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COMPARATIVE ANALYSIS OF THE RESULTS OF MEASURING ON THE COORDINATE MEASURING MACHINES

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ABSTRACT
Coordinate measuring machines are devised for most complex measurements. Besides their dimension measuring abilities, the CNC operated machines can measure geometrical characteristics of form, such as straightness, roundness, cylindricity, etc. These are vital features in current times when control needs to submit very thorough reports not only on the form, but also on the geometrical features of the given workpiece. Yet the question arises: are these measuring data regarding roundness received from the CMM accurate and reliable enough for them to be exploited?
In order to confirm this statement, the geometrical roundness characteristics are measured on three types of coordinate measuring machines, the results of which are analyzed from several aspects.
The results have shown a special importance of specific measuring parameters and have shown to be independent of the type of measuring machines.
Keywords: coordinate measuring machines, measuring roundness, circularity.

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 forms of the real surfaces regularly have a certain degree of deviation in comparison to the geometrically ideal surfaces. The causes of deviation basically match with the causes of inaccuracy of measuring workpieces. Functional dimensions are always done with a certain degree of tolerance that simultaneously limit the form deviation of that workpiece.
If one needs a greater degree of precision, than the one provided by the tolerance level formed by the tolerance of longitudinal dimensions, then the form must be separately tolerated.
One specific version of form tolerance is analyzed in this paper, namely **roundness**.
In order for this analysis to be carried out the following measuring machines were used:

- PRISMO MPS – *CARL ZEISS Industrial Metrology,*
- DEA – *Hexagon Metrology* and
- Crysta – Apex C776 – *Mitutoyo.*

The measurement in all three cases were carried out according to ISO 10360 standard regulations.

2. MEASUREMENTS

2.1. About measurement workpieces

Measurement workpieces used for the realization of the experimental measurements are versatile from the aspect of dimensions and locations of measurement plains. We chose master rings (measurement of interior surfaces), a tolerance measurement for the master plug, and a pivot, produced in the company ATB SEVER from Subotica, Serbia as part of the centrifugal pump construction – high quality accuracy considering dimensions, roundness, and cylindricity.

The tolerance master plug and pivot are representations for measurements of exterior surfaces. The dimensions chosen for measurement workpieces are the following:

Master rings of the diameter D=Ø49,991 mm and D= Ø30 mm. Master plug is of the diameter of d= Ø80 mm, and finally, the pivot is of the diameter Ø12 mm. The chosen measurement workpieces are portrayed in Fig. 1.

Figure 1. The chosen measurement workpiece

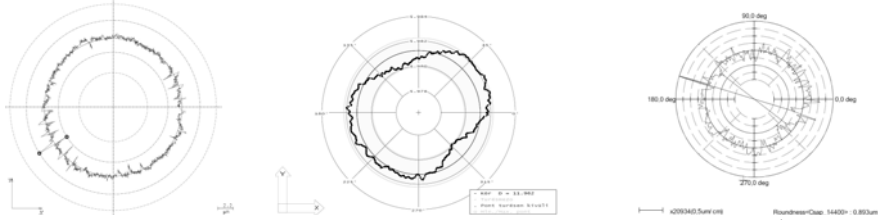
3. GAINED RESULTS

Measurement of roundness was carried out on the three described types of CMM. When distributing the measurement workpieces to the various machines, it was vital that on all machines there were interior and exterior surfaces measured by the same measuring probes. The distribution of measurement workpieces on the measuring machines was the following:

1) On the *DEA - Hexagon Metrology* type machine we measured: pivot ϕ 12 mm and master ring ϕ 30 mm.
2) On the *PRISMO MPS – CARL ZEISS Industrial Metrology* type machine we measured: master plug ϕ 80 mm and master ring ϕ 49,991 mm.
3) For comparative results to the coordinate measuring machines, all pieces were also pre-measured on the *Crysta Apex C776 – Mitutoyo* type machine.

Finally, the comparison of the results from the first two machines and the third machine – Mitutoyo was carried out, comparing them with the diagram from the measuring machine for roundness *Roundtest RA-2100 – Mitutoyo.*

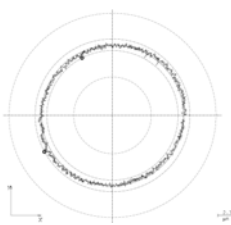
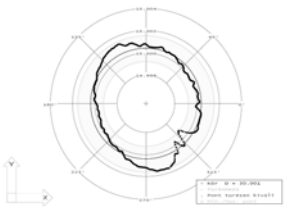
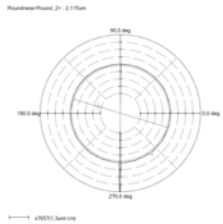
Results of measurement on the ϕ 12 mm pivot



DEA Crysta – Apex Roundtest

- form of the diagram: all diagrams show multiangle contours,
- the location of extreme points: no clear image was attained in this aspect,
- the bandwidth of roundness: the reference value is 0,6 μm, while the values measured on the CMM is 2 μm.

