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EXPERIMENTAL CHECK OF THE SIMULATED CYLINDER'S GEOMETRICAL CHARACTERISTICS OBTAINED FROM THE EXPERT PROGRAM

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Abstract – In the paper, the issue of the form deviation measurement with coordinate measuring machines is being discussed. As an example, the out-of-cylindricity was taken, and their dependence on the various factors, that affect the final results of measurement and could expand its uncertainty. The supporting expert program Valetz is presented, too. It was designed to simulate the measurement of out-of-cylindricity with various input data, and to analyze the possible final uncertainty. In the paper, the simulation results are compared with the experimental measurement with CMM, and also with reference measurement with specialized device. Comparative analysis contained the evaluation of the relative error of the method.

Keywords: cylindricity, form deviation, Coordinate Measuring Machines

1. INTRODUCTION

Coordinate Measuring Machines are winning wider and wider application in industry. The customers tend to use them more and more often for the measurement of form deviation. However, unlike the dimensional measurement, the check of form is affected by numerous factors about which operators often do not care. To mention only the most important and obvious ones:

- Maximal permissible error of CMM – MPEE,
- Error MPEP,
- Number of collected probing points,
- Number of defined measurement intersections,
- Out-of-roundness type,
- Out-of-cylindricity type,
- Mechanical filtration of the probe,
- Approximation criterion choice.

All the mentioned factors have something in common. It could be easily seen that they are connected with the measurement strategy which is a matter of the operator's choice. It is clear that the mistakes of the operator during all the measuring and interpretation process heavily affect the measurement result and its uncertainty. With the out-of-cylindricity measurement as an example, Authors undertake the effort to support the decisive process and to give the operator a tool aiding proper measurement strategy choice.

2. MEASUREMENT STRATEGY

The form deviation measurement requires the reproduction of the form possibly close to the true form of the detail [1, 2]. In the Coordinate Measurement Technique, the measurement strategy is one of the most important problems. Besides of the number and localization of probing points, the error model and the filtering should be chosen appropriately. It is important also to choose the fitting method for reference element in the way ensuring that the obtained result is in the bounds of the assumed uncertainty (Fig. 1) [3].

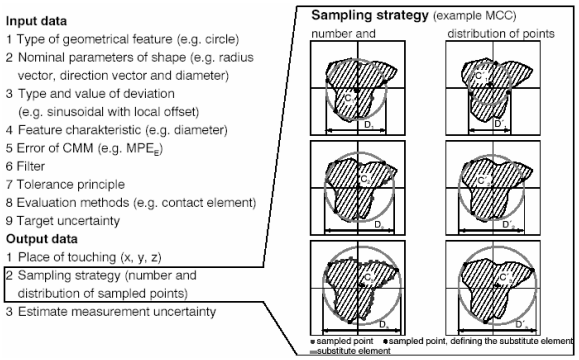

Fig. 1. Information transfer between the measurement process planning system and the measurement strategy generator [3].

3. IDEA OF THE EXPERT PROGRAM

Initial analysis of the operators' problems with strategy planning, has led to the idea to create an expert program able to simulate the errors that could occur during the measurement of the out-of-roundness and out-of-cylindricity. The

investigations and works started, and the final version of the program will be aiding the operator's decision on the number and localization of the probing points allowing to obtain the information on the form deviation of given type with assumed uncertainty.

Hence, the Author's purpose was metrological analysis of the form deviation measurement with Coordinate Measuring Machine and creation of new expert software that would enable the full metrological analysis of the decisive and measurement process in order to determine errors and their influence on the final measurement result.

4. EXPERIMENTAL VERIFICATION

The algorithms applied in the program underwent experimental verification [4].

Test with the CMM was performed in two stages:

- Repeatability test – the measurement of the same cylinder oriented in the same coordinate system was repeated 30 times.
- Repeatability test with coordinate system rotation – the same cylinder was measured with rotation of the coordinate system. Step was 5º in the range from 0 to 90º.

