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THE INFLUENCE OF DIFFERENT METHODS OF MILLING A ROUND PIN ON THE PROPERTIES OF SURFACE LAYER USING VERTICAL MILLING CENTER

WPŁYW RÓŻNYCH SPOSOBÓW WYKONANIA CZOPA OKRĄGŁEGO NA WŁAŚCIWOŚCI WARSTWY WIERZCHNIEJ Z WYKORZYSTANIEM PIONOWEGO CENTRUM FREZARSKIEGO

Key words:

surface layer, waste machining, surface roughness, diagnosis

Słowa kluczowe:

warstwa wierzchnia, obróbka ubytkowa, chropowatość, diagnoza

Abstract

The aim of the article was to show how different strategies for making a round pin influence the properties of the surface layer. Measurements will be made of the circular interpolation and accuracy of movement of the rotary axis. The first strategy was to make circular interpolation using a work X and Y-axis. The second embodiment of the method is presented using the rotational C-axis, while the third method covered the execution of the round pin in the

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implementation of circular interpolation X- and Y-axes and the displacement of the rotary C-axis. Thus, the formed samples were subjected to measurement of surface roughness. The analysis led to showing how different strategies affect the processing properties of the surface layer around the pins.

INTRODUCTION

The purpose of machining is to seek to achieve a given shape and dimension of the workpiece and quality of the surface layer. For such requirements, the relevant machine is adapted for this purpose as well as the appropriate method of implementation of the subject **[L. 1]**. The basic methods of obtaining this are to choose the appropriate treatment parameters. They depend on the type of the material to be treated and the tools used for this purpose. We must also remember that machine designed for these tasks must properly fulfil them. A properly chosen method of implementation of the subject will also be reflected in its accuracy. An item should be made with the minimum movement of the axis of the machine with the maximum amount removal of material. This article aims to show the impact of different strategies to mill a round pin on the properties of the surface layer. The first strategy will be executed with circular interpolation with the statement of work in X- and Y-axes. The second will present a method of execution by the rotary C-axis. The third would include the making of a round pin in compiling circular interpolation of X- and Y-axis and simultaneous movement of the rotary C-axis. Then, the formed samples will be measured of roughness.

DESCRIPTION OF INSTRUMENTS AND POSITIONS OF RESEARCH

The study was conducted on a vertical 5-axis DMU 50 milling centre. With this machine, the first step is heating following the displacement of each axis, and then subjected to the diagnosis. For these purposes, a kinematic-ball rod Ballbar QC10 was used **[L. 2, 3]**. The machine was programmed for a set point of the spindle circular interpolation in the X-Y plane **(Fig. 1a)**.

a)  b) 

Fig. 1. (a) Kinematic-ball rod Ballbar QC10, and (b) RX10 position for rotation axis
Rys. 1. a) pręt kinematyczno-kulkowy Ballbar QC10, b) stanowisko do pomiaru ruchów obrotowych osi obrabiarki CNC z zastosowaniem sondy RX10

The next step was to check the accuracy of movements with a rotary axis machine tool. For these purposes, the Renishaw RX10 probe was used **(Fig.1b)**, which was mounted on the rotary axis of the table. The table performs rotation in two directions, and the probe remained in a fixed position, which allowed a reading of the accuracy of rotary axis motion **[L. 4, 5, 6, 7]**. After measuring, machining was performed on the samples (**Fig. 3b**). For this purpose, C45 steel rods (C 0.42-0.5%, Mn 0.5-0.8%, Si 0.1-0.4%, P 0.04% max, Cr max 0.3% Ni max 0.3% Mo max 0.1%, Cu max 0.3%) were used, which were then assembled in a three-jaw clamp on the machine table. An end mill ORION Type N 1682812 with a diameter of 12 mm to perform end pivots. Three different methods were used, with the use of circular interpolation with work in the X- and Y-axes **(Fig. 2a)**, by maintaining a constant position of the rotating tool and rotary motion of the table **(Fig. 2b)**.

