MEASUREMENT OF DIAMETER AND ROUNDNESS DEVIATION FOR CIRCLE WITH INCOMPLETE CONTOUR

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Abstract: Shafts and holes are the most common elements in the construction of machines. Their mating creates the sets for various purposes, but in most cases these elements create responsible couplings, e.g. mating surfaces with the bearing friction, surfaces of mounting bearings, positioning dowels of elements, pair of piston - cylinder, etc. Control of circle parameters – outside ones on a shaft or internal ones in a hole, is one of the most common tasks in metrology of geometrical quantities.

Measurement of diameter and roundness deviation could be conducted using wide range of measuring devices in dependence on tolerances of particular characteristic. In most cases, the measurement is carried out on a complete contour. However, there are some cases when the measurement needs to be done for incomplete contour – it can be the value of 180° or 45°.

The aim of this paper is to present the recommendations for proper definition and interpretation of the results for the parameters achieved from the measurement of incomplete contour. Presented results of measurement of diameter and roundness deviation on a specialized form tester were related to different angular lengths. Measurement objects had various form errors. The influence of position of the measuring sector in relation to extremum (minimum and maximum) of roundness was considered. Analysis of measuring accuracy and also the impact of verification of measuring sector length on a loss of information on the measured object was conducted.

Keywords: diameter measurement, form deviation, roundness, accuracy of measurement, uncertainty

1. INTRODUCTION

Consumer's requirements for various types of product are connected with continuous improvement of product quality. The issue of quality can be widely treated in this case – starting from a correctness of manufacturing of particular subassemblies, manufactured mechanisms and ending on a service, trainings or operation costs. The offered prices should not be higher than previous consumer prices. This forces the manufacturer to solve the difficult task which is a connection of two contradictory requirements. This situation exacts the use of innovative solutions which allow for a cost reduction on each stage of designing and manufacturing. In connection with this situation, composite materials, manufacturing processes which reduce the waste materials and etc. should be used. In order to confirm the rightness of made activities, it is necessary to conduct different types of control-measuring works. In addition, the general increase of requirements causes that full control of particular geometrical features is needed [1, 2, 3]. The measurement of elements which are circular sectors exacts this control too.

The measurement of the part of a circle is not a trivial task – in case of both cylinder and hole. Depending on the type of measuring task, it is required to give a position of circle centre or origin of radius, diameter or radius of circle/arc and the value of form deviation [4].

2. THE POSSIBILITIES OF MEASURMENT OF A CIRCLE WITH INCOMPLETE CONTOUR

There are many possibilities of measurement of the part of a circle, i.e. the measurement of an arc [5, 6]. Workshop methods for the verification of radius are based on e.g. contour masters. These tools allow to fit the arc contour to the master and to estimate the approximate value of outer or inner radius. Versatile and accurate methods allow to measure not only the diameter/radius, but also form deviations. It is possible to apply the coordinate measuring machines or formtester [7, 8, 9, 10, 11, 12].

3. PRELIMINARY MEASURMENTS OF THE MASTER RING

The master ring with diameter of 100mm and undefined type of roundness deviation with the value of 0.0009mm and the ring with defined type of roundness deviation - ovality, with the value of 0.045mm and diameter of 100.32mm were measured during the investigations [13].

Each element was measured in a scanning mode with CMM and form measuring machine (FMM). Full contour of the ring – 360° was measured and it was taken as a reference value. Next, incomplete contours were measured for the following sectors: 180°, 90° and 45°. Reduction of measuring length causes that obtained information is only referred to a part of the contour. In order to verify the possibilities of detection of form deviation in relation to the position of measuring length and contour extremum, the following measurements were performed:

contour of 180° which was measured 4-times – arranged at every 90°,

contour of 90° which was measured 8-times – arranged at every 45°,

contour of 45° which was measured 16-times – arranged at every 22.5°.

Figure 1 presents the measurement results of the master ring with the use of CMM. Each line in this figure denotes the different angular range of the measurement. Axis of abscissae shows the angular scale which allows to present

the values of roundness deviation in relation to angular position of the starting point of contour measurement.

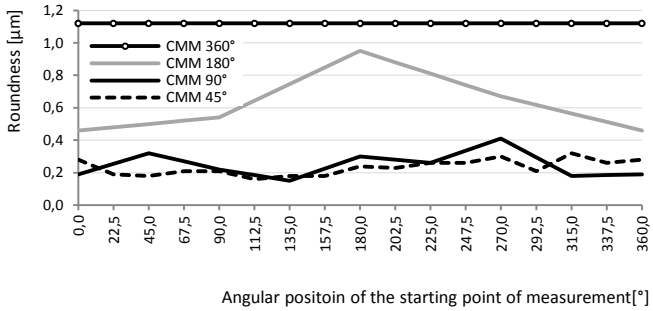

Fig. 1: Measurement results of the master ring with the use of CMM for the defined incomplete contours of circle

Figure 2 presents the measurement results of the master ring with the use of FMM.

