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COMPARISON RESULTS OF MEASURING ROUNDNESS ON THE BASIS OF MEASURING POINTS

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ABSTRACT
Under contemporary conditions of the manufacturing process of parts and assembly the accuracy of production is of great significance. Accuracy does not refer only to dimensional but also to geometric precision. These characteristics are imposed by tolerance in dimension and form.
This paper treats a control analysis of a geometric property: roundness.
Measurements are done on a contemporary CNC controlled coordinate measuring machine using different conditions of measurement.
In the paper two-factor analysis of the variance belonging to method ANOVA is compared to the influences of qualitative variables on accuracy. These factors are: Measuring points on the machine table and the Number of measuring points along the rim of the measuring objects.
Keywords: roundness, CMM, measuring, ANOVA method.

1. INTRODUCTION

A workpiece from dimensions all workpieces have certain micro and macro geometrical surface characteristics. For deviation from dimension and macro geometrical characteristics of form, location, and direction there are functional limitation which, if they are overstepped, this may endanger the functionality of the workpiece. The tolerances on the drawings (PLANS, DESIGNS) have to completely ensure the dimensions and geometrical form, so that nothing is left to subjective evaluation of the factory staff or the control service.
Geometrical tolerances are determined only when necessary from the aspect of functional requirements, changeability and eventually from the aspect of production. However, this does not mean automatically that a special way of manufacture, measuring or control has to be used. One specific version of form tolerance is analyzed in this paper, namely **roundness**.

2. DEFINITION OF THE ROUNDNESS

When defining the roundness we are led by the principle of the minimum zone. On the basis of that principle the definition of the roundness is the following: the tolerance zone is presented by means of two concentric circles which must be chosen in such a way that the radial distance (t) between them is minimal (Figure 1/d) [1].

So the value of the form deviation for the roundness is equal to the distance between the two concentric circles (t), and the tolerance zone is the area between these circles.

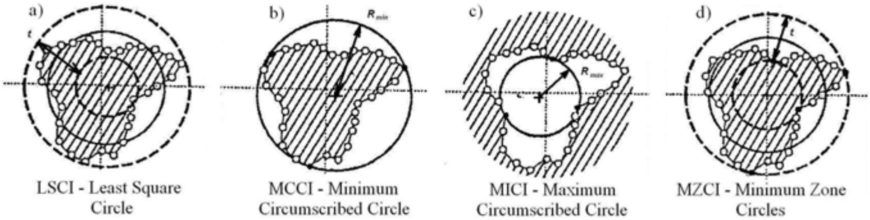

Figure 1. Presenting of the roundness deviation on the basis of different methods of evaluation

The part equalizes with the given tolerance if the real area of the tolerated element is inside the field of tolerance – reduced by the value of the measuring uncertainty. The general concept of defining geometric tolerances is called GPS (**G**eometrical **P**roduct **S**pecification), and in it the roundness is defined according to the standard of ISO 12181.

3. MEASURING THE ROUNDNESS

Measurements were done in the Metrology Laboratory at the Faculty of Technical Sciences in Novi Sad, Serbia, on a coordinate measuring machine **Carl Zeiss** CONTURA G2 ACTIV. (Figure 2.)

Figure 2. Coordinate Measuring Machine Carl Zeiss CONTURA

The most important technical parameters of this measuring machine are:

- The workspace of the machine (length x width x height) – 600x600x800 mm,
- Optimal precision (Extremely low dimension errors at ambient temp: 18-22ºC. HTG option increases it to 18-26ºC. HTG option includes CMM and workpiece temperature sensors.
- Pneumatic bearing of the moving elements in the mechanism,
- Measuring uncertainty (MPE_E): (1.9 + L/330) µm, where L is the length in mm,
- Software machines: Calypso
- Type of measuring sensor: VAST XXT (scanning sensor)

The conditions of the measurement were standard: temperature 21ºC and humidity of the air 40 – 60%. The measurement workpiece was an etalon cylinder 19.3 mm in diameter, fixed onto the machine table. (Figure 3.)

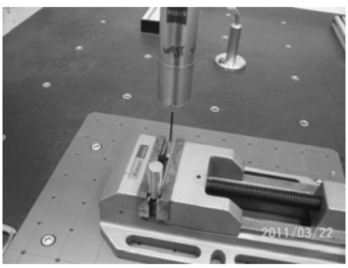

Figure 3. Measurement workpiece

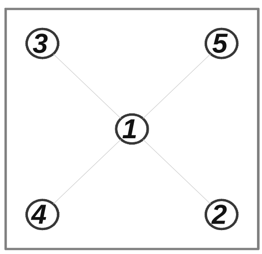

Figure 4. Setup of the measurement locations on the machine table

Measurements were effected by fixing the object undergoing control measuring at five different places onto the machine table so that comparing the measurement results one could state how big the influence of the choice of measurement position is – factor A (Figure 4.) The other influential factor of analysis was the number of measurement points on the contour of the chosen section of the workpiece – factor B. The chosen numbers of measurement points are of a large scale in order to increase the efficiency of the preliminary influence of this factor. The numbers of the measurement points are: 100; 400 and 1600. So that the chosen procedure (ANOVA) may be adopted, in each measurement position and with each number of measurement points, measurements are repeated five times. During the course of proceedings much attention was paid to secure identical conditions of measurement, except the variability of chosen influential factors. So measurements are always effected on the same section of the measurement workpiece, 10 mm distant from the upper basic surface. At each measurement the speed of the passing round the contour was the same, and naturally the same filters were always used for the elaboration and presentation of the acquired results.

