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THE ANALYSIS OF RELATIVE OSCILLATION DURING FACE MILLING

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Abstract: *This article is to present the results of research concerning oscillation generated by end milling of steel C45. Measurement of rooms in the layout tool-machined object was conducted at a vertical milling center AVIA VMC 800 with the use of a laser interferometer Renishaw XL-80. The process of machining was performed with a milling cutter R245-80Q27-12M manufactured by Sandvik Coromant, equipped with 6 cutting plates. The analysis concerned the impact of technological parameters, such as: cutting speed, feed on the cutting edge, and the depth of cut on the value of relative oscillation in the layout tool - machined object generated during the machining. Additionally, an amplitude-frequency analysis of selected machining tests was also performed.*

Keywords: Oscillation, End milling, Shifts in layout tool - machined object, Amplitude-frequency analysis, Vertical milling.

1. Introduction

The process of forming the surface of manufactured machine parts (Takosoglu et al., 2016a, 2016b) depends on many factors that accompany the process of machining. The greatest influence on the quality of formed surface (Nowakowski et al., 2016) is caused by technological parameters of the conducted machining process and the physical phenomena (Blasiak et al., 2014; Blasiak et al., 2016) accompanying those processes (Bartoszuk et al., 2011; Miko, 2005; Nowakowski et al., 2016). One of the physical phenomena that accompany the process of end milling are shifts generated within the layout machine tool-grip-tool-machined object (Nowakowski, Lukasz Miecesikowska et al., 2016). Oscillation occurring during the process of machining has a direct impact on the condition of formed surface and the speed of wear of cutting edge (Grzesik et al., 2005). What is more, oscillation has an impact on the value of forces that occur during the process. Oscillation is also the reason for the noise generated during the machining process. Oscillation during machining result in an increase of production costs and constitutes a significant limitation for the technological parameters available for the process of machining (Adamczak et al., 2016; Bochnia, 2012).

2. Methods

The process of machining involved end milling of rectangular samples made of C45 steel with dimensions of 30 x 70 x 50 mm. All machining tests were conducted at a vertical machining center AVIA VMC 800. The machining process was executed with a milling cutter CoroMill R245-080Q27-12M manufactured by Sandvik Coromant with the diameter of Ø80 mm, equipped with 6 cutting plates R245-12 T3 M-PM 4030. The process involved a single movement of the tool within a section with length of 70 mm and width of 30 mm. All the parameters of the machining process have been presented in Tab. 1. The measurement of oscillation within the layout tool-machined object was executed with a laser interferometer. One of the mirrors was fixed directly to the spindle of the machining tool (10), while

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another was fixed to the bench of the machining tool on which the machined object was mounted (14). Fig. 1 presents the drawing of the working stand for the measurement of relative shifts.

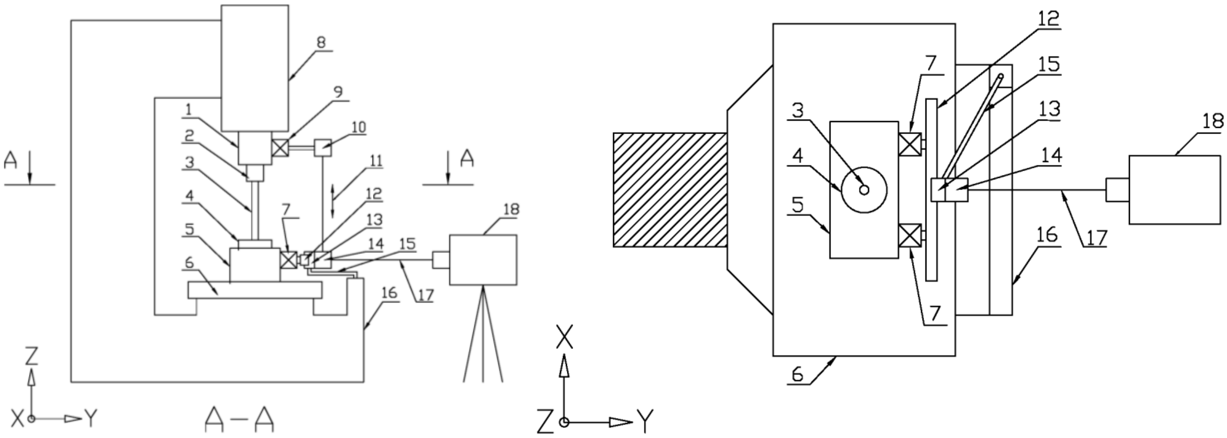

Fig. 1: Schematic of device for measuring vibrations in the tool-workpiece system: 1- spindle body, 2 - spindle, 3 - tool holder, 4 - milling head, 5 - workpiece, 6 - table, 7 - magnetic base, 8 - headstock, 9 - magnetic base, 10 - linear reflector, 11 - vibrations in the tool-workpiece system, 12 - rail, 13 - block, 14 - linear interferometer, 15 - link, 16 - machine body, 17 - laser beam, 18 - XL 80 laser (Miko and Nowakowski, 2012).

