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Contact and Non-contact Measurements of Grinding Pins

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Abstract. The paper presents the results of contact and non-contact measurements of external profiles of selected grinding pins. The measurements were conducted in order to choose the appropriate measuring technique in the case of the considered measurement task. In the case of contact measurements the coordinate measuring machine *ACCURA II* was applied. The used coordinate measuring machine was equipped with the contact scanning probe *VAST XT* and the *Calypso* inspection software. Contact coordinate measurements were performed by using of different measurement strategies. The applied strategies included different scanning velocities and distances between measured points. Non-contact measurements were conducted by means of the tool presetter produced by the *Mahr* company. On the basis of gained results the guidelines concerning measurements of grinding pins were formulated. The measurements of analyzed grinding pins performed by means of the non-contact measuring system are characterized by higher reproducibility than the contact measurements. The low reproducibility of contact measurements may be connected with the inaccuracy of the selected coordinate measuring machine and the measuring probe, the measurement parameters and environmental conditions in the laboratory where the coordinate measuring machine is located. Moreover, the paper presents the possible application of results of conducted investigations. The results of non-contact measurements can be used in the simulation studies of grinding processes. The simulations may reduce the costs of machining processes.

1 Introduction

Grinding pins are widely used in different machining tasks performed on CNC grinding machine tools. They can be applied in the case of hybrid machining processes with the assistance of tool vibrations [1,2]. It can be stated that grinding pins are a kind of grinding wheels which are characterized by a relatively small diameter. Moreover, an abrasive layer is fixed to a metal mandrel. Both conventional (e.g. corundum, silicon carbide) and superabrasive (diamond and CBN) grinding pins are nowadays used in machining processes of products made of different materials.

The geometrical shapes of grinding pins substantially influence the results of machining processes of products. The improved accuracy of machined objects will be obtained if the real geometry of tools is taken into account. Therefore, the actual geometry of grinding pins should be used while programming of CNC grinding machine tools. The real shapes of grinding pins can be obtained based on the analysis of results of their measurements. The results of measurements can also be used in order to assess the wear of tools. If a programmer of a CNC machine tool can predict the tool wear, the better accuracy of a machined part will be achieved. There can be distinguished a lot of precision measuring gages which can be used in order to measure grinding pins. The selection of an appropriate measuring technique may improve machining processes.

The inspection processes of grinding pins are classified into measurements of their micro-geometry and macro-geometry. The analysis of micro-geometry of grinding wheels concerns the investigations of surface topography and abrasive grains characteristics. The inspection of macro-geometry of grinding wheels may be associated with the measurements of form deviations of profiles [3]. Macro- and micro-geometry of grinding wheels can be shaped in conditioning processes. Mechanical, thermal, chemical, electro-chemical and hybrid conditioning processes are well-known [4]. Some of these processes may be applied in conditioning of grinding pins. However, removing the big amount of an abrasive layer in profiling processes is not very suitable for small grinding pins because of their relatively small dimensions. Therefore, cleaning or sharpening processes are usually applied to restore cutting properties of these grinding pins. Literature data associated with the inspection of macro-geometry of grinding wheels is limited. However, authors of the paper [5] investigated macro-geometry and stated that slotted wheels may improve cooling efficiency during grinding processes. Nadolny and Kapłonek [6] constructed, manufactured and tested the device for shaping of micro- and macro-geometry of a grinding wheel active surface.

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The article concerns the measurements of external profiles of two selected superabrasive grinding pins. The measurements were conducted in order to choose the appropriate, among analyzed, measuring technique in the case of the considered measurement task. In the next parts of the paper the results of both contact and non-contact measurements of grinding pins are presented. The end of the article includes the possible application of gained results of experimental investigations and the conclusions concerning the performed research.

2 Contact coordinate measurements of grinding pins profiles

There were performed contact measurements of two considered grinding pins. The analyzed grinding pins had the same nominal data. The nominal diameter of grinding pins was equal 6 mm. Two grinding pins were measured in order to verify the results of conducted measurements. The measurements were conducted with the use of the selected coordinate measuring machine (CMM) and different measurement parameters. The inspection processes of grinding pins were conducted by using of the coordinate measuring machine *ACCURA II* equipped with the contact measuring probe *VAST XT* (Fig. 1) and the *Calypso* software. The applied measuring system is produced by the *Carl Zeiss* company and is characterized by the following accuracy parameters [7,8]:

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

The nominal diameter of the stylus tip of the measuring probe, used during the experimental investigations, was equal 0.5 mm. The measurement processes of grinding pins were performed along their longitudinal sections by using of the *2D curve* measurement element which is available in the *Calypso* software. The investigations were conducted with the use of different measurement parameters associated with a scanning velocity and a distance between measured points. In the beginning of measurement processes start and end points of measured profiles were defined. The coordinate measurements were performed with the following parameters of coordinate measurements:

- scanning velocities (denoted as *v*): 0.5; 1.0; 1.5 mm/s;
- distances between measured points (denoted as *d*): 0.1; 0.15 mm.

