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ABSTRACT

A proposal for estimating the uncertainty of coordinate measurements is presented, which can be applied in industrial conditions. The basis is the sensitivity analysis method supplemented with an experiment with the use of a non-calibrated object. The measuring task modelling procedure for complex geometrical characteristics is described. The results of research on the correlation of experimental results and the sensitivity analysis results are given.

1. Introduction

The accuracy of machine parts is described by a large number of different GPS (Geometrical Product Specification) characteristics [1,2]. As far as estimating the uncertainty of coordinate measurements is concerned, there is full agreement that the measurement uncertainties of different characteristics measured on the same coordinate measuring system (CMS) are different, and in some cases the differences can be significant [3]. Hence, emphasizing that a given technique is "task-specific", both in publications and in the ISO 15530 standard (e.g. Ref. [4]) becomes redundant.

Numerous works on estimating the uncertainty of coordinate measurements focus on obtaining the highest possible accuracy of the results [5–7]. This requires taking into account very specific factors that may influence the uncertainty, such as the sampling strategy (number and location of sampling points, length and diameter of the stylus tip, scanning parameters), position and orientation of the object in the CMS space, temperature of the object and CMS standards, etc. the list can be found e.g. in Ref. [4]). Such a detailed approach justified for calibration laboratories is very often not possible in industrial conditions, where simple procedures are needed and less accurate results are enough.

At first glance, the use of calibrated workpieces [8] (but rather not use of "measurement standards") technique is well suited for industrial applications. However, the condition for ease of use is that the "calibrated workpiece" form is identical. The main disadvantage is the high cost of making and calibrating the appropriate artefact. It should be remembered that in industrial measurements the object is placed in a specially designed holder and even slight differences in the design of this artefact with the workpiece may make it impossible to perform the experiment. It is less problematic to use one of the produced workpieces. However, even in the case of a workpiece with a complex design (engine body, camshaft, crankshaft), the calibration itself is cumbersome and expensive. By the way, it is worth noting that the earlier version of ISO 15530-3, i.e. the technical specification ISO/TS 15530–3:2004 [9,10], is better suited for industrial applications. The reason is the issue of the so-called systematic error, which is simply included in the measurement uncertainty in the ISO/TS 15530–3:2004.

The work [11] shows a universal way to estimate the uncertainty of coordinate measurements, namely modelling the measurement as an indirect measurement with the use of a mathematically minimal number of points enabling the definition of individual characteristics. These can be both surface points as well as axis or plane points and should represent the measurement strategy used, usually consistent with good measurement practice. These assumptions allow all particular geometric characteristics (dimensions, geometric deviations) to be expressed as functions of differences of workpiece points coordinates (it should be clearly emphasized that these are coordinate differences and not coordinates). Relations expressing the point-point, point-axis, point-plane distances [12] are particularly useful for this purpose.

In the same work, as in the classic virtual measuring machine (VCMM) [13], the residual (remaining after mathematical correction) geometric errors and head errors were used as information about the accuracy of the coordinate measuring machine (CMM). However, unlike VCMM, instead of simulation, type B evaluation was used, in which, based on the identified geometric errors, functions describing the maximum differences of geometric error values were determined. The arguments of these functions are differences of coordinates of workpiece points.

The concept of using a minimum number of points and models based on strict mathematical formulae expressing every individual geometrical characteristic as a function of the distances or differences in the coordinates of the pairs of points is continued in Refs. [14,15], where the use of the CMM kinematic model was abandoned. Instead, it was decided to use the CMS accuracy information contained in the formula on $E_{L,MPE}$. More specifically, the standard measurement uncertainty of coordinate differences is calculated according to the formula from Ref. [16]:

$$u = E_{L,\ MPE} \cdot b \qquad (1)$$

This approach according to the classification of methods for estimating the uncertainty of coordinate measurements given in Ref. [17] is classified as sensitivity analysis, and according to GUM as GUM uncertainty framework [18,19].

This study analyses the possibility of the simultaneous use of the

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coordinated by Alessandro Balsamo, INRIM [20].

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