3-2-1" alignment system was employed. For that purpose, three features (a plane, a line and a point) were first measured manually. All further measurements were done automatically, using the CAD model, as described further.

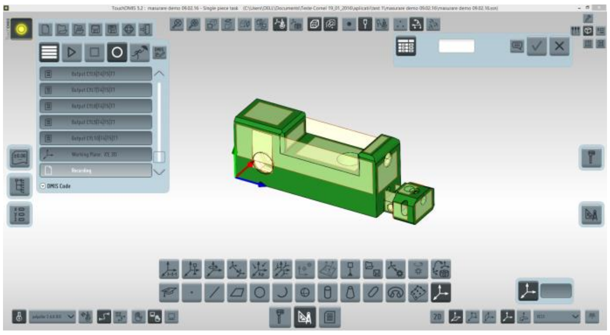
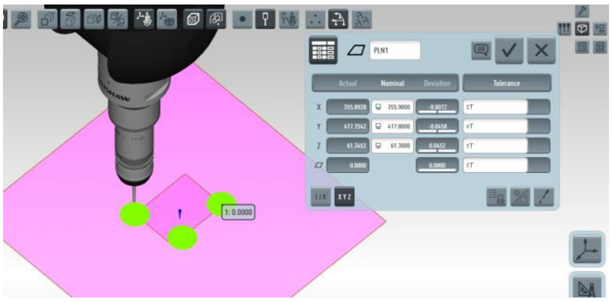


Figure 4: Part alignment

After the part is properly positioned and aligned with the machine coordinate system, the majority of its features are accessible for the CMM probing system.

A first step in creating the control sequence is to choose the number of measurement points probed for each geometric feature. However, measuring the minimum number of points (e.g. 3 points for a plane or 6 points for a cylinder) doesn't offer accurate readings for the geometric and positioning precision of the investigated feature. For example, if only 3 points are measured for a planar surface, this will generate an ideal plane, with no deviation, as illustrated by Figure 5.



PLN1

	Actual	Nominal	Deviation	Tolerance
X	355.8928	355.9000	-0.0072	±T
Y	417.7542	417.8000	-0.0458	±T
Z	61.3452	61.3000	0.0452	±T
▱	0.0000		0.0000	±T

Figure 5: Ideal plane by 3 points

Similarly, measuring too many points will only be more time consuming, without bringing further advantages in accuracy. As illustrated below, for the same planar surface, measuring 5 points yielded a deviation of 0,0066mm (figure 6), 9 points lead to a 0,0138mm deviation (figure 7) and 22 points yielded a deviation of 0,01320mm (figure8).

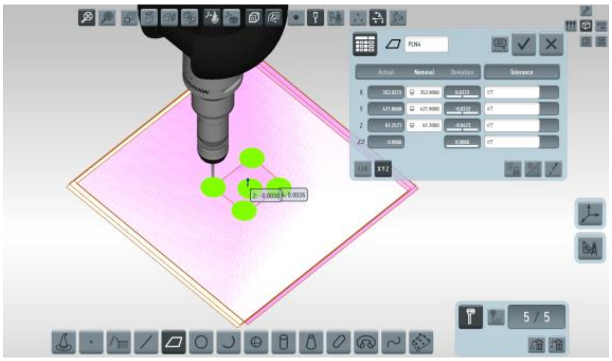
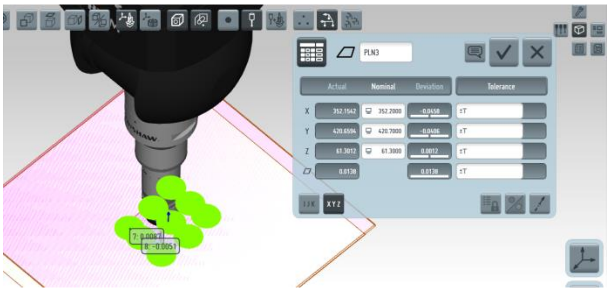


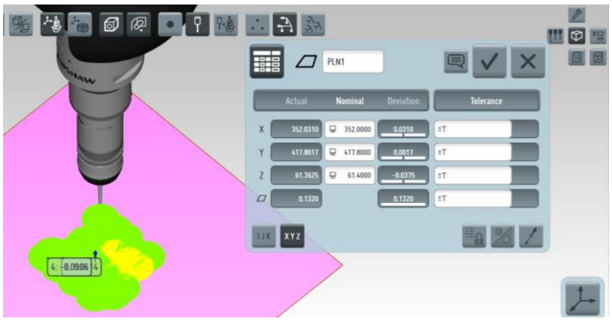
Figure 6: Plane by 5 points



PLN3

	Actual	Nominal	Deviation	Tolerance
X	352.1547	352.2000	-0.0458	±T
Y	420.6594	420.7000	-0.0406	±T
Z	61.3012	61.3000	0.0012	±T
▱	0.0138		0.0138	±T

Figure 7: Plane by 9 points



PLN1

	Actual	Nominal	Deviation	Tolerance
X	352.0310	352.0000	0.0310	±T
Y	417.8017	417.8000	0.0017	±T
Z	61.3625	61.4000	-0.0375	±T
▱	0.1320		0.1320	±T

Figure 9: Plane by 22 points

When creating an automated measuring sequence, the goal is to obtain as good as possible measurement accuracy without measuring more points than necessary.