4. ANALYSIS OF THE MEASUREMENT RESULTS

Measurement results are presented in table 1.

Table 1. Measurement results in [mm]

factor A / **factor B**	Measuring place ***1***	Measuring place ***2***	Measuring place ***3***	Measuring place ***4***	Measuring place ***5***
Number of meas. points 100	0,0033	0,0021	0,0046	0,0024	0,0021
	0,0035	0,0020	0,0035	0,0026	0,0020
	0,0035	0,0021	0,0032	0,0025	0,0020
	0,0037	0,0019	0,0031	0,0025	0,0021
	0,0035	0,0021	0,0032	0,0022	0,0020
Number of meas. points 400	0,0025	0,0026	0,0035	0,0041	0,0031
	0,0026	0,0024	0,0036	0,0039	0,0032
	0,0026	0,0025	0,0042	0,0040	0,0031
	0,0025	0,0024	0,0037	0,0033	0,0031
	0,0027	0,0025	0,0032	0,0034	0,0032
Number of meas. points 1600	0,0038	0,0040	0,0038	0,0046	0,0039
	0,0038	0,0040	0,0040	0,0040	0,0039
	0,0039	0,0038	0,0040	0,0044	0,0038
	0,0038	0,0039	0,0041	0,0041	0,0038
	0,0042	0,0038	0,0044	0,0041	0,0039

We can state the following by preliminary surveying of the acquired results:

- the dispersion of the results inside the group of data with the same factors of repetition starting from the minimal 0.1 μm (at measurement position 4 and 5 – from 100 measurement points, and numbers of measurement points 400 and 1600 at measurement position 5) to maximum 1.5 μm (at measurement position 3 with the number of measurement points 100),
- the dispersion of the results linked to each measurement position moves from 1.5 μm at measurement position 3 to 2.4 μm at measurement position 4,
- the dispersion of the results according to the numbers of measurement points extends from the minimal 0.2 μm at the second repetition with 1600 measurement points to the maximum of 2.5 μm at the first measurements with 100 measurement points.

4.1. Applying the Method ANOVA

A preliminary survey does not give us the opportunity of adequate conclusions in connection with the influences of the observed factors, so we must apply some of the other methods for processing results. In this paper the method of **AN**alysis **O**f **VA**riance is applied. Using the double-factor analysis of variance we got the results presented in table 2.

Table 2. Results of ANOVA procedure

	DF	SS	MS	F 0	P
Factor A	4	0,0000081899	0,0000020475	34,9795	<0,05
Factor B	2	0,0000215208	0,0000107604	183,8337	
Interactions AB	8	0,0000103485	0,0000012936	22,0997	
Rezidua (error)	60	0,0000035120	0,0000000585		
Summa (total)	74	0,0000435712			

For interpreting the acquired values we use the table of limits F distribution – Snedecor's distribution. In this case a distribution with 95% reliability (α=0,05) was used.
Granične vrednosti F raspodele su:

$$F_{A(a-1,\Sigma n-1),a}=F_{(4,74),0,05} = 2,53 \tag{1}$$

$$F_{B(b-1,\Sigma n-1),a}=F_{(2,74),0,05} = 3,15 \tag{2}$$

$$F_{AB((a-1)(b-1),\Sigma n-1),a}=F_{(8,74),0,05} = 2,10 \tag{3}$$

5. CONCLUSIONS

On the occasion of the measurement of roundness referring to the measuring workpiece two factors are varying: the position of the measuring workpiece on the machine table and the number of measurement points on the contour. On the basis of processing the results of the measuring data we can conclude the following:

- both factors seem to have significant influence on the measurement results. It could be also established on the values in the table of results, although it was not possible to make certain the extent of the influence produced by one and the other factor.
- the ANOVA procedure proved the prevision about the effect of both factors and gave the answer to the question about the degree of efficiency of the influence: factor A (measurement place) is the factor which has less influence on the value of roundness than factor B (number of measurement points).
- the influence of factor A on factor B (interaction of two factors) shows that in different positions the influence of the number of the measurement points is not the same; in fact the accuracy of the results depends on the reciprocal values of these factors.
- this means: it is not the same where we put the workpiece on the table. The reason of this had been analyzed in many works already published which were dealing with the increasing accuracy of the CMM. [2] The extent of the influence produced by factor B is also logical and explainable. In the table of results we can easily see that the size of roundness proportionally increases with the number of measurement points. It proves how important it is to find out the optimal number of measurement points for each machine and each measurement workpiece.

5. ACKNOWLEDGEMENT

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