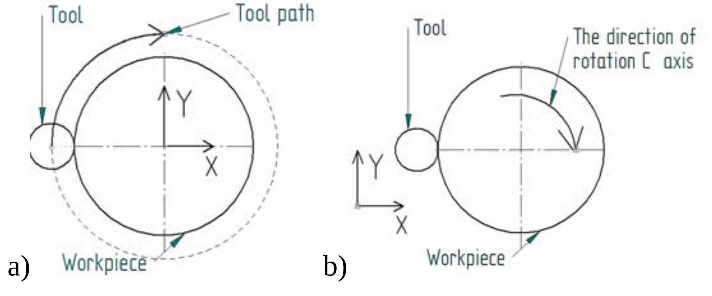

Fig. 2. (a) The first method of making a round pin, and (b) The second method of making round pin
Rys. 2. a) pierwsza metoda wykonania czopa okrągłego, b) druga metoda wykonania czopa okrągłego

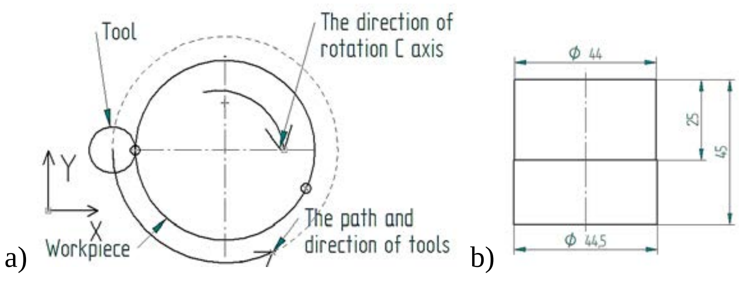

Fig. 3. The third method of making a round pin
Rys. 3. Trzecia metoda wykonania czopa okrągłego

Moreover, by using the movement axes X and Y with the rotation of the table **(Fig. 3a)**, all round pins are made of the same parameters: v_c = 189 m/min, n = 5000 rev/min, and f = 200 mm / tooth, a_p = 25 mm a_e = 0.25 mm.

MEASUREMENTS

Analysis of the diagnostic machine led to the conclusion that the errors affect its geometric accuracy. These are the deviation in the positioning, which was -10.1 microns, the deviation in squareness, which was -21.8 µm, in straightness, which was Y = 2.9 µm, the error recurrence, which was Y = 1.4 / 1.1 µm, and backlash return, which was Y = 1.2 / 1.2 mm. Diagnostic measurements showed that the roundness deviation amounted to 9.7 µm. The next step was to analyse the accuracy of rotary C-axis. Based on the collected data, the positioning accuracy of the rotary axis was 5.24 µm with 1.34 µm backlash return. The samples made using a variety of strategies were analysed using the following instruments: Topo L120 and Tayysurf CCI Lite allowing the creation of profiles and topography of the sample **[L. 8, 9]**. The samples were measured at the entry and exit tool on the side surface, and at the point for reversing the movement axis during machining. Below is a diagram showing the results of the place made for surface roughness measurements strategy with the circular interpolation with the statement of X- and Y-axes **(Fig. 4)**.

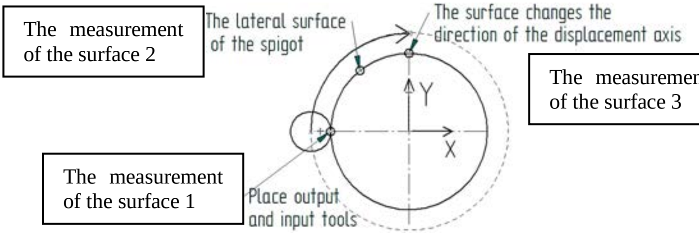

Fig. 4. Places for the measurements strategy with the statement of the X-axis and Y-axis
Rys. 4. Miejsca dokonanych pomiarów dla strategii z wykorzystaniem zestawienia osi X i Y