Another important step when an automated measurement sequence is created is to choose the machine's probing system trajectories. When determining the optimal trajectories, one must consider several important factors such as: gap and collision avoidance, as well as covering as much as possible from the surface to obtain good measurement accuracy.

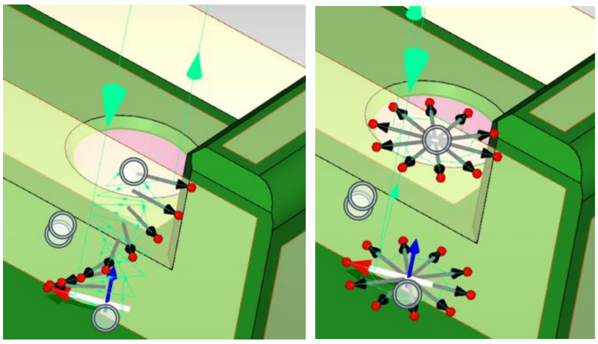


Figure 10: Two possible measuring paths for a cylinder

Figure 10 illustrates two software proposed possible measuring paths (for the same number of points) that can be taken when aiming to control a cylinder.

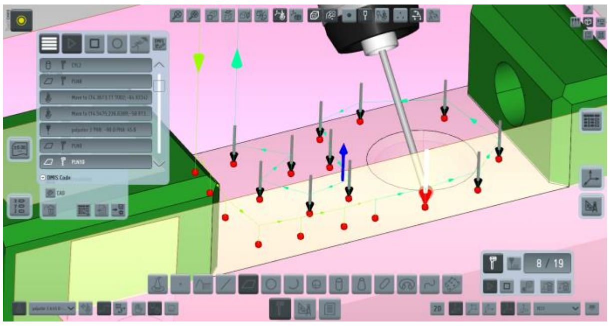
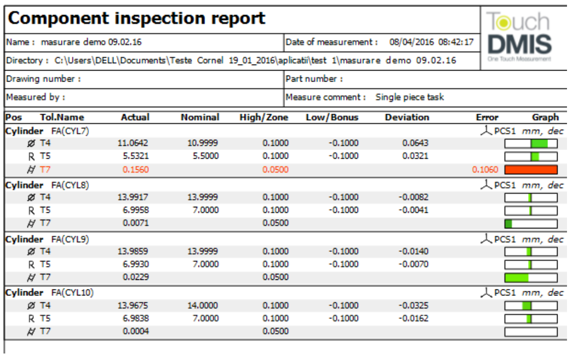


Figure 11: Personalized surface measuring path

Depending on each application, an adequate measuring path can be chosen from the ones automatically proposed by the software, as shown in Figure 10, or a personalized path can be generated, as shown in Figure 11.

The final step to be considered when creating an automated coordinate measurement sequence is to compare the obtained measurement values with the part specifications. This is usually done by generating a measurement report, as shown in Figure 12.



Component inspection report

Name : masurare demo 09.02.16
Date of measurement : 08/04/2016 08:42:17
Directory : C:\Users\DELL\Documents\Teste Cornel 19_01_2016\aplicatii\test 1\masurare demo 09.02.16
Drawing number :
Part number :
Measured by :
Measure comment : Single piece task

Pos	Tol.Name	Actual	Nominal	High/Zone	Low/Bonus	Deviation	Error	Graph
Cylinder	FA(CYL7)						PCS1 *mm, dec*	
Ø	T4	11.0642	10.9999	0.1000	-0.1000	0.0643		
R	T5	5.5321	5.5000	0.1000	-0.1000	0.0321		
⌭	T7	0.1560		0.0500			0.1060	
Cylinder	FA(CYL8)						PCS1 *mm, dec*	
Ø	T4	13.9917	13.9999	0.1000	-0.1000	-0.0082		
R	T5	6.9958	7.0000	0.1000	-0.1000	-0.0041		
⌭	T7	0.0071		0.0500				
Cylinder	FA(CYL9)						PCS1 *mm, dec*	
Ø	T4	13.9859	13.9999	0.1000	-0.1000	-0.0140		
R	T5	6.9930	7.0000	0.1000	-0.1000	-0.0070		
⌭	T7	0.0229		0.0500				
Cylinder	FA(CYL10)						PCS1 *mm, dec*	
Ø	T4	13.9675	14.0000	0.1000	-0.1000	-0.0325		
R	T5	6.9838	7.0000	0.1000	-0.1000	-0.0162		
⌭	T7	0.0004		0.0500				

Figure 12: Measurement report example

The measurement report indicates both nominal and actual values for each requested feature, as well as an indication on the deviation between measurements and specifications. This allows to easily make decisions regarding the investigated parts.

4. Conclusions

From the present paper, several conclusions can be summarized, as described below:

The main function of coordinate metrology is to measure and assess parts surface and dimensions, to compare the results with the specifications and eventually to provide and evaluate metrological information with respect to dimensions, shape, orientation and position deviations and precision.

Depending on the needed measurement accuracy (imposed by the indicated geometric and dimensional tolerances), there are several criteria to be considered when choosing CMM equipment.

When creating an automated measuring sequence, the goal is to obtain as good as possible measurement accuracy in the shortest time interval. This is achieved by correctly choosing the number of points as well as the CMM trajectories.

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