5. PRACTICAL SOFTWARE TESTS

5.1. Test for various measuring machines

In order to determine influence of the CMM's inaccuracy on the simulation algorithms [5], the following test was performed. The measurement of cylinder of the same parameters was simulated for various errors of CMM given by the producers for DEA Global machine as $MPE_E = \pm 1{,}5 + L/333\mu m$ and Wenzel LH54 as $MPE_E = \pm 3{,}0 + L/350\mu m$. Both machines had various sampling systems installed. For the reference measurement, the specialized device PIK-2 for the form deviation measurement of the rotary-symmetrical details was used. The radial deviation of the device rotation is $(0.02 + 5H/10000)\mu m$. For the comparative analysis, the same shafts measured with CMM were examined. The cylindricity was calculated from 5 intersections, repeated 30 times.

The results of simulations and measurement are presented in the Table 1 and in the Fig. 2. They prove satisfactory level of the simulation quality.

Table 1. Simulation and measurement results for the machines with different permissible errors.

Number of probing points	CMM DEA		CMM Wenzel	
	Measure-ment with CMM DEA µm	Simulation with program Valetz µm	Measure-ment with CMM Wenzel µm	Simulation with program Valetz µm
4	9.16	31.39	11.20	30.69
8	32.26	34.53	33.90	35.16
12	35.69	36.76	37.30	37.71
16	36.68	36.51	39.50	38.50
20	37.59	37.45	40.30	38.66
24	38.84	37.84	41.90	39.06
28	37.24	37.97	41.10	39.38
32	37.57	38.06	40.50	39.61
64	38.75	39.06	41.00	40.99
Reference measurement with specialized device PIK2 µm				
38.67				

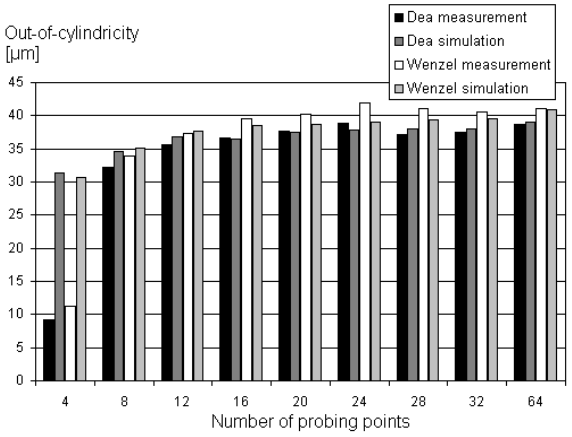

Fig. 2. Simulation and measurement results.

5.2. Repeatability test for the cylinder

To evaluate repeatability of the obtained results, the test was performed in two stages:

- 30 times measurement in the same fixation,
- measurement in the coordinate system rotating with step of 5 degrees.

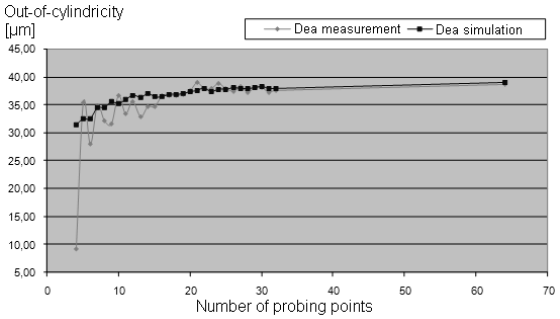

Fig. 3. Example of the test repeatability results (without rotation).

However, when the measured detail has deviations from the ideally geometrical form, it could affect the simulations and the measurement results as well. Therefore, the mentioned above repeatability tests were performed with the cylinder which has got its conoidal form with known value. The example of obtained results are shown in the Fig. 4 It is clearly seen that the program passed the test successfully.