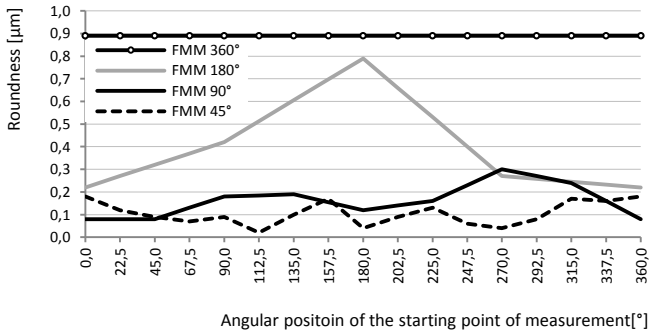

Fig. 2: Measurement results of the master ring with the use of FMM for the defined incomplete contours of circle

The analysis of the presented measuring data allows to affirm that the results which were obtained with CMM and FMM are converged and the differences are in a range of 0.0004mm. The highest values of deviation were observed for full contour for both devices. Contour of 180° allows to obtain lower deviations, whereas the values of roundness deviation for contours of 90° and 45° are converged – these values are the lowest ones.

The master ring is characterized by very small value of roundness deviation and undefined type of roundness deviation. This situation causes that we can obtain stable values for contours of 90° and 45°. This results from the fact that local peaks and cavities are not present at the circumference of the ring. Therefore, the values of deviation are on a constant level irrespective of the position of the measured contour. In comparison with full contour, the values for these two contours are smaller, because we can't detect all peaks and cavities during the measurement of the part of contour.

4. PRELIMINARY MEASUREMENTS OF THE RING WITH OVAL DEVIATION

After the preliminary measurements of the master ring, the measurements of the ring with oval deviation were conducted. The ring was measured with the use of CMM (fig. 3) and FMM (fig. 4). The obtained measuring data are illustrated in diagrams by four lines which denote different angular positions of measuring contours. Axis of abscissae shows the angular scale which allows to present the values of roundness deviation in relation to the angular position of measuring length.

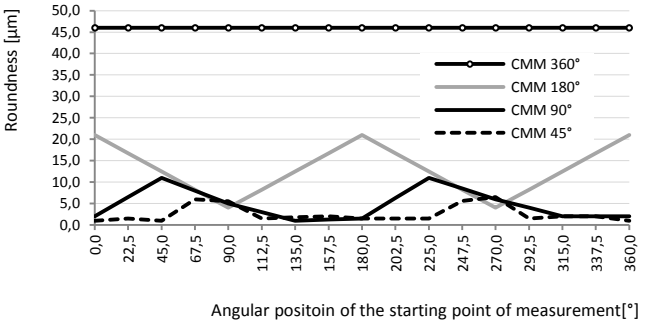

Fig. 3: Measurement results of the ring with oval deviation with the use of CMM for the defined incomplete contours of circle

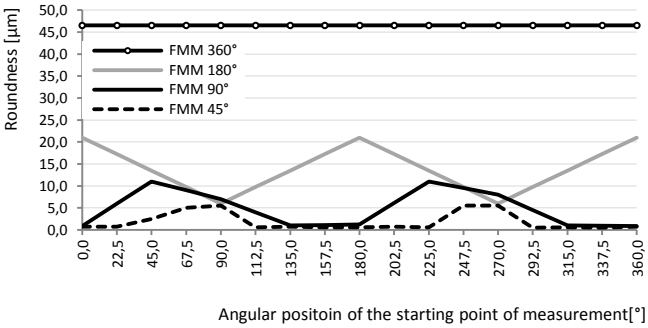

Fig. 4: Measurement results of the ring with oval deviation with the use of FMM for the defined incomplete contours of circle

On the basis of analysis of the obtained results from CMM (fig. 3) and FMM (fig. 4) we can observe that the results are converged. Difference between the values of roundness deviation which were obtained from these two devices for full contour does not exceed the value of 0.0002mm. This difference is within the area of measuring uncertainty for both devices, so it can be taken as a correct value.