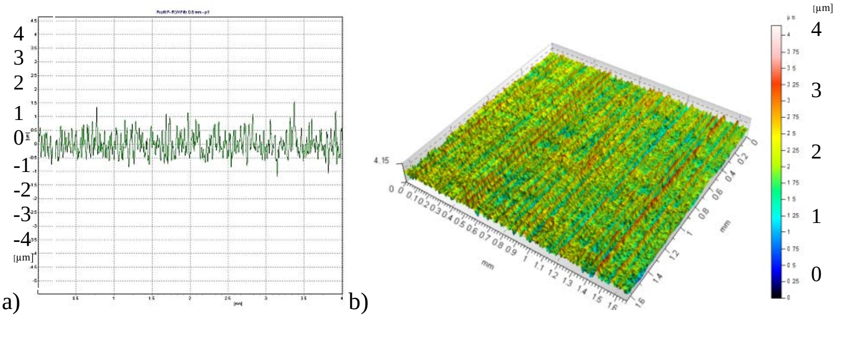

Fig. 5. Measurement 1 at the points of entry and exit tools: (a) the surface profile, and (b) the surface topography
Rys. 5. Pomiar 1 w miejscu wejścia i wyjścia narzędzia: a) profil powierzchni, b) topografia powierzchni

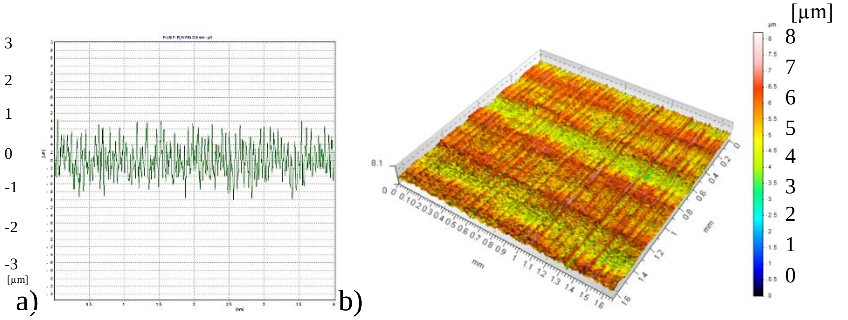

Fig. 6. Measurement 2 on the surface of the side: (a) surface profile, and (b) surface topography

Rys. 6. Pomiar 2 miejscu powierzchni bocznej: a) profil powierzchni, b) topografia powierzchni

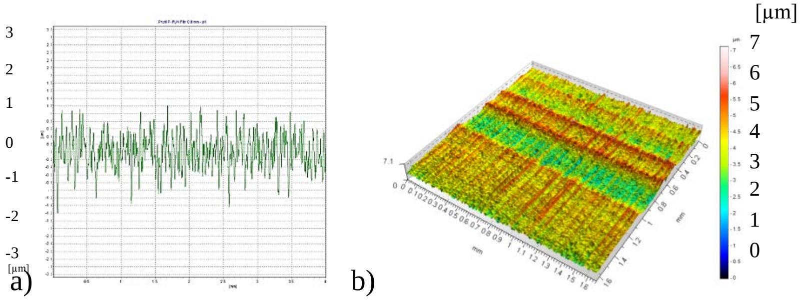

Fig. 7. Measurement 3 at the point of axis shift: (a) surface profile, and (b) surface topography

Rys. 7. Pomiar 3 w miejscu zmiany przemieszczania się osi: a) profil powierzchni, b) topografia powierzchni

Figures 5–7 shows the surface subjected to measurement of roughness. **Table 1** summarizes the parameters of the examined samples.

Table 1. Summary measurement strategy I

Tabela 1. Zestawienie pomiarów strategii I

Strategy I	Sq [µm]	Ssk	Sku	Sp [µm]	Sv [µm]	Sz [µm]	Sa [µm]
Measurement 1	0.4299	0.2554	2.9907	2.1452	2.0055	4.1506	0.3443
Measurement 2	0.6446	-0.0536	2.8724	2.6794	5.5144	8.1973	0.5169
Measurement 3	0.7298	-0.1483	3.0648	2.9883	4.1436	7.1319	0.5788

Data analysis of the first strategy led to the conclusion that, at the entrance of the tools, the lowest values were observed: Sq, Sp, Sv, Sz, and Sa. The lowest values were observed of roughness on the lateral surface of the round pin. On the topography of the surface, cyclic repeated bumps and indentations surface were observed, as the movement of the arc is carried out with a combination of two axes. Where there was a change in the direction of the movement of the axis, increased parameters Sp and Sa were observed. On the surface topography, a spike on the surface of the sample can be seen. It is caused by clearances in the control axes of the machine tool and the late response of the mechanical system machine control signal. The following diagram and test results show the location of measurements of surface roughness for the strategy at a fixed tool position and movement of the rotary C-axis **(Fig. 8).**

