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THE ASSESSMENT OF THE IMPACT OF THE INSTALLATION OF CUTTING PLATES IN THE BODY OF THE CUTTER ON THE SIZE OF GENERATED VIBRATIONS AND THE GEOMETRICAL STRUCTURE OF THE SURFACE

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Abstract: *This article is to present the assessment of the impact of the installation of cutting plates in the body of the cutter on the vibration amplitude generated during machining and the 3D parameters of the geometrical structure of the surface. The research was conducted, respectively, for one, two, three, and six cutting plates mounted in the body of the endmill head CoroMill 245. The experiment was conducted at a vertical machining center AVIA VMC 800. The machined material was C45 steel. The measurements of displacements in the layout tool-workpiece were conducted with the use of a laser interferometer Renishaw XL-80, while the measurements of the geometrical structure of the surface were conducted with the use of an optical profilometer TalySurf CCI.*

Keywords: Vibration, End milling, Displacement in layout tool - workpiece, Geometrical structure of the surface.

1. Introduction

The formation of the geometrical structure of the surface is determined by the interaction of individual elements of the machined layout (Miko, 2005; Miko and Nowakowski, 2012). The impact of individual factors that significantly affect the quality of created surfaces (Adamczak and Bochnia, 2016) might be classified in four main groups: factors related to the machining tool (Nowakowski, Lukasz et al., 2016), the cutting tool, the properties of the machined material (Blasiak et al., 2014), and the phenomena accompanying the process of machining (Nowakowski, L et al., 2016). Among the factors related to the tool used in the shaping of the surface (Adamczak et al., 2015), we might include: its shape, radius of curvature of the cutting edge, material and its coating (Grzesik et al., 2005, 2001), the radius of curvature of the corner of the cutting edge, wear of the cutting edge, firmness, number of cutting edges, as well as errors concerning their setting. Errors in the setting of cutting plates, both radial and axial, have a significant meaning for machining with tool heads. It is possible to solve that problem by applying one, so-called, honing plate, meaning a plate the position of which is lower than in the case of other plates, so that the shaping process of the surface in the case of such cutter is performed only by one plate. Such an assumption is correct and enables limiting the roughness parameter of produced parts (Krajcarz, 2014; Krajcarz and Spadło, 2015). In fact, the process of surface shaping in the case of such cutters is also affected by the plates set above the honing plate. That phenomenon is caused by vibrations occurring in the layout tool - workpiece (Miko and Nowakowski, 2012; Nowakowski et al., 2016). In the case of occurrence of vibrations with higher amplitude components, the outline of individual plates shaping the surface is distinguishable in the 3D image presenting the roughness of the surface (Nowakowski, L and Wijas, 2016). Those issues are of significant importance in the case of forming precision machine parts (Takosoglu et al., 2016a, 2016b). In order to limit costs of production, there are attempts to achieve that directly by the use of tool heads or preparation of the most precise surfaces for next operations, e.g.

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grinding of surfaces. In many articles concerning prediction of roughness of the surface, one of the factors acknowledged in prediction of Ra parameter of surface roughness is axial displacement of blades of the cutter.

2. Methods

The process of machining involved end milling with identical technological parameters (V_c = 250 m/min, a_p = 0.5 mm, f_z = 0.2 mm/tooth) of rectangular samples made of C45 steel with dimensions of 30 x 70 x 50 mm. Individual machining attempts differed from one another by the number of plates used in the formation of the surface. Respectively, the performed attempts involved one, two, three, and six mounted cutting plates. The machining attempts with the use of four and five cutting plates were skipped due to the lack of possibility of their symmetrical distribution in the body of the tool, i.e. the even load of the sockets of the tool head (thus, the same cross section of the formed chip). Before starting the machining attempts after fixing the plates in the sockets of the tool head, the measurement of the maximum length of individual plates was performed with the use of the external tool setter Kalimat-C manufactured by KELCH. Such an operation was to clearly determine that, theoretically, the process of formation of the surface should involve only one plate placed as low as possible in the body of the cutter. Then, machining attempts were performed at the vertical machining center AVIA VMC 800. What is more, during the experiment, relative displacements in the layout tool-workpiece were measured with the use of a laser interferometer. Then, the measurement of the 3D geometrical structure was performed with the optical profilometer TalySurf CCI for the obtained surface.