For the measurement of four contours of 180° we obtained the differences between results which do not exceed the value of 0.002mm for both devices. We can also observe that the values of deviation are equal to ca. 0.021mm for contours which are starting from the position of 0° and 180°, and for contours which are starting from the position of 90° and 270° these values are equal to ca. 0.005mm. Appreciable differences between alternating sections result from the character of form deviation of the measured ring with ovality.

For the measurement of contours with angular length of 90° with the use of CMM and FMM we obtained the values of roundness deviation which do not exceed the value of 0.011mm. Differences between the values obtained with the use of these two devices do not exceed the value of 0.002mm. On the basis of the analysis of the obtained results we can stated that for the sector of 25% of full contour the value of roundness deviation alters together with the position of this sector in relation to extrema of form

deviation. We can distinguish the measuring lengths which contain positive deviation and negative deviation with the similar absolute value – then the value of form deviation of contour is higher, and also the measuring lengths which contain positive and negative deviations, but one of these deviations has a dominant value – in this case the value of deviation is smaller. For all eight contours of 90° we got the values of deviation which are much lower than for full contour.

The observations for contours of 45° are similar to the ones for contours of 90°. The values of roundness deviation depend on the position of measuring length in relation to extrema of oval. This effect is similar to the case of contour of 90°, but its influence is weaker, because it is difficult to find two extrema with opposite signs and high value of deviation for a shorter measuring length.

5. DETAILED INVESTIGATIONS OF THE MASTER RING AND THE RING WITH OVAL DEVIATION

On the basis of analysis of the preliminary investigations we decided to verify in details the influence of length of measuring sector on the value of roundness deviation and diameter. On the basis of the preliminary measurements it was found that the results obtained with the use of CMM and FMM are converged. Therefore, during detailed investigations we used only the FMM which allowed for the measurements with lower uncertainty.

The measurements were conducted for angular length in the range of 360° - 10° with a step of 1°. The measurements were performed for the elements which had been used in the preliminary investigations. The master ring had very small value of form deviation and its type of deviation was undefined. For this case of element, the position of measuring length has not any influence on the obtained values – this fact was shown in the preliminary investigations.

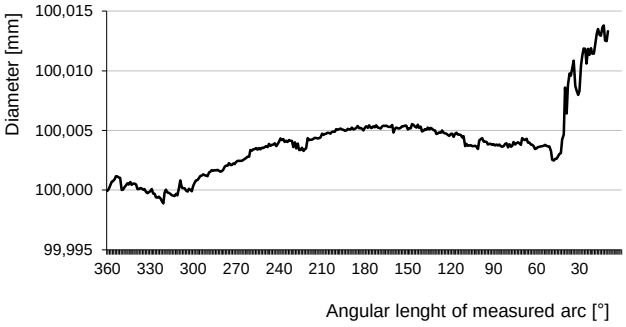

Fig. 5: Measurement results of diameter of the master ring for measuring sectors with different angular lengths

On the basis of measurement results of diameter of the master ring (fig. 5) it was found that during the first stage (up to ca. 300°) the diameter value is constant. In the range of 300° - 50° this value increases and alters in area of 0.005mm. For the measuring sectors with angular length below 50° we can see a rapid increase of the diameter value of the measured element – i.e. 0.014mm higher than the actual diameter.

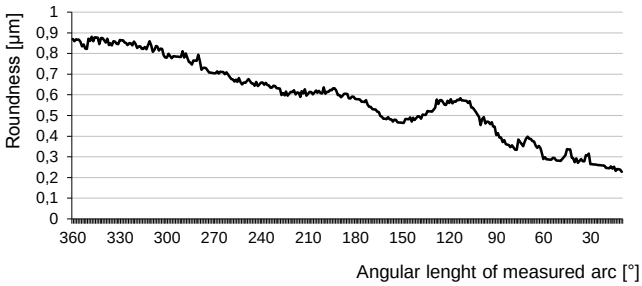

Fig. 6: Measurement results of roundness deviation of the master ring for measuring sectors with different angular lengths

Figure 6 presents the variation of the value of roundness deviation for the master ring. We can observe that the value of this deviation decreases when measuring sector is reduced. This inclination can be seen from the deviation value of 0.0009mm for full contour of 360° up to the deviation value of 0.0002mm for contour of 10°. It can be stated that this inclination is linear approximately.

For the case of the measurement of the ring with oval deviation we can observe three special cases – the centre of measuring length can be placed in positive or negative extremum of contour or between these two extrema. During the detailed investigations, these three cases were verified.

