THE ERRORS OCCURING IN THE CMM FITTING METHOD

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Abstract. *The characteristics of the errors in the software of the Co-ordinate Measuring Machines is very iomportant from the metrological point of view. When the number of measuring points is small, the error grows, beaceuse of the lack of stability in the approximation area of the interpolation methods. The tests hd been performed for different fitting methods: Gauss, Tschebyscheff, inscribed and circumscribed circles.*

1. INTRODUCTION

To evaluate a geometrical element one of the possible fitting criterion is used. Depending on this criterion the following elements are considered [1]:

- mean (according to Gauss),
- according to Tschebyscheff,
- tangent.

Method of measurement result assessment should be connected with function assigned to a measured surface [2]. Gauss method that is often used is not always suitable for this purpose. Inspection of particular features (dimensions, location, setting) is not enough. Least square method is first of all appropriate for workpieces with relatively small form error, whereas using this method for large form error values leads to incorrect circle equations.

2. ANALYSIS OF THE ERRORS OF FITTING METHODS

An important issue when using a CMM is an assessment of fidelity of representation regarding an actual shape and the one calculated from measurement data, using calculation algorithms included in CMM software [3]. Commonly, algorithms basing on least square method are used, what may lead to form errors. Fittings or dimensions critical for functionality are the ones with tight tolerances [4]. Traditional plug gauge allows solely for inspection whether the smallest dimension of bore is larger or smaller than gauge diameter. It is than a quality assessment, not a quantity one. From multipoint measurement it is already now possible by calculation to determine the smallest dimension (or in case of shaft – the largest). It enables for optimum match of fittings. When single point measurement is considered and with a small number of points practically only Gauss algorithm was used. Thus as a result of calculations with least square method a mean value is obtained. The result does not directly correspond to functional dimension. Values that are not typical are not included only conditionally and ranges are relatively small. Functional dimensions on the other hand are calculated according to the following methods:

- "inscribed circle", that is the largest possible inner diameter corresponding to inner dimension relevant from the fitting point of view,
- "circumscribed circle", that is the smallest possible outer diameter corresponding to outer dimension,
- "Tschebyscheff ", that is the mean diameter fitted into form deviation

However, a question arises which method to choose and what criterion should be taken. For relatively small number of measuring points it is difficult to choose properly. Stability of approximation and interpolation methods does not come earlier than with large number of measuring points [5].

In order to determine accuracy of approximation methods a geometrical model type casing for future tests was created. Most often measured elements are within 6 – 8 class of accuracy, what effected in level of errors assumed on geometrical model. In this casing four circles with different

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form errors were located. Distribution of measuring points was the same for all the circles. Circles I and II are in XY plane, whereas III and IV are in XZ one. Distribution of geometrical elements in casing together with dimensions was shown on fig.1. Results were shown on fig. 2÷4.

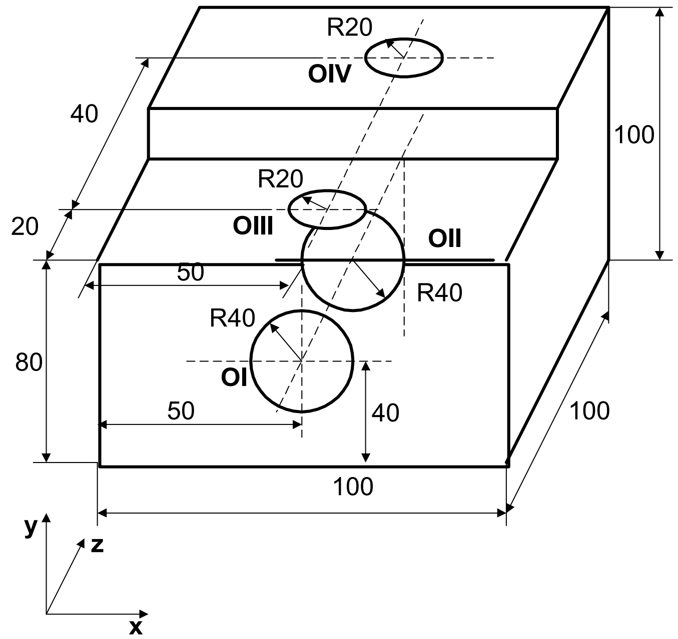


Fig.1. Tested circles in 3D space

Particularly interesting is determination of circle I (ideal) using four approximation methods. None of them was able to calculate both its center and radius correctly (!). Only radius calculated using inscribed circle is good (fig.2). Proper determination of center of circles took place only in two cases: in circle III using inscribed circle method and circle IV using circumscribed circle method (fig.3).