3. Results

The results of conducted research, along with their technological parameters, have been collected and presented in Tab. 1. In the table, the respective designations are f_z – feed on the cutting edge, h_{ex} – theoretical thickness of chip, v_c – cutting speed, a_p – depth of cut, A – peak to peak value of relative oscillation, D_ξ – standard deviation of relative oscillation.

Tab. 1: Measurement of relative shifts within the layout tool-machined object.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
f_z [mm/edge]	0.1	0.15	0.2	0.25	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
h_{ex} [mm]	0.07	0,11	0.14	0.18	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
v_c [m/min]	205	205	205	205	205	220	235	250	205	205	205	205
a_p [mm]	1	1	1	1	1	1	1	1	0.5	1	1.5	2
A [μm]	36.4	40.2	43.2	51.5	43.2	70.2	116.6	57.5	30.4	43.2	54.5	66.1
D(ξ) [μm]	7.4	8.2	8.8	10.6	8.8	16.5	21.4	11.1	6.0	8.8	11.4	13.6

The obtained results show that the value of oscillation amplitude and its standard deviation increases along with the increase of the feed on the cutting edge. That results from the increasing cross section of the chip, which is reflected by the greater cutting resistance. The peak to peak value, in comparison to the machined object, increases in that case from 36.4 μm to 51.5 μm, while the standard deviation of oscillation changes within the range of 7.4 – 10.6 μm. The increase of oscillation parameters occurs when there is an increase of the depth of cut resulting from the increased volume of material removed by each plate of the cutting head. In that case, the peak to peak is within the range from 30.4 – 66.1 μm, while the standard deviation of that oscillation covers the range from 6 μm to 13.6 μm. In the case of the influence of cutting speed on the size of generated oscillation in the layout, it has been noticed that the increase of the cutting speed does not directly affect the increase of oscillation. The oscillation for the speed of 205 m/min is 43.2 μm and increases up to 116.6 μm at the speed of 235 m/min. Another increase of cutting speed up to 250 m/min results in a decrease of oscillation by over a half and amounts to 57.5 μm. Such a result means that in the case of cutting speed of 235 m/min, additional self-oscillation is generated for that tool, resulting in disruption of the conducted machining process. The process of machining is, then, conducted under unstable conditions.