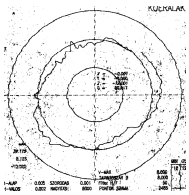
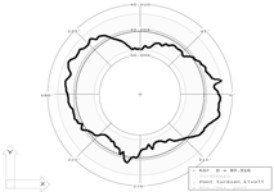
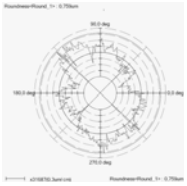
Results of measurement on the ϕ 30 mm master ring

DEA Crysta – Apex Roundtest

- form of the diagram: in this case, too, all diagrams show a multiangle contour,
- the location of extreme points: it is difficult to evaluate results of the analyzed methods when the reference itself is bent due to the extremeness in the discrete point,
- the bandwidth of roundness: the reference value without extremes is 0,4 μm, while the values measured on the CMM is 2 μm.

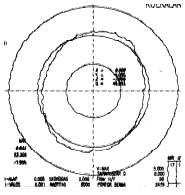
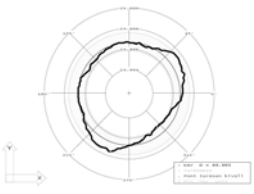
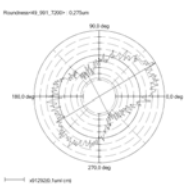
Results of the measurements on the ϕ 80 mm master plug

PRISMO MPS Crysta – Apex Roundtest

- form of the diagram: on all diagrams the elliptic character of the form can be clearly seen. The form of the round diagram of the reference results is only superficially different from the others due to the huge magnification (around 32000 times) so the form can be seen with an amount of detail that makes it seem distorted. Thus the results from the CMM are almost ideal in the magnification of 8000 times,
- the location of extreme points: with this measurement workpiece the extreme points are clearly visible on all diagrams. More importantly, if the extreme points are connected, as done with blue and red lines in the reference, those connecting lines will close angles of about 90^{o} on all diagrams. This shows that those results are highly similar.
- the bandwidth of roundness: the reference value in this case is 0,7 μm, while the values measured on the CMM are 2 μm.

Results of the measurement on the ϕ 49,991 mm master ring

PRISMO MPS Crysta – Apex Roundtest

- form of the diagram: if the roundness diagrams are considered, the same image is portrayed – all diagrams are of similar form (taking into consideration the difference in magnification, these differences are almost insignificant)
- the location of extreme points: with this measurement workpiece the extreme points are clearly visible on all diagrams, and by connecting them we receive the same results as previously described, confirming a great degree of similarity, if not complete identity

- the bandwidth of roundness: the standard value in this case is 0,275 μm. With the CMM the measurements of this workpiece amount to 1 μm, meaning that the result is again 3-4 times greater than the reference.

4. CONCLUSIONS

Based on the described facts and comparisons of the measurement results the following can be stated:

- The used machines for determining roundness globally give reliable results concerning the form of deviation of roundness – for the same measurement workpiece not once did it result in versatile forms.
- Recognizing the form of deviation depends in a great degree on the optimal magnification. This can be seen in the case of the CMM *DEA - Hexagon Metrology*, where the magnification was about 4000 times, thus reading the deviation from the form of the diagram was more difficult. Magnification with the other two measuring machines was about 8000 times, thus the form was easily recognizable.
- In the cases where the extreme points are recognizable, all measuring machines ensure their location and calculate their location except with special machines for roundness, which is not meant for such tasks,
- It is important to note that all measured bandwidths of roundness with coordinate measuring machines for the same measurement workpieces were identical or extremely close. This means that the results of the measurement of roundness in these cases did not significantly depend on the size of the measuring uncertainty. Hence, this parameter moved in a rather wide range in the three coordinate measuring machines used. This aspect will need further research.

As far as accuracy of determining bandwidth of roundness is concerned, the coordinate measuring machine which was not specifically aimed at this type of control and measurement, providing about 3 – 5 time higher values than the results on the roundness machine. Taking into consideration that the sizes in question are only several micrometers, it can be stated that in production, where the tolerance level is usually about one hundredth of a millimeter, the coordinate measuring machines perfectly satisfy the present needs in determining the roundness of the workpieces.

5. REFERENCES

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