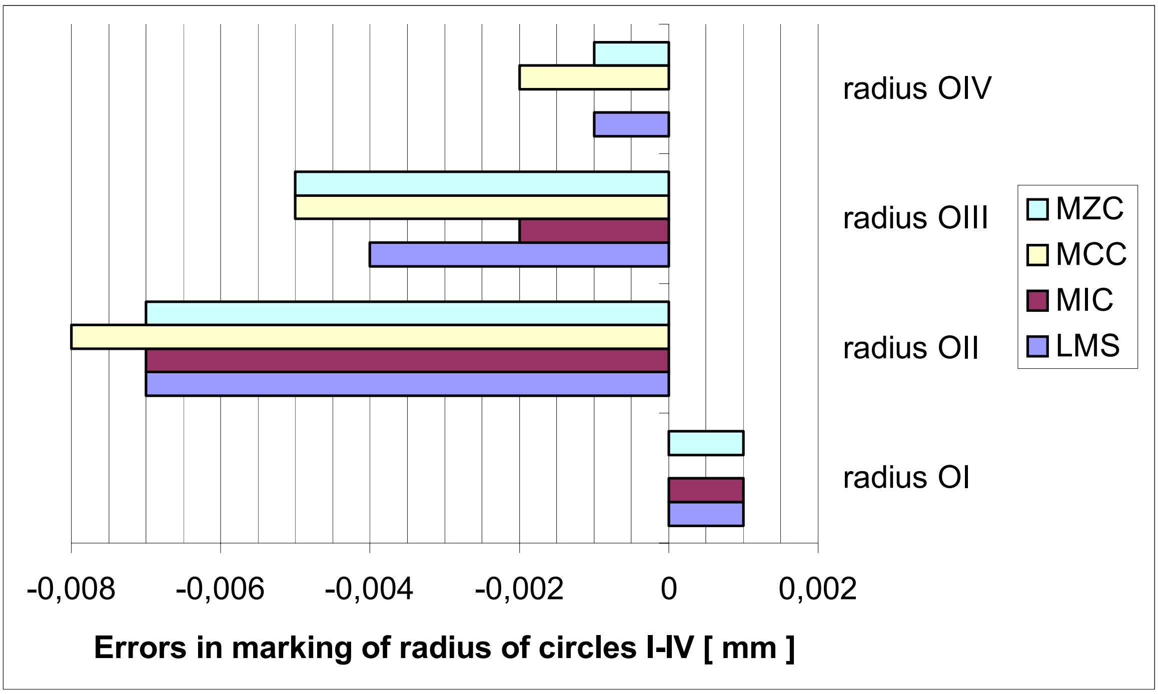


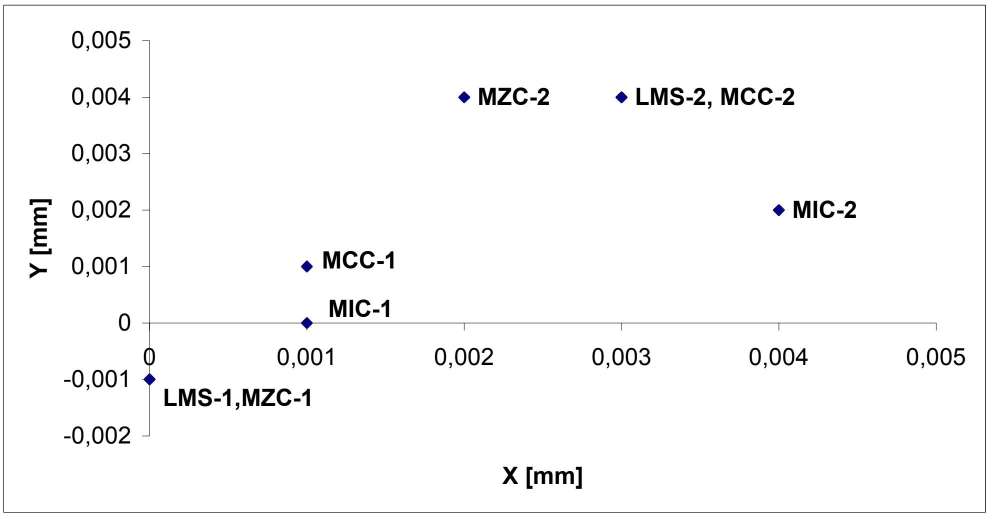
Fig.2. Errors in determination circles I-IV

The largest coaxiality error between circles I and II was found when using Gauss method (LMS). Error on similar level occurred with Tschebyscheff inscribed circle and circumscribed circle. Error that appeared during calculation of radius and center of circles I – II must be transferred to coaxiality between them.

The same situation happens when distance between centers of circles III – IV is calculated. Circles III – IV are also biased by form error. Tested approximation methods (except for one case) incorrectly calculated centers of circles III – IV, which in turns causes error in distance between them.

The most accurate in this test are circumscribed circle methods where 42% of correct results were found and inscribed circle methods with 33% good results (fig.4). Surprising is level of correct results for commonly used Gauss method (only 8%). The most results obtained with Gauss method were in area B (58%), where error ≤ |0.001|µm. In circumscribed and inscribed error methods in area B only 17% of results occurred. Still these two methods showed error greater than 0.001µm on level of 50%. In Tschebyscheff method results of A – only 8%, B-42%, C- 50% were obtained respectively.