The measurements, with the above mentioned measurement parameters, were conducted in order to asses the possibilities of using the selected coordinate measuring machine in the considered measurement task. The coordinates of measured points, representing the external profiles of grinding pins and obtained with the use of different measurement strategies, were exported from the *Calypso* inspection software of the CMM *ACCURA II* and imported to the *CATIA V5* computer aided design (CAD) software. The selected CAD software was used in order to analyze the gained results of coordinate measurements. The analysis of results, obtained by using of the applied CMM and the measurement parameters, was conducted with the use of the *Digitized Shape Editor* module of the *CATIA V5* software. The measured profiles were compared to nominal data in order to calculate the maximum local form deviations of measured contours of analyzed grinding pins. In order to evaluate deviations, there were conducted the best fit processes of measured data to nominal data. The evaluated maximum local form deviations in the case of two analyzed grinding pins and different measurements parameters are presented in the Tables 1 and 2. Based on the results of measurements the dispersion was calculated.

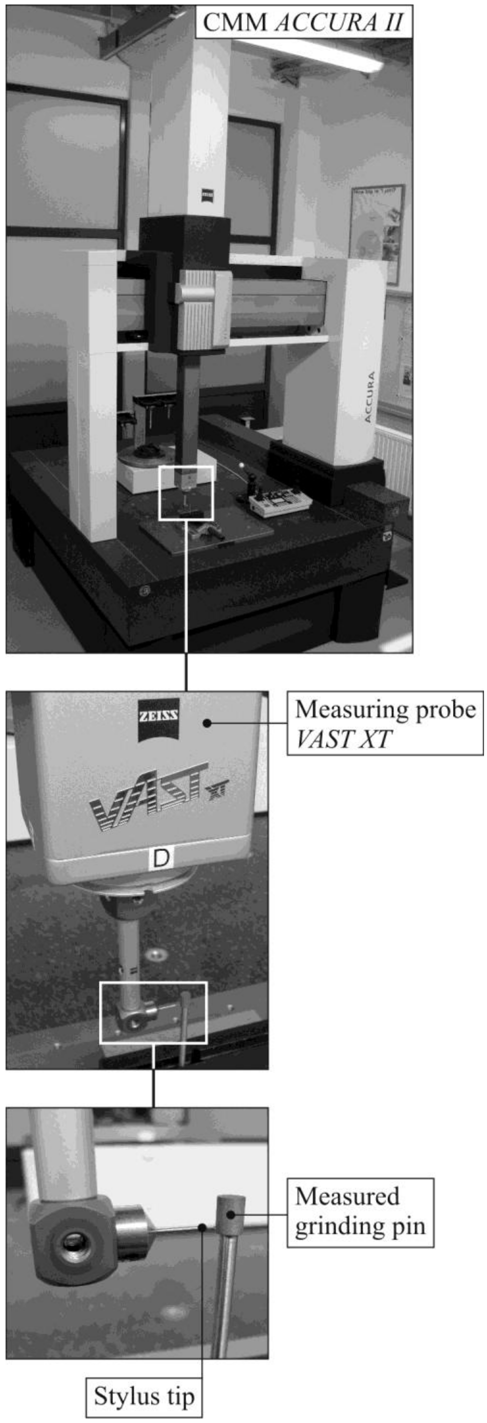

Figure 1. The measurements of the grinding pin by using of the selected coordinate measuring machine.

Table 1. The results of coordinate measurements in the case of the first grinding pin.

v, mm/s	*d*, mm		Dispersion, mm
	0.1	**0.15**	
0.5	0.071 mm	0.062 mm	**0.009**
1.0	0.056 mm	0.048 mm	**0.008**
1.5	0.988 mm	0.221 mm	**0.767**
Dispersion, mm	**0.932**	**0.173**	

Table 2. The results of coordinate measurements in the case of the second grinding pin.

v, mm/s	*d*, mm		Dispersion, mm
	0.1	**0.15**	
0.5	0.260 mm	0.238 mm	**0.022**
1.0	0.220 mm	0.241 mm	**0.021**
1.5	0.273 mm	0.048 mm	**0.225**
Dispersion, mm	**0.053**	**0.193**	

3 Non-contact measurements of profiles of grinding pins

After performing contact coordinate measurements, the same two superabrasive grinding pins were measured with the use of the selected tool presetter which enables non-contact measurements (Fig. 2). The investigations were conducted for different external profiles of grinding pins than measured using the contact measuring technique. The used presetter is produced by the *Mahr* company. The grinding pins were fixed into the *HSK-63* tool holder and were not pulled out between single measurements. There were performed a series of measurements in order to check the usability of the applied measuring system. The considered grinding pins were placed by the operator in the measuring gauge five times. Then the grinding pins were measured five times at each position.

