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Comparison of selected methods of probe radius correction based on measurements of ceramic workpieces

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Abstract

The article concerns the analysis of results of coordinate measurements of ceramic products. The measured parts were made of ZrO_2 based ceramic material and machined using the CNC machine tool Ultrasonic 20 linear. The analysis of results of measurements of ceramic workpieces concerned the comparison of corrected measured points obtained by means of different algorithms of the probe radius correction process. The first algorithm was developed based on the Lagrange interpolation method of indicated measured points. The second method was the commercial one and it is available in the Calypso software which can cooperate with a coordinate measuring machine.

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1. Introduction

The coordinate measuring technique may be used in, e.g. aerospace and automotive industries in order to measure products characterized by regular shapes [1] and free-form surfaces [2]. Coordinate measurements may be performed by using of both contact and non-contact measuring systems. The selection of a measuring instrument for a measurement task depends most of all on the expected accuracy of a manufactured product. Coordinate measuring systems may include, e.g. coordinate measuring machines (CMMs) [2,3].

The accuracy of coordinate measurements conducted by means of CMMs is affected by a number of factors, which may be the following [4]:

- the environmental conditions in the laboratory, where a measuring gage is located;
- the accuracy of applied measuring probes cooperating with CMMs;
- the form deviations of a measured workpiece;
- the used strategy of coordinate measurements.

The strategy of coordinate measurements may include, e.g. different algorithms of the probe radius correction process, various methods of localization of measured points on surfaces of measured workpieces and applied scanning velocities. The probe radius correction process has the significant impact on the results of contact coordinate measurements. The objective of the probe radius correction is the calculation of coordinates of corrected measured points based on coordinates of indicated measured points, which represent the centre of a stylus tip of a measuring probe during its contact with a measured surface of an object. Corrected measured points should be the real contact points of a stylus tip with a measured surface of a product [5]. In most measurement tasks the probe radius correction process is conducted independently from the process of form deviations calculation of a workpiece and a user of a particular measuring system has no detailed knowledge concerning the applied method of calculation of coordinates of corrected measured points.

In the paper [6] there was presented the method of calculation of form deviations, which can be used in the case of coordinate measurements of free-form surfaces of products. That method is based on the Lagrange and Chebyshev

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interpolation algorithms of corrected measured points. Those measured points are divided into groups which are composed of five components. Each group is interpolated with fourth degree polynomials using the mentioned interpolation methods. In the next stage local deviations between nominal points and intersection points are calculated. The intersection points are constructed by using of actual curves interpolating measured points and lines perpendicular to the measured profile of a workpiece at its nominal points. The form deviation is computed based on the information about local deviations calculated in the previous step.

The following article presents the new method of the probe radius correction process which can be relatively simply included in the presented algorithm of deviation calculation of curvilinear surfaces. Analogously to the described algorithm of form deviation evaluation the new method is based on the Lagrange interpolation. In the next parts of the following paper ceramic products analysed during experimental research, an applied coordinate measuring machine and the results of conducted experiments are presented. The main objective of performed investigations was to verify the precision of the new method of the probe radius correction process. The experimental research concerned the comparison of two groups of corrected measured points calculated by using of the new algorithm of the probe radius compensation and the method which can be found in a selected commercial metrological software.

2. Developed method of probe radius correction

The new method of the probe radius correction was developed based on the selected part of the algorithm of form deviation calculation presented by Magdziak [6]. In the case of the proposed method of calculation of corrected measured points there are constructed, analogously to the mentioned method of deviation estimation, the groups of points composed of five elements. However, in the new method, in contrast to the algorithm of deviation calculation, those elements represent indicated measured points successively distributed along measured surfaces. Each group of measured points is interpolated by using of fourth degree curves by means of the Lagrange interpolation method like during the process of deviations evaluation. The probe radius correction vectors are normal to the above mentioned curves at indicated measured points. Having the information about the coordinates of indicated measured points, the vectors of the probe radius correction process and the value of the radius of a stylus tip the coordinates of corrected measured points can be calculated.

In the case of the Lagrange interpolation method, which is applied in the proposed algorithm of the radius correction, the interpolation polynomial $w(x)$ can be obtained by using of the following equations [7]:

$$w(x) = \sum_{i=1}^{n} y_i L_i(x) \quad (1)$$

$$L_i(x) = \prod_{j=1, j\neq i}^{n} \frac{x - x_j}{x_i - x_j}, \quad i = 1, \dots, n \quad (2)$$

3. Ceramic products

The considered workpieces (Fig. 1), used in order to check the efficiency of the new method of the probe radius correction, were made of ZrO_2 based ceramic material and machined by using of the Ultrasonic 20 linear CNC machine tool. Each of the manufactured objects (denoted as **w1** and **w2** in the next parts of the paper) was analysed in two arbitrarily selected cross-sections, in which two curves (denoted as **c1** and **c2**) were registered (Fig. 1).

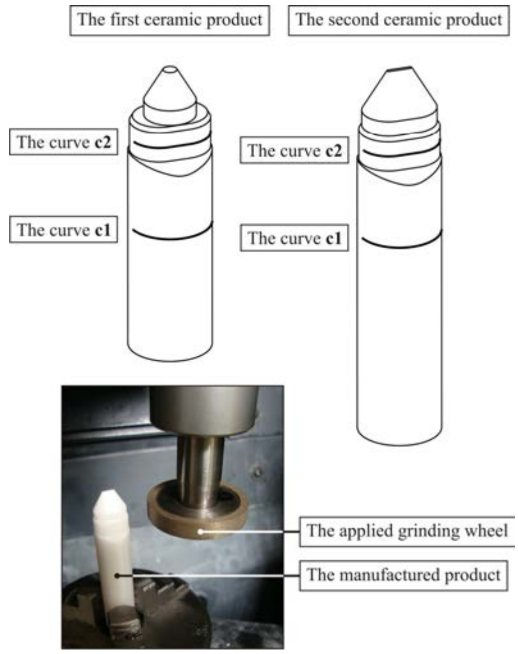

Fig. 1. The analysed ceramic workpieces and the used grinding wheel.

4. Experimental investigations

The experimental investigations were conducted by means of the measuring system produced by the Carl Zeiss company which was composed of the ACCURA II coordinate measuring machine, the VAST XT scanning measuring probe (Fig. 2) and the Calypso software. The selected accuracy parameters of the applied CMM are the following:

- $E_{L,MPE} = 1.6 + L/333$ µm
- $P_{FTU,MPE} = 1.7$ µm
- $MPE_{Tij} = 2.5$ µm
- $MPT_{\tau ij} = 50.0$ s

The comparison of the considered methods of the probe radius correction process was performed in the case of digitalization of the selected parts of the ceramic workpieces (Fig. 1). Digitalization was realized using the command *unknown contour* which is available in the applied measurement element curve 2D of the Calypso software and which is dedicated to the first stage of the reverse engineering process. In the case of that function a user of a coordinate