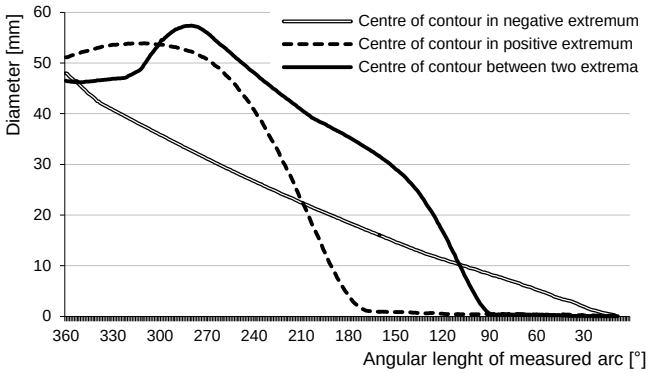

Fig. 7: Measurement results of diameter of the oval ring for measuring sectors with different angular lengths

On the basis of the analysis of data in figure 7, it was found that the variation of diameter for the measuring sector which has its centre in positive extremum and between two extrema is small. This variation does not exceed the value of 0.065mm. High variation of diameter can be observed for the measuring sector which has its centre in negative extremum of the measured contour. For this case the diameter value increases when the measuring length is reduced. For the measuring lengths in the range of 360° - 100° the increase of the diameter value is equal to 0.1mm. For the measuring sector lengths shorter than 100°, the increase of the diameter value is appreciable and for the sector of 10° the diameter reaches the value of 101.20mm. This diameter is greater about 0.88mm than the diameter for full contour.

Figure 8 presents the variation of the value of roundness deviation in relation to the variation of angular length of measuring sector. We can observe that the variation of roundness deviation for the measuring length which has its

centre in negative extremum of contour is linear and it decreases from the value of 0.048mm for contour of 360° up to 0.0002mm for contour of 10°. For the case of the measuring length which has its centre in positive extremum of contour, the course of variation is different. At the beginning, the value of deviation increases and it reaches the value of 0.054mm for measuring sector with angular length of 310°. Next, the value of deviation decreases and it reaches the value of 0.004mm for measuring sector of 180°. From this moment, a slow decrease of the value of roundness deviation can be seen – it reaches the value of 0.0001mm for measuring sector of 10°.

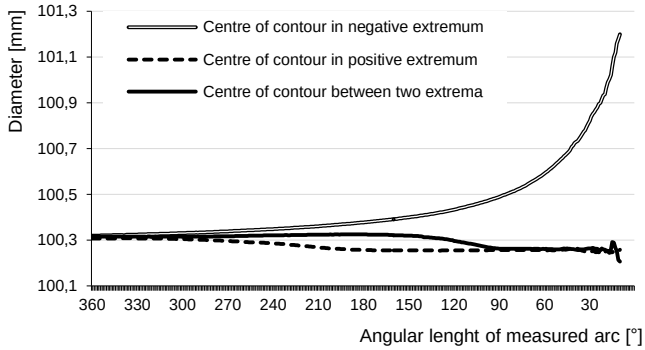

Fig. 8: Measurement results of roundness deviation of the oval ring for measuring sectors with different angular lengths

Measuring length which has it centre between positive and negative extremum of contour is characterised by the other course. At the beginning, the value of deviation increases slightly and at the angular length of 323° it starts to increase rapidly. The highest value of deviation can be found for the angular length of 280° - it is equal to 0.057mm. From this moment, the decrease of the value of roundness deviation can be seen – it reaches the value of 0.0005mm for the angular length of 90°. Further reduction of the measuring length causes the decrease of the value of deviation up to 0.0001mm for the angular length of 10°.

6. SUMMARY

The paper presents a part of the investigations which are conducted in a scope of the influence of measurement of incomplete contour on the values of roundness deviation and diameter. The analyses were done on the basis of the results of investigation which had been obtained with the use CMM and FMM.

Two series of investigations were performed. First, the preliminary investigations were conducted in order to verify the impact of measuring sector with angular length of 360°, 180°, 90° and 45°. Next, the detailed investigations were performed for measuring sector lengths in the range of 10° - 360° with a step of 1°. These investigations have showed that roundness deviations do not always decrease their values when measuring length is reduced. The position of measuring length in relation to extrema of contour has also an appreciable influence on the value of roundness deviation. The higher the deviation value for full contour, the higher the variation of deviation for reduced measuring sector length.

The variation of length of measuring sector and its position have also the impact on the measured value of diameter. For the case of the master ring, these variations are small. However, for the oval ring which has its centre in negative extremum of contour the increase of the diameter value is equal to 0.88mm for the ring diameter of 100.32mm.

To sum up, we concluded that the measurement of diameter and roundness deviation for incomplete contour is ambiguous and the obtained values depend on many factors.

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