The results of measurements were the set of points, which represents the external profiles of grinding pins. The coordinates of measured points were saved by using of the software cooperating with the used tool presetter. In the next stage the points were exported to the *CATIA V5* software, which was used in order to analyze the gained results. The analysis was done, similar to the contact coordinate measurements, using the *Digitized Shape Editor* module. The measured data was edited in order to make the analysis easier. The edition consisted of filtering and removing of selected measured points. The form deviations were calculated by fitting the measured data to nominal data by means of the *best fit* function available in the *CATIA V5* software.

The results of non-contact measurements are presented in the Figs. 3 and 4. The shown results concern the arithmetic means of maximum local form deviations obtained at different positions of analyzed grinding pins in the measuring instrument. On the basis of gained results the expanded uncertainties of measurements were calculated. The coverage factor and the level of significance were equal respectively 2.776 and 5 %. The Student's t distribution, which is used in the case of a small number of measurements, was applied in order to select the coverage factor. Based on the arithmetic means of form deviations and the uncertainties the dispersion of results was calculated.

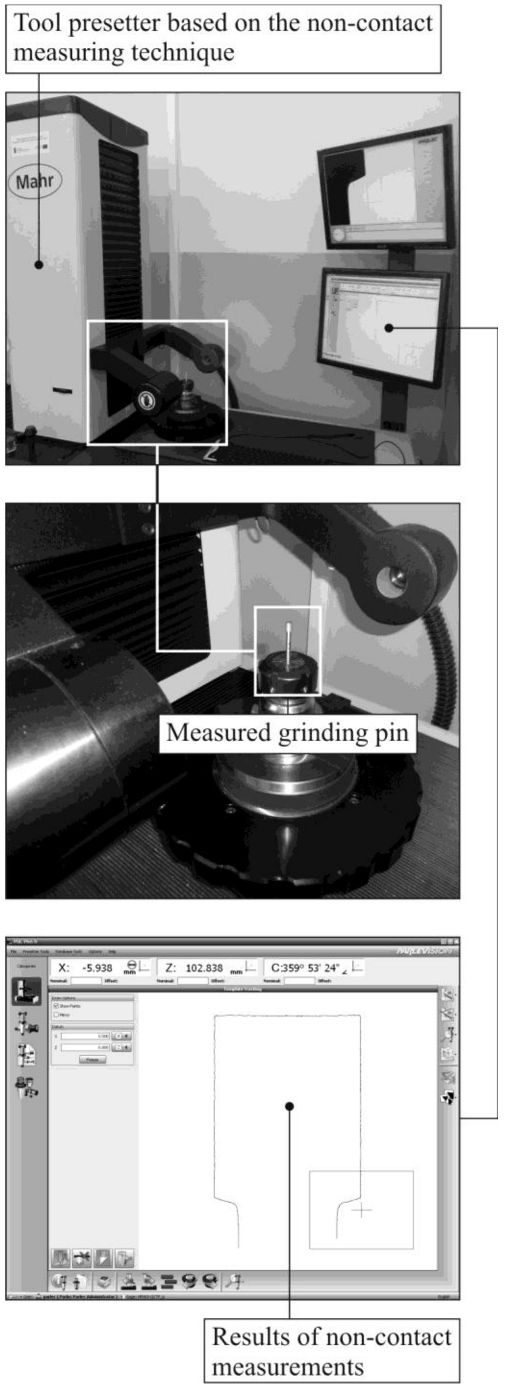

Figure 2. The measurements of the grinding pin by using of the selected tool presetter

4 Application of results of conducted measurements of grinding pins

Based on the results of performed measurements the appropriate measuring technique, among analyzed, of grinding pins can be selected. This technique can be used during digitalization processes of tools. The digitalized grinding pins can be applied when performing simulation investigations of grinding processes of products.

The simulation investigations can be done e.g. by using of the *Esprit* computer aided manufacturing (CAM) software. The user of the *Esprit* software has the possibility of defining special geometry of tools (Fig. 5). This geometry can represent for example the analyzed grinding pins. The models of grinding pins, created based on the coordinates of measured points by using of most CAD software, can be imported to the *Esprit* CAM software and used during simulations.