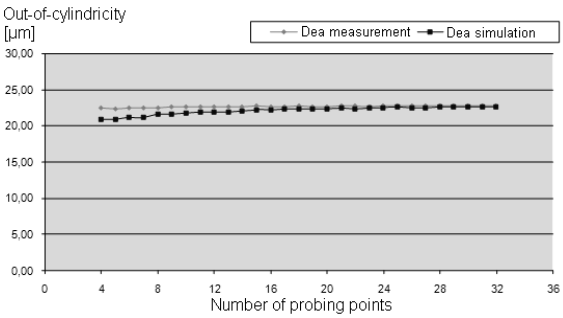

Fig. 4. Example of the test repeatability results for the cylinder with known conoidal form.

5.3. Statistical tests

The simulation results were analyzed under the parameter of main interest of presented investigations – out-of-cylindricity. In order to determine the experimental error of the method, the relative method was calculated from following formula:

$$W_{\Delta CYL} = \frac{\Delta CYL_S - \Delta CYL_M}{\Delta CYL_M} \qquad (1)$$

where:

ΔCYL_S – out-of-cylindricity calculated from the simulation with the expert program Valetz,

ΔCYL_M – out-of-cylindricity calculated from the measurement with the CMM (DEA)

For the method error evaluated from the formula (1), the procedures proposed by Prof. Adamczak [4, 5, 6] were applied in order to evaluate the quality of the obtained results. Analysis was performed for the results obtained from the CMM DEA and simulation by Valetz program in reference to the results of the measurement with the specialized device PIK-2. In the comparative analysis, the following was made:

- Estimation and significance test for the mean value,
- Estimation and significance test for the for the variance and the mean deviation,
- Estimation of the confidence intervals of the single method for the assumed confidence,
- Test of goodness of fit in the population with a theoretical distribution.

6. CONCLUSION

The presented software based on program Valetz is still in the stage of tests. At present, the additional module of the software is being prepared. Its task is to aid the final decision of the operator on the measurement strategy choice. The presented tests, as well as the tests described in the papers [7] prove that the program fulfils the initial assumptions and the expectations of the industrial operators of CMMs. After the initial experimental check program will undergo the industrial tests.

REFERENCES

[1] Nuemann H. J.: *Präzisionsmesstechnik in der Fertigung mit Koordinatenmessgeräten*, Renningen, ISBN 3-8169-2211-2, 2004.

[2] Weckenmann A., Beetz S. *Determination of measurement strategy for coordinate measurements supported by an assistance system.* Zeszyty Naukowe ATH w Bielsku-Białej, Budowa i Eksploatacja Maszyn. Konferencje. Zeszyt Nr 22

[3] T. Killmaier, A. Ramesh Babu: Genetic approach for automatic detection of form deviations of geometrical features for effective measurement strategy. Precision engineering 2003, vol. n7 nr 4 p. 370-381

[4] Adamczak S., Janusiewicz A.: *Assessing the accuracy of a computerized roundness profile measuring instrument used under industrial conditions*, IV Kongres ICPM - Obróbka Precyzyjna, Kielce - Sandomierz 2007, s. 143-148, 2007

[5] Adamczak S., Makieła W., Fajdek S.: *Algorithm determination of a curvilinear profile basing on co-ordinate measurement with pulse heads.*, Zeszyty Naukowe Akademii Techniczno-Humanistycznej w Bielsku-Białej, Budowa i Eksploatacja Maszyn, Nr 3, s. 23-29, 2002

[6] Adamczak S., Makieła W.: *The simulation method for the determination of the measuring error of a curvelinear profile examplified by a circle using a co-ordinate measuring maschine* Metrology and Measurement Systems, vol. IX, Number 3 (2002)

[7] Pawłowski M., Gapinski B., Grzelka M., Rucki M., *Expert Programs Supporting the Form Deviations Measurement*. Abstract of Conferences, VIII Conference On Advanced Mathematical And Computational Tools In Metrology And Testing "AMCTM 2008", 23-25.06.2008 r., ENS Cachan, Paris, France, s. 3/5-6.