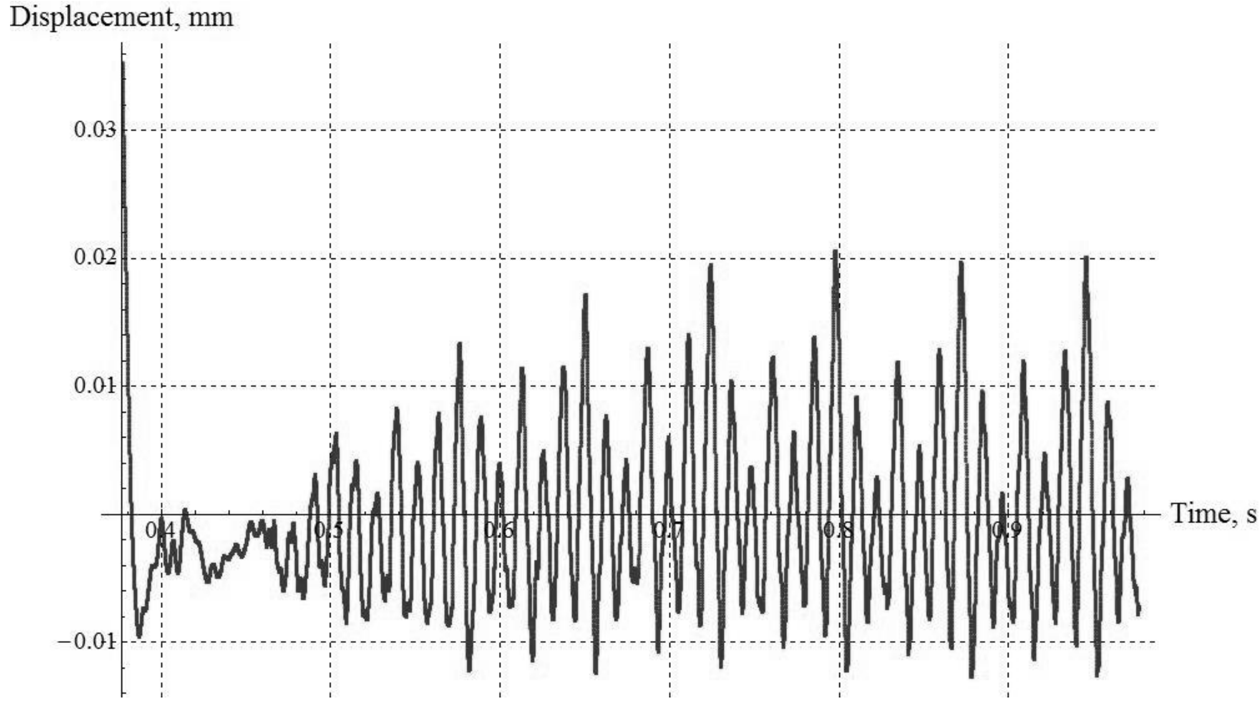

Fig. 2: Chart of the filtered signal of relative shifts within the layout tool-machined object machined under the following conditions: V_c = 205 m/min, f_z = 0.1 mm/tooth, a_p = 1mm.

Fig. 2 has presented the chart of shifts in the tool against the machined objects for sample no. 1. The chart has been divided into 3 characteristic areas. The first area is the characteristic movement of the tool to the material, the moment of cut of the tool into the machined material. The second area is the one with visible shifts caused during the machining. The last area is the one with the tool leaving the machined object and moving away. On the basis of those charts, an analysis of the value of shifts generated during the machining has been conducted.

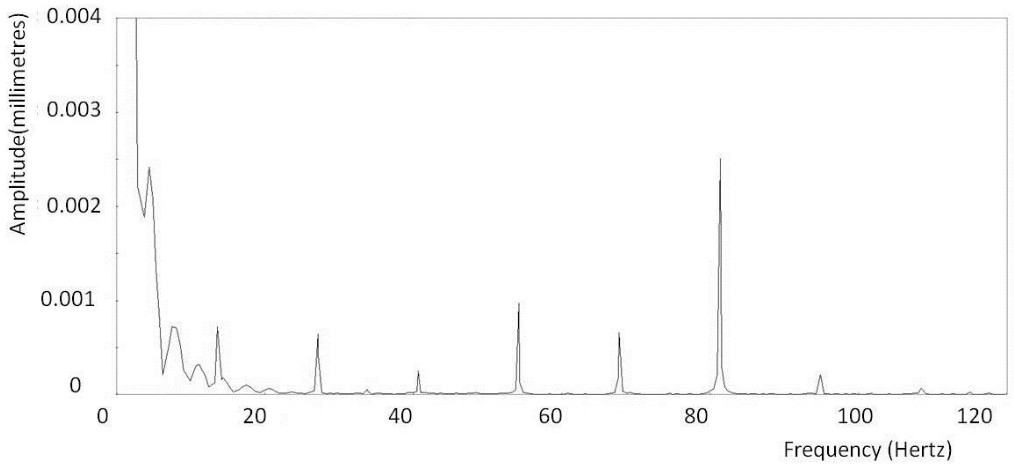

Fig. 3: Amplitude-frequency chart for the sample for V_c = 205 m/min, f_z = 0.1 mm/tooth, a_p = 1mm.

Fig. 3 has presented the amplitude-frequency analysis for sample no. 1. The chart has included 6 component frequency characteristics that are responsible for each cutting place mounted in the end milling head, respectively: 13.6, 27.1, 40.7, 54.2, 67.8, 81.3 Hz. The last component characteristic is 81.3 Hz and it results from the rotations of the spindle of the machining tool, which were, in that case, 813 rpm. The component amplitude values for individual harmonics are responsible for the load of individual sockets of the head. The chart suggests that the socket with the highest load is the last socket with a honing plate. The lowest load is on the plate no. 3 that removes the smallest layer of material. That is why it is the one with the lowest load. The load of cutting plates resulting from the amplitude-frequency analysis overlaps with the radial and length error of their placement in the body of the tool head, measured with a tool setter.

4. Conclusions

The conducted research on oscillation in the layout tool-machined object allowed the analysis of the impact of technological parameters on the size of occurring oscillation, which enabled drawing the following conclusions:

1. An increase of feed on the cutting edge causes an increase of peak to peak value and standard deviation of oscillation within the range 7.4 – 10.6 μm, which is reflected in an increased cutting resistance. It is the result from the increased cross section of generated chip.
2. The increase of depth of cut causes an increase of the size of peak to peak of relative displacement and its standard deviation, which results from a greater load of the cutting head during the process of machining.
3. The amplitude and standard deviation of oscillation increases and for the speed of 235 m/min, it reaches the maximum value. Then, for the speed of 250 m/min, it decreases twofold. With the cutting speed at 235 m/min, the layout loses its stability and self-oscillation occurs.
4. Thanks to the amplitude-frequency spectrum, the load of individual cutting plates mounted in the body of the head has been determined. After measurements conducted with a tool setter and the analysis of the spectrum, it has been determined that the highest load was in socket no. 6 with a honing plate, while the lowest load was in socket no. 3.

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