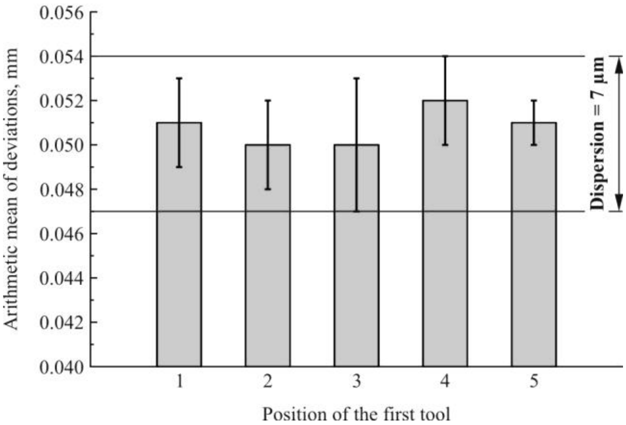

Figure 3. The results of non-contact measurements conducted by using of the selected tool presetter in the case of the first tool

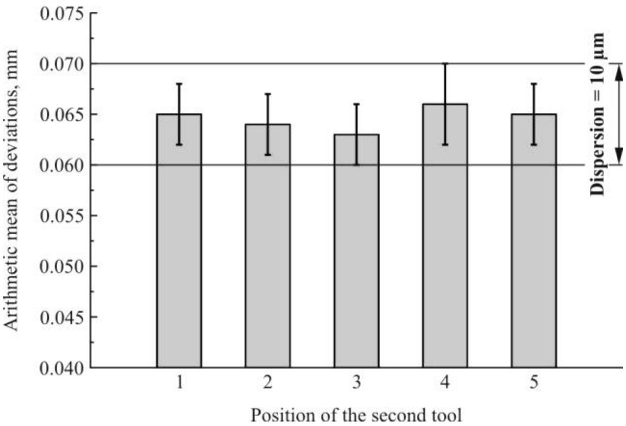

Figure 4. The results of non-contact measurements conducted by using of the selected tool presetter in the case of the second tool

5 Summary

There were performed the preliminary studies regarding the selection of a measuring system for the specific case of measurements. Based on the analysis of results the coordinate measurements of grinding pins are not appropriate for the considered measurement task. The obtained results indicate that measurements conducted using the contact measuring technique are characterized by low reproducibility, which is associated with different measurement parameters applied during coordinate measurements. The large dispersion of results was obtained mostly because of loops of external profiles calculated based on the coordinates of measured points. The loops may result from, among others, the inaccuracy of the applied coordinate measuring machine and the measuring probe, the measurement parameters and environmental conditions in the laboratory where the coordinate measuring machine is located.

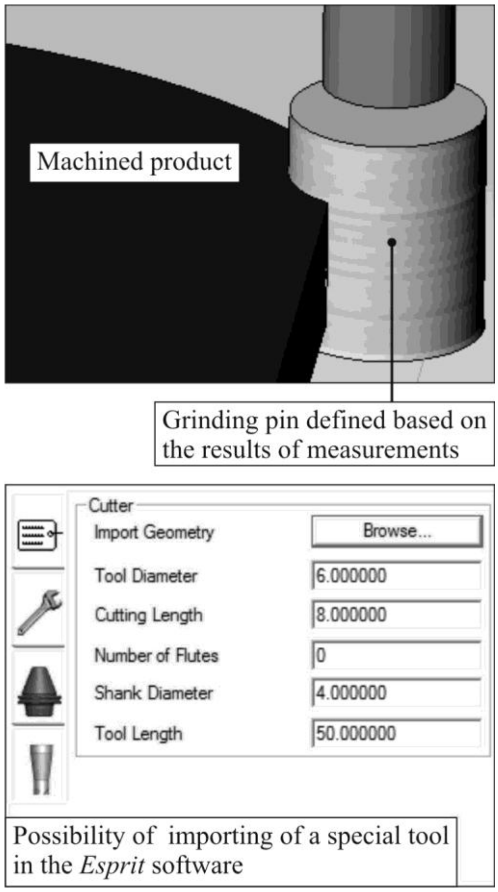

Figure 5. The simulation of a grinding process

Therefore, the measurements of analyzed grinding pins should be performed by means of the non-contact measuring system. The dispersion of results, which was equal respectively 7 µm and 10 µm (Figs. 3 and 4), was much lower than in the case of contact measurements. The non-contact measurements of grinding pins are characterized by higher reproducibility than the contact measurements. The reproducibility is associated with the influence of the user of the optical tool presetter on the results of measurements.

However, the final application of the non-contact measuring technique should be preceded by more detailed research. The additional investigations may concern the analysis of expected accuracy of products machined by means of grinding. Moreover, the measurements of a standard, calibrated by using of a more accurate measuring system than the two analyzed, may be conducted in order to confirm the selection of the tool presetter for the considered measurement task.

The results of non-contact measurements can be used in the simulation studies of grinding processes. The results of simulation studies can be applied in order to reduce the costs of machining processes by predicting for example the accuracy of machined workpieces and the wear of grinding pins.

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