Circle I-II



Circle III-IV

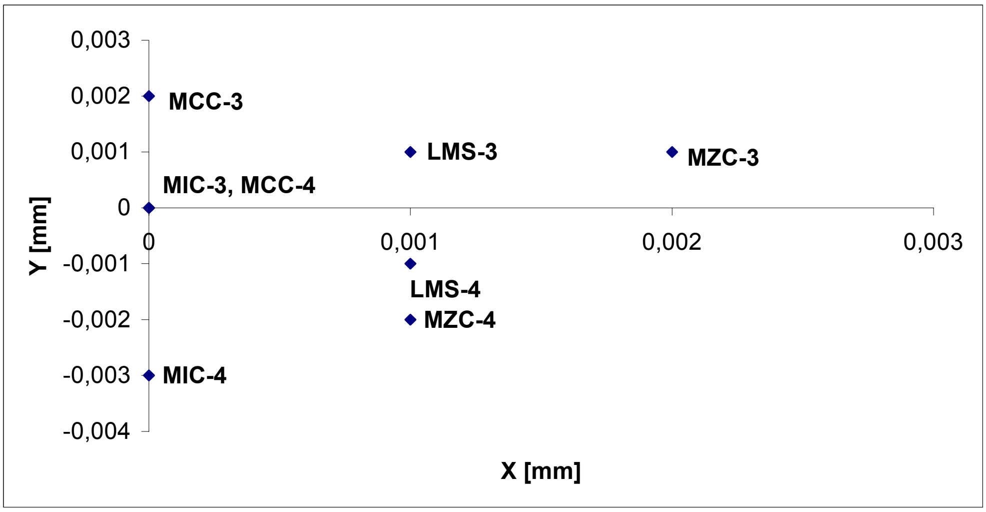


Fig.3. Determined coordinates of circle centers I-IV in particular approximation methods

3. CONCLUSIONS

There was only one correct result found when determining circle equation. It is the one calculated according to the circumscribed circle – IV (flatting). Algorithm errors are first of all the effect of form element description and applied mathematical description simplifications (equation linearization, series accuracy, approximation and interpolation, methods of element calculation, non – linear equations solving methods). Circumscribed circle, inscribed circle and Tschebyscheff methods assume multipoint technique (scanning) and give results with high repeatability. Tschebyscheff polynominals create calculation difficulties in case of large number of nods – require a lot of calculation time. It is then particularly difficult to assess inaccuracies of complicated shape measurements. CMM gives a discrete set of coordinates with a small number of points in relation to scanning methods.

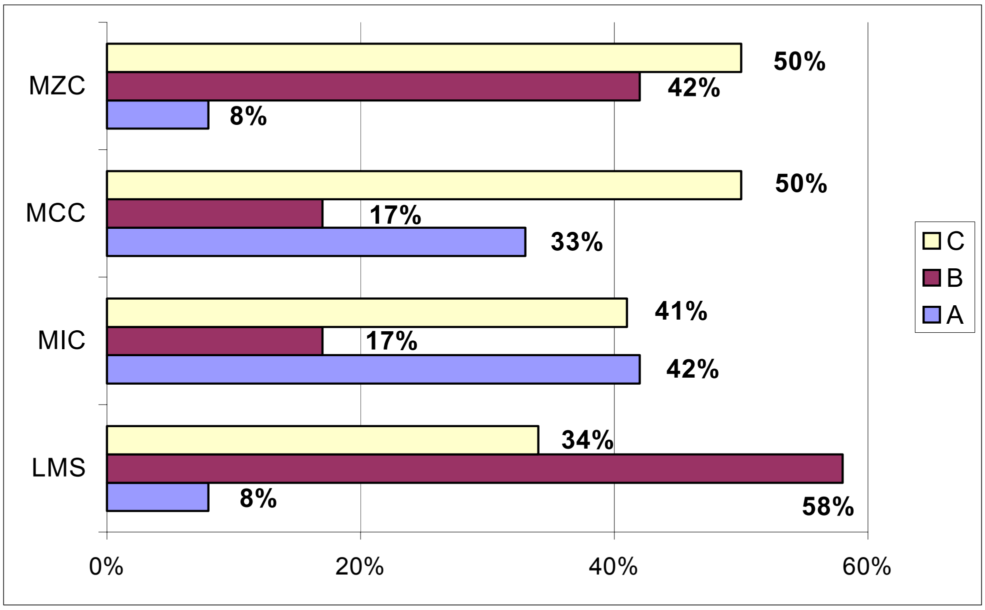


Fig.4. Share of results in particular areas: A-correct result, B-│error│ ≤0.001mm, C-│error│>0.001mm

Classical Gauss algorithm has lesser meaning with both: diameters calculation as well as form and position measurements. A question arises which method to choose and what criteria should be then applied. For relatively small number of measuring points it is very difficult to choose correctly. Stability of approximation and interpolation methods appears only for large number of points.

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