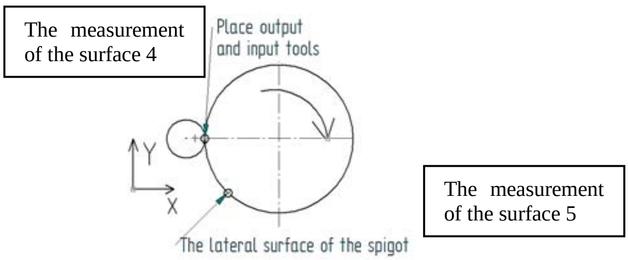

Fig. 8. Location of the measurements with a fixed tool position and movement of the rotary C-axis

Rys. 8. Miejsca dokonanych pomiarów dla strategii przy stałym położeniu narzędzia i ruchu osi obrotowej C

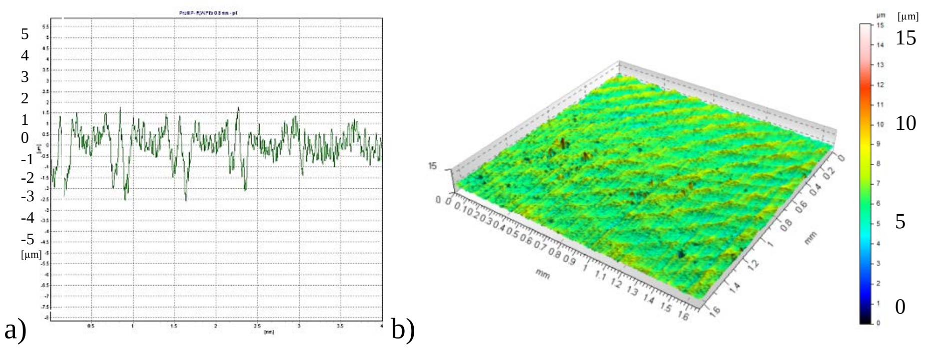

Fig. 9. Measurement 4 at the point of entry and exit tools: (a) surface profile, and (b) surface topography

Rys. 9. Pomiar 4 w miejscu wejścia i wyjścia narzędzia: a) profil powierzchni, b) topografia powierzchni

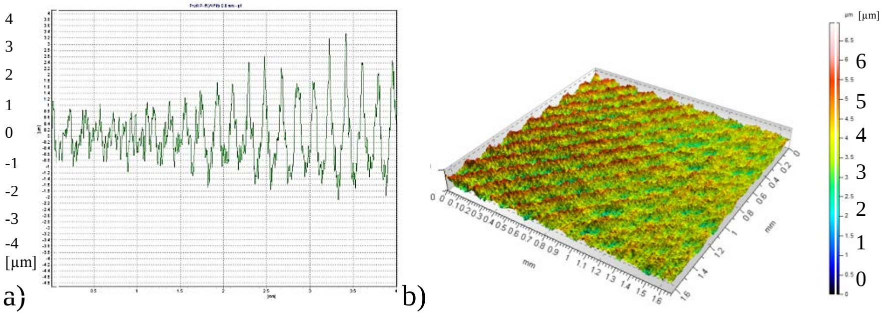

Fig. 10. Measurement 5 on the side surface: (a) surface profile, and (b) surface topography
Rys. 10. Pomiar 5 na powierzchni bocznej: a) profil powierzchni, b) topografia powierzchni

Figures 9–10 shows the profiles and topography of the surface assessed in Strategy II. Evaluation parameters of the surface are summarized in **Table 2.**

Table 2. Summary measurement Strategy II
Tabela 2. Zestawienie pomiarów strategii II

Strategy II	Sq [µm]	Ssk	Sku	Sp [µm]	Sv [µm]	Sz [µm]	Sa [µm]
Measurement 4	0.6806	0.2550	5.1620	8.6891	6.3710	15.0603	0.5310
Measurement 5	0.7279	0.1900	2.9881	3.2107	3.7526	6.963	0.5775