3. Results

Results of the obtained results for relative displacements in the layout tool - workpiece for individual attempts of the experiment, as well as the protrusion distance of the honing plate, have been presented in Tab. 1.

Tab. 1: Measurement of relative displacements in the layout tool - workpiece, where (z - number of cutting edges placed in the tool head, fz - feed on the cutting edge, ap - depth of cut, vc - cutting speed, A - the maximum peak-to-peak amplitude of the vibrations of the tool in relation to the machined object, D_ξ - standard deviation of relative vibrations, ΔL- the minimum difference of the axial placement of the honing plate).

No.	**z**	**f_z [mm/tooth]**	**a_p [mm]**	**v_c [m/min]**	**A [µm]**	**D (ξ) [µm]**	**ΔL [µm]**
1	1	0.2	0.5	250	25.38	4.8	-
2	2	0.2	0.5	250	31.82	6.3	10
3	3	0.2	0.5	250	42.87	8.25	22
4	6	0.2	0.5	250	94.44	16.29	16

The analysis of the obtained results helped in the conclusion that the maximum peak-to-peak amplitude of the vibrations and their standard deviation increase along with the increasing number of cutting placed used in the process of machining. In the case of machining attempts with one plate, the standard deviation is 4.8 µm and increases up to 16.29 µm for machining with six plates for identical machining conditions. In the case of sample no. 4, those values might be higher than in the case of newly mounted plates due to the increased radius of curvature of the machined edge -r_n resulting from the wear of the cutting edge from previous operations. What is more, it was noticed that the peak-to-peak amplitude of vibrations occurring during the machining process was significantly higher than the minimum difference of the axial setting of cutting plates in the body of the cutter. That suggests that vibrations generated in the machining layout should have an impact on the created surface by involving the remaining plates fixed in the tool head in the process of the final shaping of the surface. Additionally, in the case of Sample no. 4 with six cutting plates, the value of standard deviation of relative vibrations is higher than the difference of axial shift of the cutting plate. In order to verify those assumptions, a 2D and 3D analysis of roughness and surface waviness were conducted in the performed experiment. The results of the obtained parameters of the surface have been presented in Tab. 2. The comparison of isothermal images of the measured surface has been presented in Fig. 1.

Tab. 2: The comparison of average parameters of roughness for the obtained surfaces.

No.	tooth	Sq [μm]	Sp [μm]	Sv [μm]	Sz [μm]	Sa [μm]	Ra [μm]	Rt [μm]	RSm [mm]	Wa [μm]	WSm [mm]
1	1	0.24	0.96	1.13	2.09	0.19	0.16	1.25	0.026	0.31	0.21
2	2	0.43	1.46	1.39	2.85	0.36	0.20	1.40	0.041	0.18	0.39
3	3	0.28	2.23	2.69	4.94	0.20	0.19	2.28	0.036	0.12	0.61
4	6	0.59	2.48	1.44	3.92	0.47	0.31	2.19	0.034	0.50	1.21

Thanks to Tab. 2, it might be concluded that along with the increased number of involved plates used in the process of final shaping of the surface, the roughness parameters also increase. The Ra parameter for the involvement of one plate in the machining process is 0.16 μm and increases along with the number of plates involved in the machining process. In the case of six plates, that parameter is 0.31 μm. Similar behavior has been noted for other parameters depicting the roughness of the surface. The parameter Wsm, which changes within the range from 0.21 to 1.21 mm, has had a significant importance for the performance parameters of created surfaces.