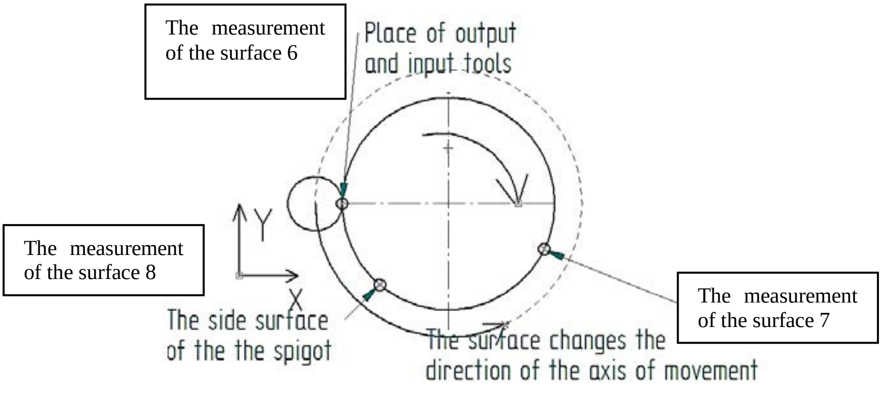

Fig. 11. Location of the measurements strategy with movement in the X- and Y-axes and rotational axis C
Rys. 11. Miejsca dokonanych pomiarów dla strategii z zestawieniem pracy osi X, Y oraz osi obrotowej C

In the next analysed strategy of milling a round pin, two characteristic surfaces can be observed, which are the surfaces of input/output tools and the surface of the side. The maximum height of the surface irregularities were found in the course of the input tools. This is caused by differences in the positioning tolerances of the test machine. In contrast, the side surface of the spindle had parameters of constant height by virtue of the type of treatment. This means that the rotational axis of the machine worked properly. The following diagram and test results show the location of measurements of surface roughness for Strategy III with movement in the X- and Y-axes and the rotational C-axis **(Fig. 11)**.

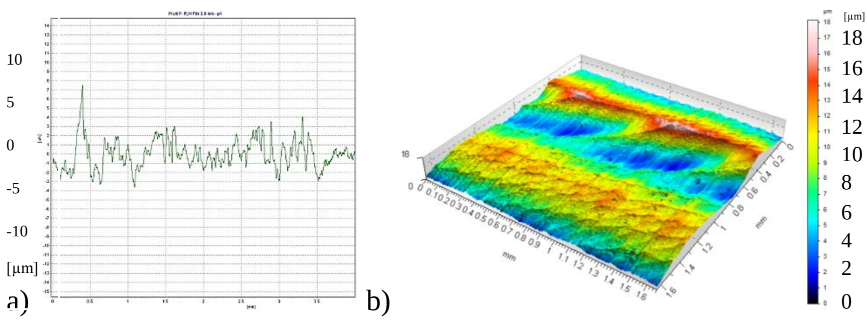

Fig. 12. Measurement 6 at the entry and exit tools: (a) surface profile, and (b) surface topography

Rys. 12. Pomiar 6 w miejscu wejścia i wyjścia narzędzia: a) profil powierzchni; b) topografia powierzchni

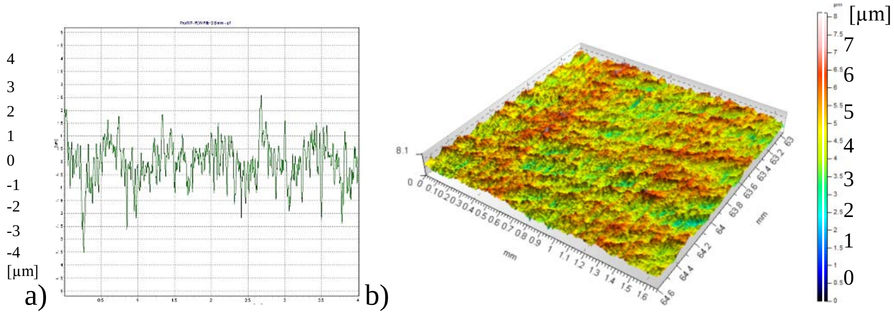

Fig. 13. Measurement 7 on side surface: (a) surface profile, and (b) surface topography

Rys. 13. Pomiar 7 na powierzchni bocznej: a) profil powierzchni, b) topografia powierzchni

Figures 12-14 shows the surfaces subjected to measurement of roughness. **Table 3** summarizes the roughness parameters tested sample.

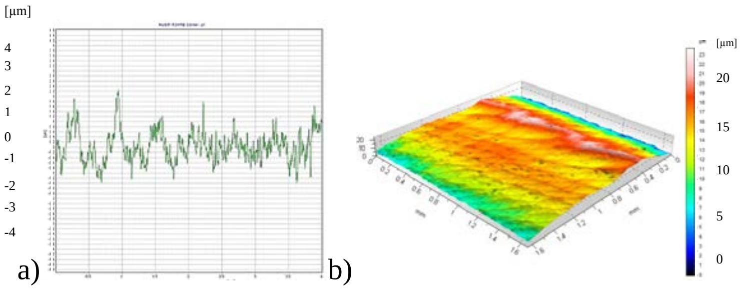

Fig. 14. Measurement 8 of the change in direction of the axis: (a) surface profile, and (b) surface topography

Rys. 14. Pomiar 8 na powierzchni przy zmianie kierunku osi: a) profil powierzchni, b) topografia powierzchni

Table 3. Summary measurement Strategy III

Tabela 3. Zestawienie pomiarów strategii III

Strategy III	Sq [µm]	Ssk	Sku	Sp [µm]	Sv [µm]	Sz [µm]	Sa [µm]
Measurement 6	1.4873	0.3965	3,1381	4.2552	2.8668	7.1228	1.1941
Measurement 7	0.7750	-0.2479	3,5085	3.2521	4.8536	8.1057	0.6008
Measurement 8	0.5795	0.3050	3,0980	1.7272	1.2600	2.9871	0.4614

The third sample has the largest diversity of the surface, which is caused by using a three-axis machining. They appear at the input / output attachments. In addition, due to the use of a rotary axis, increased inequalities resulting from poor geometrical precision of the machine tools can be seen. As a result of the linear movements in the X- and Y-axes and a rotational C-axis, the machined surface has aggravated geometrical parameters of the surface layer.

CONCLUSIONS

The study helped show how the choice of an appropriate strategy is reflected in the accuracy of the manufactured items. Depending on the selected method, one can get various properties of the surface layer. When selecting the strategy, one should pay attention to the performance of the machine as well as the selection of appropriate processing parameters. It was observed that the side surfaces, using each method, maintained a constant level of roughness parameters of the top layer. The best results were obtained with the combination of work in both the X and Y-axes, and at the worst results were obtained with a combination of working in all three axes – the X- and Y-axes along with movement in the rotational C-axis. Due to the presence of geometrical inaccuracies in the machine tool, there are significant jumps of individual roughness parameters of the surface layer at certain measurement locations, i.e. at input and output tool point and at the change in the direction of the axis. This is due to the occurrence of a machine error causing deviations in positioning and errors of recurrence and backlash. In extreme cases, these problems may significantly affect the parameters of the milled surface. Based on this study, the best surface is obtained in milling a round pin by performing work in only the X- and Y-axes.

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Streszczenie

Celem artykułu było przedstawienie jak różne sposoby wykonania czopa okrągłego wpływają na właściwości warstwy wierzchniej. Wykonane zostały pomiary interpolacji kołowej oraz dokładności przemieszczenia osi obrotowej. W pierwszej strategii dokonano interpolacji kołowej z zastosowaniem pracy osi X oraz Y. Druga przedstawiała metodę z wykorzystaniem osi obrotowej C. Trzecia natomiast obejmowała wykonanie czopa przy realizacji interpolacji kołowej osi X i Y oraz przemieszczenia osi obrotowej C. Tak przygotowane próbki zostały poddane pomiarom chropowatości powierzchni. Analiza pozwoliła wykazać, jak różne sposoby obróbki wpływają na właściwości warstwy wierzchniej czopa okrągłego.