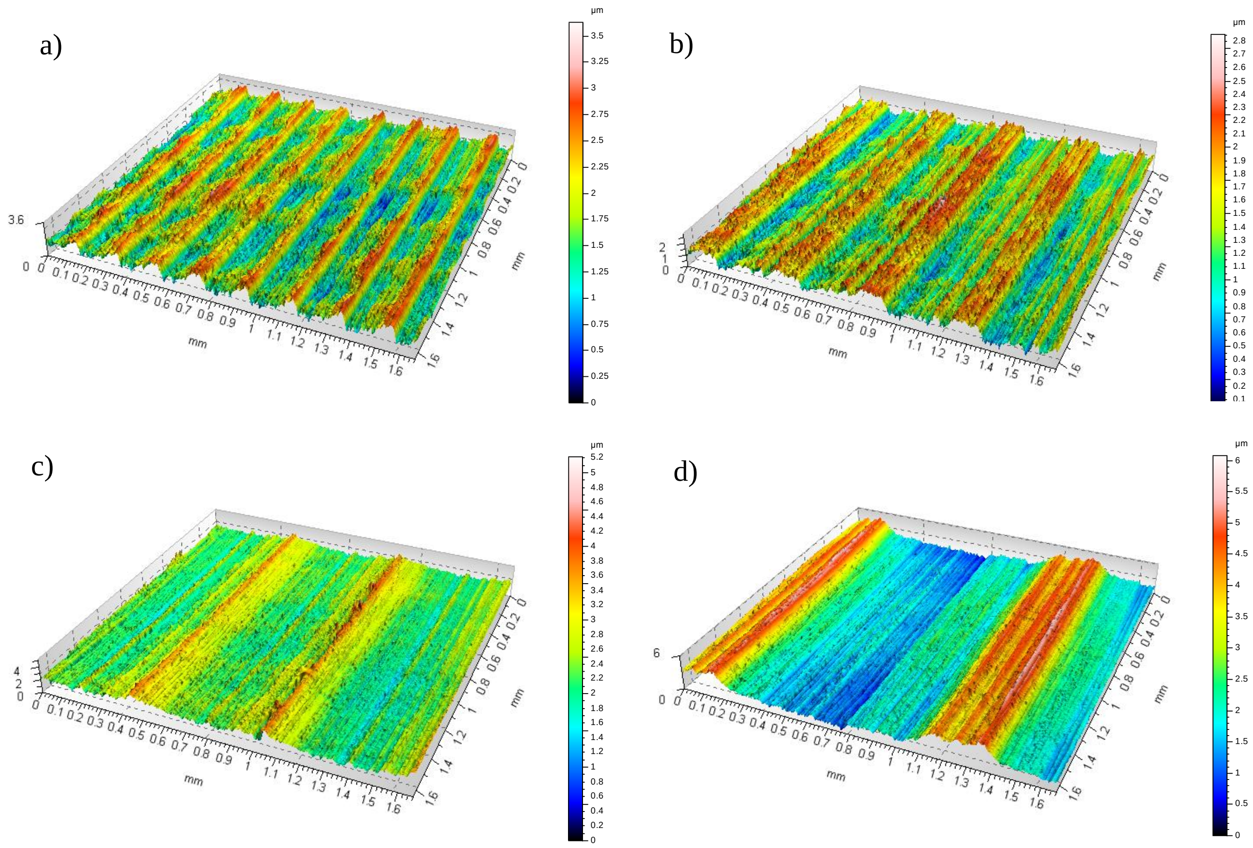

Fig. 1: Comparison of isometric images for the conducted machining attempt: a) the number of cutting places z = 1; b) the number of cutting places z = 2; c) the number of cutting places z = 3; d) the number of cutting places z = 6.

By analyzing the isometric images and results of the measurements presented in Tab. 2 and Fig. 1, it is possible to notice that in the case of machining with only 1 cutting plate placed in the head of the cutter, the results indicate the highest bearing capacity of the created surface. The most visible difference in the performance parameters of the surface may be noticed in Fig. 1d. The unevenness of the formed irregularities of the surface results not only from the axial, but also from the radial error of placement of the cutting plates in the head of the cutter. The difference in the radial error of the placement of cutting plates results in an uneven load on the sockets of the head due to different actual feed per respective sockets of the head.

4. Conclusions

The conducted research on vibrations in the layout tool - workpiece, with the simultaneous measurement of errors of the placement of cutting plates in the endmilling head, as well as measurement of roughness of the surface, has enabled formulation of the following conclusions:

1. The increase of the use of cutting plates influences the maximum peak-to-peak amplitude and the standard deviation of vibrations occurring in the layout tool - workpiece.
2. The increase of the number of cutting plates in the tool head facilitated with a honing plate results in an increase of the roughness parameters of the created surfaces.
3. The shaping of the surface performed by the remaining plates is caused by the presence of higher vibrations in the layout tool - machined object with regard to the axial difference of the shift of the honing plate.
4. The axial shift of the honing plate for the machining conducted under conditions recommended by the manufacturer is insufficient. In order to perform the final formation of the surface only by the honing plate, it was necessary to move it axially by a value higher than the maximum amplitude of vibrations occurring in the layout.

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